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A SMALL PREDATOR REMOVAL EXPERIMENT TO PROTECT NORTH ISLAND WEKA (*GALLIRALLUS AUSTRALIS GREYI*) AND THE CASE FOR SINGLE-SUBJECT APPROACHES IN DETERMINING AGENTS OF DECLINE

Summary: The hypothesis that predation on eggs and chicks by ferrets (*Mustela furo*) and cats (*Felis catus*) was limiting the productivity of North Island weka (*Gallirallus australis greyi*), was tested by removing predators from the home ranges of four breeding pairs of weka. Reproduction by four other breeding pairs was monitored to provide a control. I was not able to follow the breeding success of some weka because they died or removed their radio transmitters. Two of the pairs breeding in predator-removal areas reared five chicks to independence, while two control pairs reared no chicks to independence after three breeding attempts. It was not possible to draw solid conclusions from group comparison data gained from so few individuals. Because it is necessary to identify the factors preventing weka recovery now, I suggest an alternative way to gather reliable data about rare species like weka.

Single subject experimental designs like those developed in the social sciences offer an alternative route for investigating agents of decline in rare species; such a design would have been preferable to the one used in the present study. A common experimental procedure in single subject studies is the A-B-A series or some variant of it where A and B refer to experimental conditions with A being the control and B the treatment. Treatments are switched on and off for individuals (e.g., animals, or areas) which are considered representative of the study population. Well designed, replicated single subject studies might allow data to be used even after unplanned alterations to experimental conditions. The results of such studies would be cumulative, interpretable and more readily publishable. For some species all that may be required is a re-analysis of existing data.

Keywords: *Gallirallus australis*; conservation biology; single subject studies; experimental design.

Introduction

North Island weka (*Gallirallus australis greyi* Buller) have declined in numbers and range this century (Marchant and Higgins, 1993). There are now probably less than 2 000 weka in the North Island of New Zealand and the population is scattered (D. King, *pers. comm.*; Department of Conservation, Gisborne, NZ) and appears to be still declining (A. Bassett, *pers. comm.*; Department of Conservation, Gisborne, NZ). The cause of small weka populations in the North Island is not known and hence there is a need to identify the cause before effective management to increase the population size can begin. Several factors have been suggested to account for the original decline in weka numbers including drought (Beauchamp, 1987), and disease (E. Jones, *pers. comm.*; Department of Conservation, Russell, NZ) but it is not clear why a bird that is omnivorous, prolific and capable of reaching high densities in much-modified landscapes (at least in the past) has not recovered from these setbacks.

Predation on weka by introduced mammals has been previously ignored or lightly dismissed as a limiting factor for weka populations (Graeme, 1992, 1994). My observations of ferret (*Mustela furo* L.) predation on weka, and the high disappearance rate of chicks and many sightings of feral cats (*Felis catus* L.) at Rakauroa, west of Gisborne, suggested that predation by these mammals had the potential to be limiting the weka population on farmland (Bramley, 1994). Adult weka can kill rats (*Rattus exulans* Peale and *Rattus norvegicus* Berkenhout; A.J. Beauchamp, *pers. comm.*) and are unlikely to be threatened by them. Rats are more likely to prey on eggs at unattended nests because adult weka brood young chicks for around a week after hatching (Beauchamp, 1987). Therefore cats and ferrets were considered to be potentially important predators of older chicks and adults at Rakauroa.

In 1993 there were only 10 breeding pairs of weka in the Waikohu Valley at Rakauroa and the total number of weka was declining (G.N.B., *unpubl. data*). To determine whether cats and ferrets were limiting the production of young weka I experimentally removed them from the home ranges of four pairs of weka and measured the number of young weka reared. I also monitored four other pairs of weka as a control. While the small sample size would make it difficult to reach reliable conclusions, it was necessary to identify potential limiting factors immediately. A controlled experiment was designed in preference to simply collecting isolated observations of predation. If predation was limiting the productivity of breeding pairs I would expect an increase in the production and survival of young from pairs in treated areas compared with pairs in control areas. Hurlbert (1984) listed seven "sources of confusion" that could plague an experimenter. Such problems should be solved, he suggested, by an experimental design that provided controls, randomisation, replication and in some cases interspersion of treatments. "The impingement of chance events on an experiment in progress" he called non-demonic intrusion (Hurlbert, 1984). Non-demonic intrusion can be countered by replication of treatments and interspersion of treatments. With rare species it is often not possible to counter non-demonic intrusion by randomising and replicating sufficiently for statistical power because there are no more individuals to be included in any sample. That leaves the experimenter with only the tools of "eternal vigilance, exorcism and human sacrifices" (Hurlbert, 1984) to counter these random events. Examples of these events that plague an experiment include the deaths of study animals, loss of a radio transmitter or localised environmental catastrophe. Conservation biologists regularly work with small sample sizes because the organism they are working with is rare. Since it is impossible to increase the sample size of some studies I suggest another approach, namely the incorporation of "single subject design" (Barlow and Hersen, 1984) into conservation research programmes. The advantages and disadvantages of this approach are discussed, using my predator removal experiment to protect weka as a case study.

Methods

The predator removal experiment was undertaken in the upper catchment of the Waikohu River at Rakauroa (38°25'S and 177°34'E). Rakauroa is a hill-country farming area approximately halfway between Gisborne and Opotiki on State Highway 2, North Island, New Zealand. The area is mostly pasture land with corridors and patches of scrub associated with roads and the river and areas of native and exotic (*Pinus radiata*[1]) forest. The scrub consists mostly of manuka (*Leptospermum scoparium*), *Coprosma* species and five finger (*Pseudopanax arborea*). The native forest has been described by Rasch (1989) and is mainly tawa (*Beilschmiedia tawa*)/podocarp with kamahi (*Weinmannia racemosa*) and rewarewa (*Knightia excelsa*), some of which has been extensively grazed.

Visits to the study site were made every month between March 1992 and January 1994 except October 1992. Field visits were between 4 and 22 days in length. All cats, ferrets and rats seen during these visits were recorded. Animals were usually seen whilst driving along the valley or while searching for weka. I also noted the timing, location and the colour, pattern and pelage of each cat seen so that individuals could be identified.

Assignment of weka pairs to treatment and control groups

Eight weka (7 males, 1 female) carrying back-mounted, 2-stage VHF transmitters (manufactured by Sirtrack Ltd, Havelock North, NZ) and their breeding partners were randomly assigned to the predator removal group or the control group (no predator trapping) in August 1993. Two weka with overlapping home ranges were treated as one unit during randomisation. I captured and radioed the partners of three experimental weka as the experiment progressed. Radios were equipped with a 10-month battery cell and had external whip type aerials. Transmitters were set at 60 pulses per minute and weighed an average of 19.3 g. Transmission was set between 160 and 162MHz and radios had an expected range of 3-4 km in farmland. I walked through the home ranges of the control weka pairs daily except in the first trapping period. As I walked through the eight weka home ranges, I obtained point locations for each radio-carrying bird using a Telonics TR-4 receiver combined with a hand-held three element yagi antenna (Telonics telemetry-electronics consultants, Mesa, Arizona, USA.). Birds were not followed, but I tried to see each bird and establish its breeding status. Triangulation from a distance of <50m allowed me to pinpoint nest sites.

[1] Botanical nomenclature follows Allan (1961) and Webb, Sykes and Garnock-Jones (1988).

Trapping predators

Twelve Edgar traps for catching ferrets and stoats (*Mustela erminea* L.) (King and Edgar, 1977) and six cage traps for capturing cats were placed within the known home ranges of each of the four weka pairs in the experimental treatment group. Edgar traps were baited with one whole domestic hen egg and one cracked egg. Cage traps were baited using "sardines in aspic" cat food within a length of nylon stocking tied around the trap's bait hook. All traps were initially placed on the boundaries of known weka ranges and opened on 11 October 1993 for 14 nights. The traps were then shifted and reopened on 13 November 1993. During this period fish heads were used to bait the cage traps. I positioned the traps in areas I thought likely to be visited by ferrets and cats. These were isolated patches of scrub, features that provided shelter and areas near boundaries such as creeks, roads, hedges and fences.

Trapping was then carried out from 13-25 November (13 nights), 30 November to 9 December (10 nights), 13-22 December (10 nights), 5-16 January 1994 (11 nights) and 19-26 January (7 nights). Edgar traps were re-baited whenever something was caught, or every 7-10 days. Cage traps were re-baited every 4 days. Between each trapping episode the traps were shifted to new areas within the weka home range that I thought likely to be visited by ferrets and cats.

I checked the traps in each area daily, usually between 0600hrs and 1200hrs NZDT. Ferrets and feral cats caught in the traps were shot or killed by asphyxiation with carbon dioxide. One rat was killed for identification and any other animals were released. Ferrets and cats were sexed and the gut removed for identification of prey as recommended by Day (1966). The gut samples were stored frozen and then washed over a 500µm Endecott sieve. I identified fragments using a dissecting microscope at 10x magnification and a key to common diet items. Hairs were identified as being from lagomorphs or "other" by their medullary pattern and feathers were identified to family using the criteria in Day (1966).

I compared sightings of cats in treatment areas during November, December and January of 1992-93 (before predator trapping) with the same months during predator trapping using a Mann-Whitney U test.

Results

In the 18 months prior to the start of trapping in October 1993 I saw 55 cats on 79 occasions, two stoats (one of them dead), two ferrets (one of them dead) and one rat (identified as *Rattus rattus*).

Cat sightings were not significantly different between November 1992 to January 1993 and November 1993 to January 1994 despite predator removal (Mann-Whitney, U=1721.5, *P*=0.36). Cat sightings in predator removal areas were not significantly different to control areas during the November 1993 to January 1994 period (Mann-Whitney, U=3908.5, *P*=0.13). However, four of the sightings in November 1993 in one weka home range in a treated area were of one cat that was later captured. When these four sightings were removed from the data, sightings in predator-removal areas were significantly reduced compared to sightings from the previous year (Mann-Whitney, *P*=0.0001) and sightings from control areas (Mann-Whitney, U=3997.5, *P*=0.0082).

Predators trapped

I completed 4212 trap nights from 11 October 1993 to 26 January 1994 and caught a range of species (Table 1). After adjusting the number of trap nights by assuming that both the successful traps and those traps that were sprung but unsuccessful had been available to catch animals for 0.5 of a night the trap success equated to 0.38 predators per 100 trap nights (0.26 for cats and 0.12 for ferrets). I made 120 non-target captures including 44 weka, 29 of which were recaptures.

Four of the ferrets were males. One was a pregnant female with six early-stage embryos. Five cats were adult females, three of which were lactating. One of the six males was a kitten.

All of the ferrets and nine of the cats had food remains within their stomach (Table 2). Feathers

Table 1: *Results of trapping for ferrets and cats in four weka home ranges at Rakauroa. "Other" included magpies (*Gymnorhina tibicen *Latham), harriers (*Circus approximans *Peale), possums (*Trichosurus vulpecula *Kerr) and blackbirds (*Turdus merula *L.).*

Trap type	Trap nights	Cats	Ferrets	Hedgehogs	Rats	Other	Weka
Cage	1289	9	1	2	0	6	42
Edgar	2923	2	4	40	27	1	2

Table 2: *Gut contents of predators trapped at Rakauroa. Food remains were found in 14 guts, nine cats and five ferrets.*

	Ferrets	Cats	Total
Lagomorph	1 (20%)	5 (56%)	6 (43%)
Other mammals	3 (60%)	2 (22%)	5 (36%)
Insects	3 (60%)	4 (44%)	7 (50%)
Birds	1 (20%)	4 (44%)	5 (36%)

were found in five stomachs; in four cases these were from Passeriform birds. The stomach of the female ferret contained feathers from a rail. Weka are the most common rail in the area (only five pukeko (*Porphyrio porphyrio* L.) were ever seen) and the colour of the feathers was consistent with it being an adult weka. The ferret was caught in the range of a male weka shortly after he was last seen.

Reproduction by weka

Shortly after the experimental birds were chosen in August 1993 the radio worn by one female weka in the control group ceased transmitting and two male weka, one in the treatment group and one in the control group, dropped their radios so that no data could be obtained from them. Another weka from the treatment group disappeared in early October.

The outcome of the experiment was that two pairs of weka in the predator removal areas reared five chicks to six weeks of age from three breeding attempts. In comparison, two pairs of weka in control areas reared no young despite three breeding attempts (Table 3).

Discussion

The impact of predators on breeding success of the North Island weka population at Rakauroa may be significant. During the first 18 months of my study an average of 0.38 juveniles were raised per nesting attempt (n=25; G.N.B., *unpubl. data*). In contrast, weka pairs in predator removal areas had an average of 2.3 juveniles per nesting attempt (n=2), which is six times the productivity seen previously. I made no attempt to monitor reproductive success after the predator removal ended so whether these fledglings survived to adulthood is unknown. The findings that pairs in areas where there was no predator trapping failed to raise any chicks and that pairs in protected areas became six times more successful in raising chicks to six weeks of age is consistent with the hypothesis that predation is limiting success. The loss of at least four successful breeding adults also reduced productivity by reducing the number of breeding pairs (Bramley, 1994).

Weka productivity in other areas

The capture rate of target predators was lower than the reported capture rates for cats and ferrets in the Mackenzie Basin (0.52 cats/100 trap nights and 1.54 ferrets/100 trap nights (Murray, 1992). Grant and Page (1992) captured a comparable 0.2 cats per 100 trap nights on the Chatham Islands. The density of predators at Rakauroa may be sufficient for weka mortality to exceed recruitment. On Kawau Island weka reared 37 chicks to independence (approximately nine weeks) in less than six months (data from 12 pairs and 17 breeding attempts, A.J. Beauchamp, *pers. comm.*). Weka at Rakauroa from March 1992 to March 1993 reared one chick to independence (data from eight pairs, 12 breeding attempts, Bramley, 1994). Productivity on an island is therefore substantially higher than on the mainland. Kawau Island does have wild populations of cats and stoats, but in probably only low numbers (A.J. Beauchamp, *pers. comm.*). One major difference between Kawau Island and the mainland is the absence of predation on all age classes of weka by ferrets. Predation by ferrets and dogs (*Canis familiaris* L.) has been shown to be preventing the establishment of a weka population at Karangahake,

Table 3: *The number of known breeding attempts and the number of chicks reared to six weeks of age, by weka in predator removal and control areas. Prior to the start of the experiment the former partner of the male in Pair Six disappeared. This pair had been the most successful in the valley in 1992-93 (hatching at least nine chicks in four breeding attempts). The female in Pair Five may also have changed although I was unable to confirm this. Pair One had already raised two chicks to approximately four weeks of age when I commenced predator trapping in their home range. Those chicks are not included here. Pair One bred together at least once unsuccessfully in 1992-93 but were becoming more successful.*

Predator Removal Pairs	Breeding attempts	Chicks	Control Pairs	Breeding attempts	Chicks
1	1	3	5	1	0
2	2	2	6	2	0
3 (male died)	0	0	7	no data	
4	0	0	8	no data	

near Paeroa, North Island, NZ (Bramley, 1994, A.J. Beauchamp, *pers. comm.*).

It is difficult to prove that predation is limiting weka productivity in the North Island, and impossible based on a group comparison with sample sizes of two. The study therefore needs to be expanded, either using larger samples of another species (perhaps using other sympatric ground-dwelling birds in the North Island or western weka (*Gallirallus australis australis* Sparrman) in the South Island) or by adopting a single study experimental design on the North Island.

The gaining of "reliable knowledge" (Romesburg, 1981) from small scale experiments designed to investigate the cause of smallness of a population is made more difficult by the fact the population is small, hence the number of replicates is going to be small. This experiment, for example, was necessarily limited by the number of weka available for study, and the loss of radio transmission from two of the eight pairs has made interpretation of the data difficult. The death of a bird further reduced the sample size to three in the experimental treatment group and two in the control group.

The problem of replication

Many studies of predator-prey interactions suffer from problems of low replication - as many as 40% have no or few (one or two) replicates (Sih *et al*., 1985). Probably because of the small sample sizes involved, authors have also shied away from applying inferential statistics to predation experiments (Sih *et al*., 1985). Conservation biologists study rare organisms, they have consequently tended to focus on single or a few subjects (Caughley, 1994). By focusing on nests or home ranges, (e.g., this study), sample size is immediately increased because one is now studying individuals (although data may not be independent, Hurlbert, 1984).

Tapper, Potts and Brockless (1991) used two large areas separated by approximately 6 km as experimental areas in research on game birds. They wanted to know if predation losses during the breeding season were a factor in keeping bird numbers low. To overcome the problem of replication, the treatment and control conditions were reversed mid-way through the experiment. That they were able to reproduce the effect in both areas was convincing evidence of the effect of predation. Tapper *et al*. (1991) also noted an increase in hare (*Lepus europeaus* Pallas) density along with an increase in partridge (*Perdix perdix* L.) density which lent further weight to their claims that predators were important in the system under study. This experiment is similar in design to the so-called single subject approach.

Single subject design and conservation biology

Single subject studies have been used in a deductive way (Nudds and Morrison, 1991) to test hypotheses. The subjects of these manipulations are known to be stable in certain characteristics - so stable they can be regarded as representative of the larger population (Barlow and Hersen, 1984, p. 25). For example, a common experimental procedure in single subject experiments is the A-B-A series or some variant of it (e.g., A-B-A-B-A, or A-B-C-B-A etc.), where A, B and C refer to experimental conditions, A being the control and B and C different treatments that are switched on and off over time. Data gained by pre-trial monitoring (i.e., establishing the baseline A phase) increases one's knowledge of the problem and may lead to insights on how to sensibly solve it. This was the approach taken by Tapper *et al*. (1991), although they used an A-B regimen on two subjects (direct replication).

Direct replication (i.e., by the same researcher at the same time, with the same research aim or management goal) is desirable in that it allows one to be more confident that the results are real - by using several "representative" animals the results are able to be more generally applied than if only one animal was used. Systematic replication, defined by Barlow and Hersen (1984), as "any attempt to replicate findings from a direct replication series, varying settings, behaviour change agents, disorders or a combination thereof" (p. 347) further increases the applicability of single subject studies to other areas and times.

This approach does not make use of inferential statistics which rely on an appropriate sample size, although there are statistical techniques designed to analyse results of single subject studies that use randomisation and time series analysis (Suen and Ary, 1989, pp. 193-214). Instead, workers use graphical presentation of data to show the independent variable against time in the A-B-A series. This can result in meaningful interpretations of data and lessen the effect of random events. Because authors of single subject studies tend to use graphs to present the outcome of their manipulations, experiments need to be designed so that independent variables are altered only one at a time. Because establishment of an appropriate baseline is necessary, pre-test monitoring studies (which may be hard to fund, but may have already been done as was the case in my study), are crucial. The length of the baseline period will vary with the

species depending on what is regarded by the researcher as stable.

Rather than advocating the abandonment of traditional group comparison experiments, I am suggesting that many conservation biology experiments in New Zealand have become single subject designs by default (e.g., O'Donnell, Dilks and Elliott, 1992; Murray, 1992; Powlesland *et al.,* 1994). We should therefore look for meaningful ways to turn this to advantage and make sensible use of the data at hand, rather than attempting to apply analytical tools whose assumptions are violated. Where there are sufficient resources and animals then group comparison experiments are more general in their applicability, but adequate data are hard, if not impossible to gather from rare, cryptic species.

Leading journals shy away from studies that may have been otherwise well designed but lack adequate replication (Sih *et al*., 1985). By having a well designed and conducted single subject experiment the research may be more acceptable, despite the problem (Sih *et al*., 1985) of including no statistical analysis. "Data on failures are a sign of the maturity of a systematic replication series" (Barlow and Hersen, 1984, p.363). After many successful outcomes (systematic replicates) of a single subject experiment, negative results become more important, thus they too might become more publishable.

In conclusion, the agent of decline operating on the only remaining mainland population of North Island weka remains unknown and will be difficult to determine using traditional experimental designs because the sub-populations are so small and scattered. To test the hypothesis that predation by cats and ferrets lowers the reproductive success of breeding pairs below the level needed to balance mortality, it will be necessary to adopt another approach. I suggest that predator removal be switched on and off in the home ranges of available weka pairs after detailed measurement of their breeding performance, as in a single subject approach.

Acknowledgements

C. Veltman is thanked for her supervision during this work, which formed part of an MSc(Hons) thesis from Massey University. C. Veltman also carried out the first period of predator trapping and reviewed earlier drafts of the manuscript. Landowners at Rakauroa allowed me free access to their land, and permitted predator trapping. I benefitted from discussion about this topic with C.M. King, W. Temple, T.M. Foster, J.R. Waas, S.C. Tapper, J. Innes, J. Miles and K.A. Edge. A.J. Beauchamp made his unpublished data on weka available to me. A. Bassett at the field centre in Gisborne modified the cage traps and is thanked for his assistance in the field. This work was funded mainly by grants from the World Wide Fund for Nature and the Lottery Science Board (NZ) to C.J. Veltman. Other funding was made available by Massey University Graduate Research Fund and the Department of Ecology, Massey University. The Department of Conservation in Gisborne, Gisborne and Waikato branches of the Royal Forest and Bird Protection Society, Juken Nissho Ltd, Hikurangi Forest Farms, Footrot Flats Charitable Trust, The Clark Charitable Trust and the J.S. Watson Trust all contributed generously to this project. Comments from two anonymous referees and J.R. Waas improved the quality of this manuscript.

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