Wetapunga (*Deinacrida heteracantha*) population changes following Pacific rat (*Rattus exulans*) eradication on Little Barrier Island

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Abstract Wetapunga (*Deinacrida heteracantha*) (Orthoptera: Anostostomatidae) is the largest of the 11 giant weta species found in New Zealand and is listed as Nationally Endangered. Originally distributed throughout Northland and Auckland, it is now restricted to Hauturu (Little Barrier Island; 3083ha). Largely arboreal, wetapunga feed mostly on the foliage of a range of plants by night and hide in refuges during the day. Following the eradication of kiore or Pacific rat (*Rattus exulans*) the abundance of wetapunga was recorded at fixed sites over five years. During May each year, 121 person hours were spent searching the same areas for the same length of time by the same three-person team to provide consistent search effort. Search time was split approximately 50:50 between night and day. Wetapunga encounters more than doubled over the five years with approximately 50% increase every second year. The size classes of wetapunga found were biased towards adults or near adult instars. On average, approximately 25% of all adults found each year were in male-female pairs, either pre-, or post-mating, or actually in copulation which appears to last for about 24 hours. Some adult wetapunga were found during the day in fully exposed positions indicating their behaviour may have changed due to reduced predator pressure following Pacific rat eradication. The increasing wetapunga numbers over the study period reflect the benefit of rodent eradication and are consistent with other studies on the impacts of exotic rodents on New Zealand indigenous large bodied, flightless, nocturnal invertebrates.

Keywords: Flightless invertebrates, Hauturu, monitoring; surveying, population recovery

INTRODUCTION

The Little Barrier Island giant weta or wetapunga (*Deinacrida heteracantha*) (Orthoptera: Anostostomatidae) is New Zealand's largest weta species (Gibbs 1999) and is slow moving, flightless, nocturnal and largely arboreal in forest. Early biologists reported the species as widely distributed throughout Northland, Auckland, and on Great Barrier Island (Colenso 1882; Dieffenbach 1843; Buller 1895; Hutton 1897). However, the species is now restricted to the 3083 ha, forest covered Hauturu (Little Barrier Island) Nature Reserve. Wetapunga is a species of high conservation value and is listed as Nationally Endangered (Hitchmough *et al*. 2007).

Surveys on Hauturu located wetapunga at night on the foliage of tree species (Richards 1973; Meads 1990; Meads and Balance 1990; Meads and Notman 1993; Gibbs and McIntyre 1997; Gibbs 2001), but rarely found the weta during daytime searches of large cavities that could be used as refuges. Richards (1973) and Meads and Notman (1993) considered it easiest to locate trees containing wetapunga by examining the ground beneath them for faecal pellets. Despite finding these characteristic, very large pellets, relatively few wetapunga were ever seen although considerable time was spent searching (Meads and Notman 1993; Gibbs and McIntrye 1997).

Following several intensive surveys on Hauturu, Gibbs and McIntyre (1997) considered wetapunga poor candidates for the use of artificial refuges (Trewick and Morgan-Richards 2000) to estimate density. Some years after the current study was initiated a novel technique for detecting wetapunga involving the use of tracking tunnels was reported (Watts *et al*. 2008). While this technique is a breakthrough in detecting the presence of giant weta, its ability to monitor population density has yet to be proven.

At the beginning of our study there was thus no accepted standard monitoring technique for wetapunga other than to employ experienced searchers for labour intensive field observations (Gibbs and McIntyre 1997).

Cats (*Felis catus*) were introduced to Hauturu around 1870 but were eradicated by 1980 (Veitch 2001). Kiore or Pacific rat (*Rattus exulans*) is known to have negative impacts on a range of invertebrate species (Green 2002; Towns 2009). Wetapunga surveys during the 1990s appeared to show a decline in abundance, which led to concern that the combined effects of Pacific rats and a recent reintroduction of the insectivorous North Island saddleback (*Philesturnus carunculatus*) in 1984 (Lovegrove 1996) may have been involved (Gibbs and McIntyre 1997). Pacific rats were eradicated from Hauturu in 2004 (Bellingham *et al*. 2010). Since wetapunga is a Nationally Endangered species, its' response was included as a measure of the benefits or outcomes of the eradication. Here we describe changes in wetapunga populations during the first five years following Pacific rat eradication.

METHODS

Annual surveys of wetapunga on Hauturu were carried out from 2005 to 2009 for one week each May, which is when Gibbs and McIntrye (1997) found the largest number of individuals. Search areas comprised 10 forest locations of variable size (all < 1 ha), mostly within 1 km of the ranger's residence/base on the island. All sites were in regenerating kanuka - broadleaf forest at the base of the tracks and stream valleys indentified in Fig. 1. All forest sites were considered suitable wetapunga habitat. During each survey, a total of 121 person hours were spent searching the 10 sites for the same length of time by the same three-person team to provide a consistent search effort. The same site received the same search effort each year, with more time usually allocated to the larger sites. Search time was split approximately 50:50 between day and night, with the former carried out after sunrise and the latter during the first six hours of darkness.

All wetapunga were located visually without the use of traps or lures. Day searching concentrated on any likely above-ground refuge sites such as in the dead fronds of nikau palm (*Rhopalostylis sapida*); at the base of live fronds and in dead fronds of the treefern species silverfern (*Cyathea dealbata*) and mamaku (*Cyathea medullaris*); in cavities under bark and in thick dead brush of kanuka

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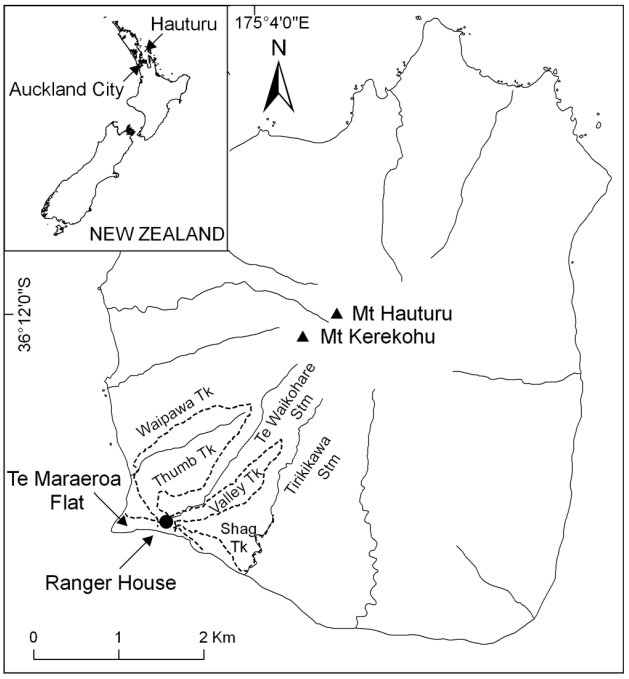

Fig. 1 Hauturu (Little Barrier Island). Wetapunga surveying occurred in 10 forest areas predominantly within 1 km of the Ranger House.

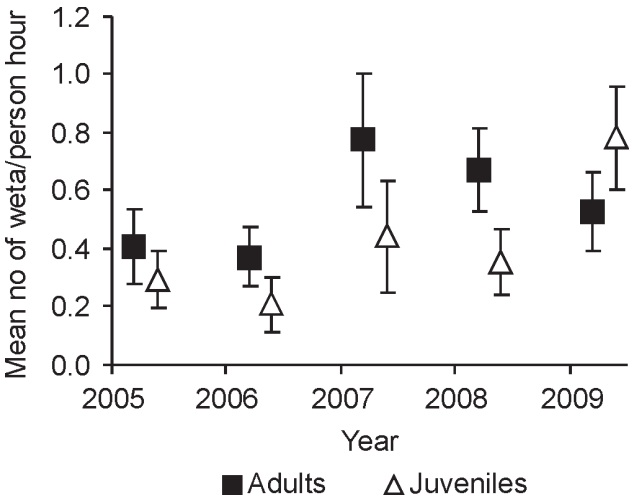

Fig. 2 Mean number of weta per person hour found each year across all sites over all search times. Error bars are standard errors.

(*Kunzea ericoides*); within dead hanging foliage of Collospermum (*Collospermum hastatum*); in any hollow trees or branches; or in thickets of dense foliage. Night searches used headlamp light beams to locate wetapunga on foliage, trunks and branches, as well as on the ground.

All wetapunga were collected and the right hind femur length measured to determine the instar. The sex was noted as well as the proximity of other wetapunga, particularly any male-female pairs. To avoid repeat recordings, each weta was marked with a Xylene-free marker pen. Weta were released in the exact location where found with particular care being taken to ensure juveniles were well hidden after release. Searching was discontinued during periods of persistent rainfall.

Data were analysed in the statistical programme 'R', version 2.9.2 (R Project, www.r-project.org), checked for normality, and are presented with standard errors. Weta counts were grouped as either adult or juvenile wetapunga. These were analysed using a linear mixed effect model with the number of weta as the response variable; year, time of day (day/night) interaction as the explanatory variable; and site as the random effect.

RESULTS

Wetapunga were found to be widely distributed on host plants and in refuges within the forest during day and night searches. Following the Pacific rat eradication in 2004, the total number of wetapunga found more than doubled from 78 in 2005 to 171 in 2009. Very low numbers of early instars (one to six) during all but the final year prevented meaningful analysis of temporal trends in each instar. Therefore the data for all juvenile instars were pooled for analysis. There was a significant increase in juvenile wetapunga over the five years (T_{64} = 2.99, P = 0.004) while the increase in adults was less pronounced (T_{64} = 2.12, P = 0.03) (Fig. 2). The mean number of adult weta doubled between 2006 and 2007 but then did not change substantially in each of the following three years (Fig. 2). Total numbers increased by approximately 50% every second year with the majority of weta being adult or late instar (eight or ninth) juveniles. As expected with such a very large but cryptic invertebrate, there was a positive relationship between weta age and numbers found, since larger weta were the most likely to be found. In the instars old enough to determine sex (fifth instar or older) there was a consistent 50:50 sex ratio recorded each year.

Over the five year study period, on average approximately 25% of all adults were found as male – female pairs, either copulating or beside each other, indicating likely pre-mating or post-mating behaviour. During the day, many copulating pairs were found in sites with little or no cover. Some were found fully exposed on large kanuka tree trunks and this behaviour was seen consistently each year. Sometimes a second male was found within 2-3 m of the pair. Copulation commenced in the evening and appeared to last for approximately 24 hours.

Over the five year period there was no significant difference in numbers of adult or juvenile weta found during the day versus night searches (T_{64} = 1.47, P >0.05 and T_{64} = -0.72, P > 0.05 respectively).

Despite searches in a wide variety of potential daytime refuge sites, weta were usually located in well protected refuges. Generally, refuge sites were at least 1 m above ground with only a few weta found lower during the entire survey period. Preferred sites appeared to be associated with foliage with colour and patterns that afforded wetapunga of all sizes extremely good camouflage. This was particularly apparent in dead, hanging silver fern fronds where weta were very difficult to detect and could only be found by silhouetting the frond against the sky to detect the weta shape. Where these dead fronds were in the form of a joined 'skirt' the individual fronds needed to be teased apart to find wetapunga within. Despite careful examination of these fronds, only adult or late instar juvenile weta were found within them during the day.

At night, wetapunga of all ages were seen out on foliage, on branches and trunks leading to foliage, which suggests that weta move from arboreal refuge sites to foliage on which to feed. Despite their large size, adult wetapunga moved nimbly along surprisingly thin twigs

and branches. Wetapunga were found on live foliage of karamu (*Coprosma robusta*), mamangi or tree coprosma (*C. arborea*), mahoe (*Melicytus ramiflorus*), hangehange (*Geniostoma rupestre*), kohekohe (*Dysoxylum spectabile*), rimu (*Dacrydium cupressinum*), kawakawa (*Macropiper excelsum*) as well as nikau and silverfern. We have not determined whether the frequency of weta sightings varied by tree species.

DISCUSSION

Our encounter-based search method revealed significant and consistent increases in the abundance of wetapunga on Hauturu following the eradication of Pacific rats. Other methods of detecting giant weta include the use of tracking tunnels (Watts et al. 2008), but these only indicate the presence of weta and as yet cannot provide robust population density measurements.

Previous surveys for wetapunga on Hauturu concentrated on night searching (Meads and Balance 1990; Meads and Notman 1993; Gibbs and McIntyre 1997), often using faecal pellets on the ground to indicate likely weta presence in foliage above (Richards 1973; Meads and Notman 1993. Pilot surveys by CJG (unpublished) indicated that wetapunga could be found in daytime refuges. We also found that faecal pellets were an unreliable indicator of weta activity, because only the freshest pellets indicated nearby individuals. Wetapunga were found regardless of whether we found pellets. This is probably because the arboreal habits of wetapunga can lead to pellets landing away from their source, as well as the wetas' mobility which can take them far away from the point of defecation.

Unlike earlier researchers, we found wetapunga at the rate of up to one per person hour search time during the day from the first year onwards. The search team probably became more proficient at locating wetapunga during the day as the first survey proceeded, but few additional daytime refuge site types were located in subsequent years. Furthermore, plant species such as tree ferns and nikau palms were consistently searched each year. Any improvements in search proficiency are unlikely to account for the more than doubling of the numbers of wetapunga recorded over the five year study.

The total number of wetapunga increased by approximately 50% every second year. Except for 2006 and 2007, this increase was largely driven by increased numbers of juveniles (Fig. 2). Why have adults not shown the same increased abundance as for juveniles? We suggest that since the rodent eradication, adult wetapunga have become more mobile in response to decreased predation pressure. Human visual range for large instars of wetapunga in these forests, which have a canopy height of about 15 m, is restricted to about 2 m during the day and perhaps double that at night. Other lines of evidence suggest that wetapunga are now using larger areas in the subcanopy and canopy where they cannot to be found by our search methods.

Radio-tracking studies suggest that wetapunga behaviour significantly changes after the final moult, when some adults travel over 50 m per night, apparently along the ground but also potentially over aerial walkways (Watts and Thornburrow 2009). In contrast, an earlier study by Gibbs and McIntyre (1997) with transmitters fitted to a few sub-adult male and female weta revealed sedentary behaviour, with just short movements to and from feeding sites close to refuges. Our study had repeated observations of several marked individuals, which confirmed the sedentary nature of large nymphs. The more recent radio-telemetry work also showed that 83% of the daytime refuge sites for adults were greater than 2 m off the ground (Watts and Thornburrow 2009). These studies indicate that, compared with sub-adult or younger instars, adult weta are substantially more mobile, make more extensive use of the entire forest structure, and are likely to be more difficult to observe from the ground. Thus we believe that the relatively low level of increase in adults compared to juveniles over the five year study period could be a reflection of relaxed predator pressure and increased adult vagility. Regardless of the mechanism, many more adult wetapunga are now being seen than were found during previous surveys while rodents were still present.

In the present study, most juvenile weta were found in (day) or near (night) refuge sites associated with dead foliage of plants such as tree fern and nikau palm. Within the forest structure on Hauturu, most dead foliage of such plants was within 3 – 4 metres of the ground. Since much of this habitat was available to us for searching, and if favoured by juvenile wetapunga then we probably had access to a greater proportion of juveniles than adults. Therefore the increased numbers of juveniles that we observed may provide a more accurate indication of wetapunga population trends.

The many adult wetapunga that we found as pairs is likely related to the early winter season of the surveys and approximates the 28% of weta radio-tracked as pairs by Watts and Thornburrow (2009). Many of the pairs in both studies were found either fully exposed or with relatively little cover to protect them from potential predators, including some pairs on the trunks of large kanuka trees in full view 1-3 m above ground. With copulation likely to last at least 24 hours, such behaviour in the presence of rats likely made these weta extremely vulnerable to predation. We also occasionally found individual adult wetapunga in relatively open positions with little or no cover, whereas surveys during the 1990s in the presence of Pacific rats made no such observations. Similar changes in conspicuousness have been recorded for several other weta species following rat eradications (Bremner *et al*. 1989; Rufaut and Gibbs 2003). Such observations indicate that the behavioural and morphological defences weta have against most natural bird predators are less effective against introduced mammals.

Invertebrates caught in pitfall traps immediately following the eradication of Pacific rats on Tiritiri Matangi Island (Green 2002) showed increased numbers of a range of nocturnal, flightless, large bodied species, including the ground weta *Hemiandrus pallitarsus* (Orthoptera: Anostostomatidae). Captures of this species increased four-fold in the first six years following rat removal (Green unpubl. data). By comparison, the doubling of wetapunga numbers in five years seems conservative, although the population is still increasing. Further monitoring is required to determine the upper limit of wetapunga population growth.

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