Lyver, P. O'B., C. J. Jones, and J. Doherty. 2009. Flavor or forethought: Tuhoe traditional management strategies for the conservation of *kereru* (*Hemiphaga novaeseelandiae novaeseelandiae*) in New Zealand. *Ecology and Society* **14**(1): 40. [online] URL: http://www.ecologyandsociety.org/vol14/iss1/art40/

Research

Flavor or Forethought: Tuhoe Traditional Management Strategies for the Conservation of *Kereru* (*Hemiphaga novaeseelandiae novaeseelandiae*) in New Zealand

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ABSTRACT. Traditional knowledge from indigenous cultures about wildlife populations can offer insights beneficial for management in the face of global climate change. Semistructured interviews and workshops conducted with Maori elders from the Tuhoe tribe in the Te Urewera region of New Zealand provided knowledge about traditional management strategies for New Zealand pigeon (*Hemiphaga novaeseelandiae novaeseelandiae*), known locally as *kereru*, as well as signals of changes in local climate patterns and how these influence *kereru.* We used a population simulation exercise to demonstrate the feasibility of a harvest management strategy used by the Tuhoe to sustain *kereru.* Our models also indicated how potential changes in climate and subsequent decisions about harvest timing might affect a theoretical *kereru* population. Elders identified *mana* (authority), *mauri* (essence or life force), *tikanga* (traditional custom), and *ture* (societal guidelines), and the use of *tohu* (signals or markings), *tapu* (sacredness), *muru* (social deterrent), and *rahui* (temporary harvest bans) as key elements and ideologies in the traditional management of *kereru.* They linked an increased climatic warming trend to delays of three to four months in the fruiting of some trees, such as *toromiro* (*Podocarpus ferrugineus*), deemed important for *kereru* nutrition and body condition. The Tuhoe have traditionally harvested both adult and newly fledged *kereru* when they are feeding on *toromiro* fruit, so a three- to four-month delay in fruiting could potentially defer the harvest until the prebreeding period. Our simulation models demonstrated that harvesting *kereru* adults and fledglings in the postbreeding stage had less impact on population abundance than only harvesting adults only during the prebreeding phase. The model indicated that the Tuhoe would need to re-evaluate their harvest strategy if climate-induced delays in *toromiro* fruiting were to become more frequent. This study emphasizes how using both science and the full matrix of traditional knowledge can offer wildlife management the better of two world views.

Key Words: *customary harvest; Mauri; Hemiphaga novaeseelandiae novaeseelandiae; New Zealand; resource management; traditional knowledge; Podocarpus ferrugineus*

INTRODUCTION

Increased recognition of the right of indigenous people to self-governance has led to greater consideration of traditional knowledge, which the Maori in New Zealand call *matauranga*, in wildlife management (Posey 1996, Taiepa et al. 1997, Berkes et al. 2000, Newman and Moller 2005). Relationships between wildlife and indigenous peoples can be important for subsistence, in defining cultural identity, and in providing links to participants' history, ancestors, land, art, and environmental philosophy (IIED 1994, Kirikiri and Nugent 1995, Berkes 1999, Moller et al. 2004). In many instances, these relationships take the form of a harvest, with contact between the user and the harvested species and its environment guided by traditional concepts, practices, and ethics.

The Tuhoe Maori are considered *tangata whenua,* i.e., the original people of the land, in the central Te Urewera region of New Zealand's North Island. For the Tuhoe, traditional knowledge forms the basis of their relationship with a culturally significant bird species, the *kereru* or New Zealand pigeon (*Hemiphaga novaeseelandiae novaeseelandiae*).

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The *kereru* is a *taonga* (treasure) for the Tuhoe from which they draw some of their cultural identity, and it is a highly valued source of food and feathers (Feldman 2001). As part of the colonialization agreement with Europeans, the Tuhoe were guaranteed access and management rights to lands and biological resources under the Urewera District Native Reserve Act of 1896 (Coombes 2003). In exchange for their acquiescence on such matters as tourism and road surveys through the native reserve, the Tuhoe were assured rights to harvest native and introduced birds and fish. However, those rights were abolished through a complex series of legislative amendments to the Animal Protection and Game Act between 1896 and 1911, and ultimately the harvesting of most native bird species, including *kereru*, was banned in 1921 (Coombes 2003). Since then there has been discord between the Tuhoe and the Crown over the right to manage and harvest native avifauna in Te Urewera (Coombes and Hill 2005).

The *kereru* is a large fruit-eating pigeon (550–850 g) that is endemic to New Zealand and inhabits temperate rain forests from 35ºS to 47ºS (Clout 1990). On the North Island of New Zealand, *kereru* nest from September to April (Clout et al. 1995). One egg is laid per nesting attempt and is incubated for approximately 28 days by both parents, males during the day and females at night. Chicks fledge at six weeks of age and may receive food from a parent for up to another week. In years when supplies of fruit are plentiful, breeding pairs may make more than one breeding attempt, whereas, in poor fruiting years, few if any breeding attempts may occur (Clout et al. 1995, Powlesland et al. 2003). Although relatively little is known about the staging of the climatic variables that drive variation in the fruiting of key *kereru* food species such as *toromiro*, a dialectal variation of *miro* (*Podocarpus ferrugineus*), the importance of temperature anomalies as cues for synchronized masting (seeding) suggests that the timing and intensity of masting may be sensitive to global climate change (Lee et al. 1997, Schauber et al. 2002).

The *kereru* was historically abundant throughout New Zealand and also recognized as a food item and game bird by early European settlers (Atkinson 1993, Coombes 2003). However, there have been large-scale declines in *kereru* populations throughout New Zealand over the last century (Clout 1988, Lyver et al. 2008*b*). Although the Tuhoe were historically the dominant tribe in the Te Urewera region and therefore responsible for the guardianship of the natural resources in the area, over the last century the land and associated flora and fauna have come increasingly under state authority and control. At present, the Department of Conservation, the government agency charged with conserving New Zealand's natural and historic heritage, manages the Te Urewera National Park and lists the *kereru* as "in gradual decline."

In this paper, we outline key cultural concepts and traditional management strategies used by the Tuhoe for the guardianship of *kereru* within their tribal area. As with other customary harvests of wildlife around the world, climate change has had, and will continue to have, real impacts on animal populations and the strategies used by indigenous people to harvest and manage those species and ecosystems (Krupnik and Jolly 2002). Therefore, we review how changing climatic patterns are perceived by Tuhoe elders to be influencing *kereru* populations and how these potential changes could affect the harvesting and management of *kereru* in the future.

As with other customary harvests of birds by indigenous peoples, e.g., the harvesting of Canada geese (*Branta canadensis*) by the Cree (Berkes 1982), *kereru* were harvested after the breeding season. There are three alternative explanations for this strategy. The first explanation suggests that the harvest is simply timed to coincide with the period when fledglings are much fatter and more appetizing than adults. However, because both adults and fledgling *kereru* are harvested, a second explanation suggests that harvesting after the breeding season was purely coincidental because this was when the birds happened to be aggregated, in prime condition, and most palatable from feeding on *toromiro* fruit. The third explanation implies a deliberate management strategy by the Tuhoe to sustain the resource for the future by protecting the breeding component of the population. The harvest of juvenile *kereru* in the postfledging period, as well as adults, could protect some adult breeders for the future, leading to better long-term outcomes for the population.

Because of the lack of evidence of the rationale behind the reported harvest strategy, we investigated whether there was any empirical support for this third "guardianship" explanation using a mathematical simulation model of a *kereru* population. We subjected this theoretical *kereru* population to post- and prebreeding harvesting strategies with varying harvest pressure, and estimated the likelihood of its long-term persistence under each scenario. We reasoned that, if there was no difference in predicted outcomes for the population under the alternative strategies, there would be little support for the active guardianship philosophy as a driver of harvest strategy. We also considered the model's predictions to discuss the consequences for *kereru* populations if climate change leads to a shift in harvesting to later in the year, just prior to the *kereru* breeding season.

METHODOLOGY

The study area and the people

The Tuhoe tribe is the ninth largest in New Zealand, with its population numbering 32,670 in 2006 (Statistics New Zealand 2006). The Tuhoe have traditionally lived in a region that overlaps the Whakatane and Wairoa Districts, which includes the heavily forested Te Urewera ranges, although most (~81%) now live outside of their tribal region (Nikora et al. 2004, Statistics New Zealand 2006). The community of Ruatahuna (Fig. 1) is located in the heart of the Te Urewera ranges and consists of about 261 people of Tuhoe descent (Statistics New Zealand 2006) clustered around a village center and 11 *marae* (traditional meeting places). Ruatahuna is surrounded by podocarp-tawa forest lands vested in the Tuhoe Tuawhenua Trust. These lands are in turn bounded by the Te Urewera National Park.

The community of Ruatoki is based around 10 local *marae* and located approximately 53 km north of Ruatahuna along the Whakatane River. Alluvial river flats within the Ruatoki Valley provide approximately 474 people of Tuhoe descent (Statistics New Zealand 2006) with mainly a livestock- and cropping-based economy. For both the communities of Ruatahuna and Ruatoki, the rivers and forests of the Te Urewera ranges provide their people with a valued source of native and introduced flora and fauna for food, medicine, building materials, firewood, and cultural and recreational activities.

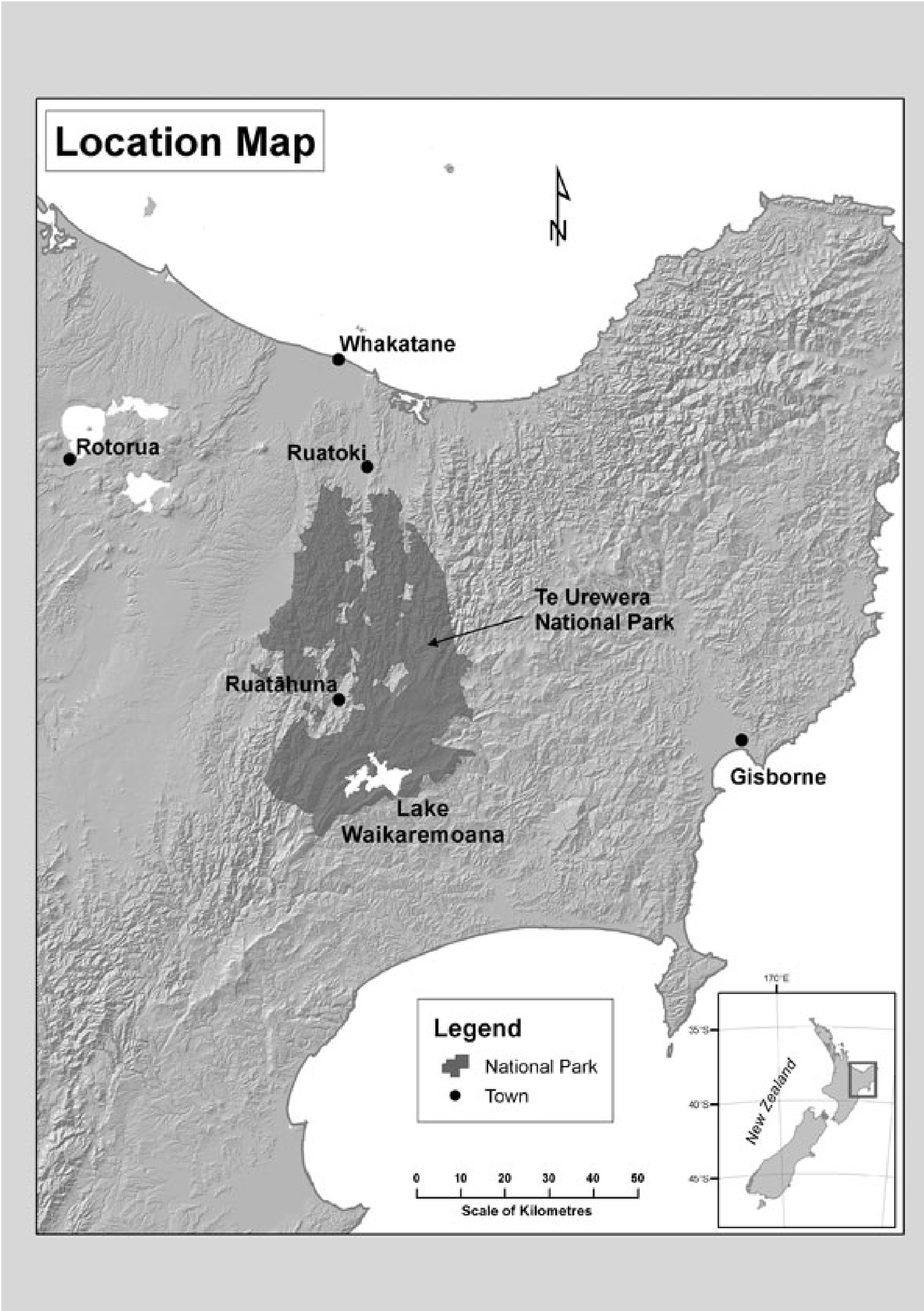
The interview process

An invitation to conduct this research was extended by the governing Tuhoe Tuawhenua Trust and sanctioned by the community at tribal meetings held at Ruatahuna and Ruatoki. The selection of elders was deliberately nonrandom. The individuals who were approached for interviews were recognized by Tuhoe Tuawhenua Trust representatives and other elders within the tribe to have extensive knowledge and experience related to *kereru*. Not all individuals were willing to be interviewed, and some passed away before they could be invited to participate. Therefore, from the pool of 20 male individuals (age range: 50–84 yr) identified as having the appropriate level of knowledge pertaining to *kereru*, 10 were interviewed . Repeated ideas and patterns of knowledge that emerged over the course of the interviews indicated that we had interviewed enough elders for the information to be considered reliable. Each of the elders had spent his life in or around the Urewera ranges and thus was able to observe the changes in *kereru* numbers, the forest, and the environment, and to talk with younger tribal members who had recently spent time in the bush.

Prior to the interview, the elders were contacted and sent a project description and an oral history agreement governing information use and confidentiality. The contents of these documents were discussed with each elder prior to commencing the interviews. Semistructured interviews, in which questions are presented in the context of discussion, were conducted to allow for a more natural conversation to occur and unanticipated insights to emerge (Huntington 2000, Telfer and Garde 2006). At the time of the interview, each elder was given a written list of the questions in both *Te Reo Maori* (the Maori language) and English so that he could follow the questions as they were asked. Elders would often provide responses related to a particular topic without being specifically asked about it, so the interviewer would refrain from asking those questions.

Three Tuhoe interviewers were used over the course of the study, and all were fluent in English, *Te Reo Maori*, and the Tuhoe vernacular. All the elders spoke some English, but most preferred to be interviewed in *Te Reo Maori*. Therefore, nine of the interviews were conducted in the Tuhoe vernacular or *Te Reo Maori* and one in English. The interviews took place between April 2004 and May 2007 and ranged from 1.5 to 3 h in length. The cultural and political sensitivities around the *kereru* and its illegal harvest meant that a large amount of time was required to build trust and relationships within the community for the interviews to occur. We do not believe that the time frame for the interviews affected the outcomes of this study because of the

Fig. 1. Map of New Zealand showing the location of the Ruatahuna and Ruatoki communities within the Te Urewera region.



longer-term nature of ecological and social conditions affecting the *kereru* population, and changes in local perspectives on harvesting were not detected by Lyver et al. (2008*b*) over this period. All of the interviews were conducted on a one-to-one basis, although family members were present at one. Seven of the interviews were recorded on digital video, of which six were translated from the Maori language into English for a transcriber. Three of the interviews were audio taped and directly transcribed from Maori into English by the Tuhoe interviewer. All interviews were transcribed vertibatim.

Interview questions were developed in conjunction with two Tuhoe elders who were knowledgeable about *kereru.* For the purposes of this paper, the interview was divided into sections that addressed key themes involving (1) customary protocols and practices related to the *kereru* harvest, (2) conservation strategies used to protect and conserve *kereru*, and (3) elders' observations of environmental patterns in the region. A workshop in which both *Te Reo Maori* and English were spoken was conducted with seven of the elders to verify the narrative and concepts that emerged from the interviews. One of the co-authors spoke fluent Maori so was able to follow and contribute to the discussion fully at the interviews and workshop. Three *hui* (meetings) were also held with the Tuhoe Tuawhenua Trust and two *hui* with the Tuhoe community to review draft research reports and approve the release of knowledge.

Simulation modeling, parameterization, and structure

Tuhoe elders provided the basis for the simulation model by identifying the traditional harvest protocols and how these might be influenced by observed climate-change patterns in the region. One of the co-authors is a Tuhoe elder and provided feedback and interpretation about model outcomes. Construction of the model, however, was primarily conducted in isolation from the community.

Robust estimates of *kereru* demographic parameters are sparse, either because studied populations have been subject to the confounding effects of heavy predation (Clout et al. 1995, Powlesland et al. 2003, Innes et al. 2004) or because the appropriate long-term studies have not yet been carried out. When the appropriate estimates were not available for *kereru*, we used those for the *parea* or Chatham Island pigeon (*H. n. chathamensis*), a subspecies endemic to New Zealand's Chatham Islands that, in recent years, has been subject to reduced levels of predation, leading to a marked recovery of the population (Flux et al. 2001). Parameter estimates used in the model, and their sources, are given in Table 1.

We built an age-structured matrix model (Leslie 1945, Caswell 2001) using a Microsoft Excel spreadsheet to describe the growth of a *kereru* population. This simple, female-only model contained four parameters: adult survival (S^A), with adults defined as those birds aged more than 1 yr; juvenile survival (S^J), with juveniles defined as those birds aged less than 1 yr; proportion of adults breeding in any one year (B); and breeding success (F), defined as the proportion of breeding attempts resulting in a fledged chick. We estimated a mean and standard deviation for each parameter based on published data. For S^J only one estimate for *parea* was available (Flux et al. 2001). In this case, we used this single value as our mean and estimated a standard deviation assuming that the same coefficient of variation applied to S^J as to S^A.

For simplicity and in acknowledgement of the limits imposed by the relatively sparse data, we made a number of assumptions in the construction of our model. First, we assumed that our theoretical population was not subject to significant predation by introduced mammalian pests and therefore used the published parameter estimates that best reflected this scenario. This was because harvest strategies were developed prior to colonization by European settlers and the introduction of their associated mammalian species. We also assumed that juvenile birds entered the breeding population at one year of age, based on the estimates for female *parea* in Flux et al. (2001). No density dependence in vital rates was included because it was reasonable to assume that all *kereru* populations in New Zealand are below their historical carrying-capacity levels and have been for some time (Atkinson 1993, Innes et al. 2004, Lyver et al. 2008*b*). Furthermore, we have no estimates of carrying capacity for this species, and density-dependent effects are more likely to have a moderating effect on population growth as population sizes approach carrying capacity. In developing this model, we also recognized that we have no historical information about the proportion of the harvested population that was juvenile.

Table 1. Parameter estimates used in simulation model for *kereru*. Means and standard deviations are based on the range of published values. Only one published estimate for juvenile survival is available.

Parameter	Symbol	Estimate	Mean	SD	Species	Source
Population size	N					
Population growth rate	λ					
Adult survival	S^A	0.96	0.90	0.09	*parea*	Powlesland et al. (1995)
		0.83			*kereru*	Clout et al. (1995)
Juvenile survival	S^J	0.87	...	...	*parea*	Flux et al. (2001)
Proportion of adults breeding	B	0.62	0.79	0.25	*kereru*	Powlesland et al. (2003)
		0.91			*parea*	Powlesland et al. (1995)
		1.00			*parea*	Powlesland et al. (1995)
		0.44			*parea*	Powlesland et al. (1997)
		1.00			*parea*	Flux et al. (2001)
Nest success	F	0.63	0.67	0.10	*kereru*	Pierce and Graham (1995)
		0.75			*kereru*	Powlesland et al. (2003)
		0.64			*parea*	Powlesland et al. (1995)
		0.65			*parea*	Powlesland et al. (1995)
		0.54			*parea*	Powlesland et al. (1995)
		0.82			*parea*	Flux et al. (2001)

A deterministic model was built first to describe the population in the absence of any harvest. We used this to estimate a reference value for the population growth rate, λ, with all parameters set at their mean values. Ninety-five percent confidence intervals around λ were estimated by running the model 10,000 times. For each iteration, parameter values were selected randomly from a normal distribution based on their mean and standard deviation (Caswell 2001).

Harvest strategies

Two alternative harvest strategies were imposed on the simulated population. These were:

1. a prebreeding harvest in which only adults were harvested. This scenario would apply if *kereru* were harvested in the spring, when fruit was available in their diet but before breeding. A range of harvest levels was based on the removal of fixed proportions of adult birds in any one year, i.e., we assumed that the harvest was density dependent.

2. a postbreeding harvest. Under this scenario, both adults and juveniles were harvested in equal numbers. The absolute size of the harvest was scaled as a proportion of available adults, so that levels of harvest were comparable between the two scenarios. For example, the removal of 10% of the adult population under the prebreeding harvest strategy was equivalent to the removal of 5% of the adult population plus an equal number of juveniles under the postbreeding harvest strategy. For completeness, we also looked at how the removal of the same number of birds, in a variation of this strategy in which adults and juveniles were taken in proportion to their abundance in the population, would affect our predicted outcomes. Relative abundances were based on the stable age distribution from the deterministic model.

To investigate the relative effects of the two strategies, we used stochastic simulation to compare the probabilities of quasi-extinction, PQE (Ginzburg et al. 1982), after an arbitrary 30 yr under each combination of harvest strategy and one of nine harvest levels. Prebreeding harvests removed from 1% to 25% of the adult population, and both versions of the postbreeding harvest strategy removed an equivalent absolute number of adults and juveniles. Environmental stochasticity was introduced by randomly sampling parameter values each year from a β-distribution (White 2000). Annual survival rates of adults and juveniles were made to co-vary by setting S^J as a fixed proportion of the randomly selected value for S^A in each year. Demographic stochasticity was applied to parameters by sampling from a binomial distribution in which the number of trials was the number of individuals in each age class in any one year, and the probability was the mean value for the parameter (White 2000, Diamond and Armstrong 2007). The initial population size was arbitrarily set at 500 adults, with the number of juveniles based on the stable age distribution from the deterministic model. For each combination of harvest level and strategy we ran the model for 10,000 iterations. The PQE under each combination was defined as the proportion of outcomes in which there was a decline of > 90% in total population size compared to the starting population.

RESULTS

Status of *kereru* within the Tuhoe traditional knowledge matrix

Elders reported that *kereru* were traditionally harvested between April and July, with the core time in May and June, depending on the degree of fruit development of the *toromiro* tree in that year. Harvesting occurred only during this period and coincided with the period at which *kereru* reached peak condition from feeding on *toromiro* fruit. It was widely believed among the elders that the *kereru* could sense the desecration of its *mana* (prestige) and *mauri* (life force or essence) when traditional *tikanga* (customs) was disregarded or inappropriate harvest practices were used. For example, elders stressed that *kereru* should be plucked and prepared for eating only when back in the community, so that hunters did not leave feathers or other traces of the harvested *kereru* in the forest. They believed that, if feathers or the remains of a harvested bird were left scattered beneath a *toromiro* tree or in the forest, the *kereru* would respond by vacating the area and making themselves unavailable to the hunters.

All the elders reported that under Tuhoe customs it was considered appropriate that only women or *rangatira* (a chief or high-ranking male individual) should eat *kereru,* which was especially revered as a food for pregnant women because it was believed that the bird's life force or essence would be passed to the unborn child. It was recognized that *rangatira* were permitted to eat *kereru* because of their status within the community. The sacredness of the *kereru* was considered to be appropriate nourishment for a chief because: *Ko te kupu e puta ana i tona waha hei whakarangatira i ngâ tangata ko te kupu e whakaora ana i tona tinana ko te kereru.* [As it is the words that come from the chief that empower the people, so it is appropriate that the words that empower his own body are the *kereru.*]

Kereru feathers were also highly prized by the Tuhoe for the ornamentation of *korowai* (cloaks), weapons, and the prows and sterns of *waka* (traditional water craft). One elder recounted that high-ranking women, i.e., women of tribal royalty, frequently did not eat *kereru* because they often wore a *korowai* made entirely from *kereru* feathers. Eating the *kereru* made it *noa* (common), whereas a cloak made of *kereru* feathers was *tapu* (sacred) because it touched the body. A woman of high-ranking status who wore a cloak of *kereru* feathers would not defile the sacredness or essence of the *kereru* by eating it.

Tuhoe strategies for the guardianship of *kereru*

The elders reported that rights to resources and connections between people and the land and forest were emphasized when assigning names and *tohu* (signals and markings) to places or objects such as traditional harvest areas, a *toromiro* grove or tree in which *kereru* regularly fed when in fruit and in which a *waka kereru* (snare and water trough system used for catching *kereru*) may have been hung to denote ownership, or the site at which hunters were killed when they were caught poaching within another tribe's hunting area. An area in Te Urewera was aptly named, in pre-European times, *Nga puku-o-kau*, which translates as "the place of intestines," after a poacher from a neighboring tribe was caught harvesting *kereru* and was disembowelled and his innards hung up in the surrounding trees. This form of *muru* (social deterrent) was used as a mechanism to protect resources and discourage violation of *tapu* (sacred covenants) or *ture* (customary lore and regulation).

It was widely recognized by all of the elders that once *kereru* stopped feeding on the *toromiro* fruit, the annual harvest would cease. After the *kereru* change their diet and begin to feed on the leaves of other tree species such as *kowhai* (*Sophora tetraptera*), their flesh becomes quite slimy, bitter, and unpalatable. The elders did not consider the nonharvest period of August to March to be under *rahui*, which denotes a temporary harvest ban or access restriction, but rather under the custom of *ture*, in which it was just common knowledge that *kereru* were not harvested when they ceased to feed on the *toromiro* fruit. Also, all the elders interviewed recognized that the harvest occurred immediately after the breeding period because this was when the *kereru* were aggregated and both newly fledged juveniles and adults were available for harvesting. They were aware that harvesting a combination of juveniles and adults reduced the impact of the harvest on the population. As one elder stated:

> *We [the Tuhoe] were well aware that harvesting after the breeding season meant we were taking young* kereru *as well as older birds, therefore lessening our impact on the population. The fact that this period coincided with when the birds were at their fattest and tastiest is just nature's way of guiding us to make sure that we harvest at the right time to ensure sustainability. We follow nature's direction.*

Half of the elders considered the concept of *rahui* that evolved through the colonialization process to have limited efficacy in the current societal environment because of compliance issues. One elder indicated that many within the Tuhoe tribe have not been raised *tuturu Maori* (under true Maori custom) and therefore do not have a clear understanding of the Maori conservation ethic. Furthermore, he strongly believed that the colonialization process over the last 200 yr had influenced the views and attitudes of the Maori toward their own traditional societal structure, values, and the environment, and that elders or traditional experts or priests no longer occupied the positions of authority within the Maori societal structure that they did in the past. An earlier attempt by some Tuhoe elders to invoke a harvest ban on *kereru* had not received unanimous support and was not, therefore, widely recognized within the tribe.

Three elders acknowledged the concept of *rahui* whereby each particular *hapu* (subtribe) controlled when, where, and who could harvest within their recognized areas. However, they emphasized that a *rahui* would be unlikely to succeed if mandated at the tribal level because of the complex nature of broader community politics. Decisions concerning the type and scale of action would need to be made at a family or subtribe level, which has traditionally come under the guardianship of local authority figures.

> *The etiquette of our old people still applies, and it is still valid even these days. Your* hapu *knows their gathering areas, and the bounty of the forest in that area is for your* hapu. *It is not right that people from other areas go there to procure food. It is akin to stealing food from your house when you go to the gathering grounds of another* hapu *to get* kereru. *The onus is on the* hapu *to retain and maintain their areas, so they should have laws and processes in place over their lands as guides, to stop others from just procuring birds because they want one.*

Even so, one elder suggested a revolving cycle of *rahui* for particular areas around the region, opening some areas up for harvest while closing others could be used to assist *kereru* restoration. However, nearly all of the elders believed that harvest restrictions alone would not be sufficient to halt the decline of the *kereru* and that multispecies control or eradication of introduced mammals such as ship rats (*Rattus rattus*), brushtail possums (*Trichosurus vulpecula*), stoats (*Mustela erminea*), and feral cats (*Felis catus*) would also be needed.

Absolute protection of the *kereru* breeding phase under Tuhoe lore was achieved in the belief that it is *tapu* (a bad omen) to inadvertently find a *kereru* nest in the forest during the breeding season. The *kereru* was referred to as "the hidden bird" of *Tane Mahuta* (God of the Forest), so to disturb a *kereru* nest was deemed a violation against the forest deity, which would bring repercussions. Also, because *kereru* is the "food of chiefs," it was considered a societal offence to disturb the species outside of the harvest period, a prohibition that community members obeyed for fear of repercussions.

Signals of climate-induced change in the environment and harvest

Increased climate variability was identified by seven of the 10 elders as a potential mechanism linked to changes in *kereru* foraging behavior. A general warming trend in the region has been noted because of a decline in the number, and the later occurrence, of frosts. Two elders reported that, prior to the mid-1980s, the first frosts had usually occurred by April, but now they do not occur until much later in the year (June–July). Frosts or cold, clear weather during fruit development was reported to be essential for setting the fruit on the trees so that it lasts longer and ripens properly. Therefore, years with frosts in April are recognized as potentially good years for *kereru.* A mild autumn period indicated a potentially poor season for *kereru* because fruit crops would be lighter and the fruit was not expected to last as long on the trees. Two elders reported that, over the last decade, fruit from some *Podocarpus* species, including *toromiro*, did not ripen until much later in the season. In 2004, *kereru* were reported feeding on ripe *kahikatea* (*Dacrycarpus dacrydioides*) fruit in mid-April, when normally fruiting for this species should have finished by the end of February. In addition, *kereru* have been observed feeding on ripe *toromiro* fruit in September and October, which is three or four months later than normal. A later ripening of the *toromiro* has meant that, in some years, Tuhoe hunters have delayed their harvest to coincide with the period during which the bird is in peak condition and most palatable. This has effectively shifted the *kereru* harvest period from the immediate postbreeding phase to the onset of the breeding season.

Simulation modeling

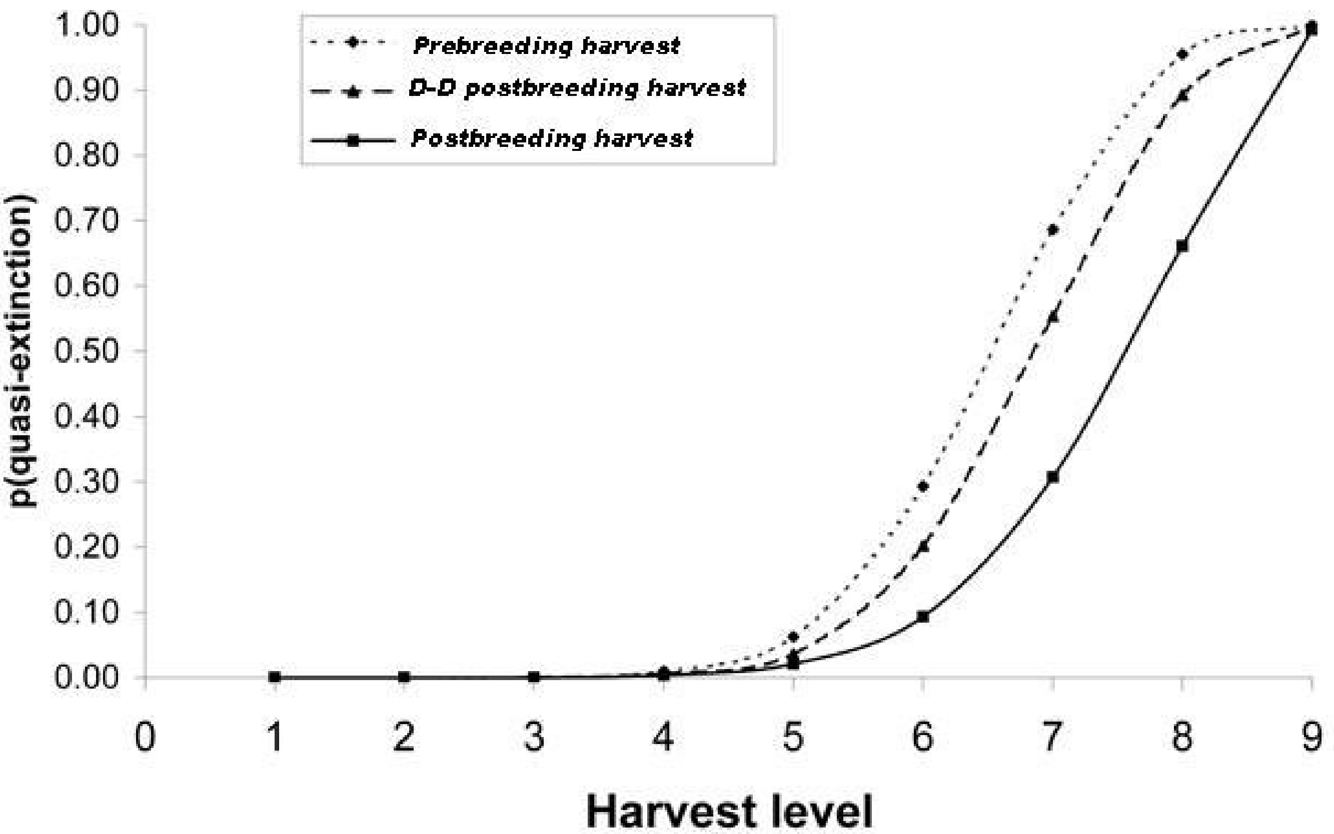
With all demographic parameters set at their mean values, the basic deterministic model predicted a population growth rate of 1.086 (95% confidence intervals: 0.85–1.30) in the absence of any harvest. At a stable age distribution, the population was made up of 82% adults and 18% juveniles. In the stochastic simulations, at low levels of harvest up to a removal of 7.5% of the adult population or its equivalent, there was no discernable difference in the probability of quasi-extinction between the modeled harvest strategies (Fig. 2). At higher levels of harvest, the PQE increased sharply under both strategies but was always considerably higher under the prebreeding harvest scenario. This difference was most marked between harvest levels representing the removal of 15–20% of the adult population, or an equivalent absolute number of adults and juveniles. At higher levels of harvest than this, both strategies led to very high probabilities of rapid population decline. The effect of harvesting adults and juveniles according to their relative abundance was to shift the PQE curve to mid-way between the pre- and postharvest, i.e., equal numbers removed, scenarios, reflecting the impacts on the population of removing increasing numbers of adult birds.

DISCUSSION

Returning authority for the *kereru* to the Tuhoe

Because the *kereru* hold immense spiritual and cultural significance for the Tuhoe people, the primary purpose of many customary rituals and practices was to protect and respect the *mana* and *mauri* of the species. The Tuhoe perceive the flora and fauna of Te Urewera as both a spiritual and physical reality in which all elements are interconnected to maintain the integrity or *mauri* of the forest ecosystem. Only through the appropriate functioning of, and respect for, all the components

Fig. 2. Relationship between level of harvest and probability of quasi-extinction for kereru after 30 yr under two different harvesting strategies. Harvest levels are defined by: (1) the proportion of adults removed in the prebreeding harvest scenario (dotted line), (2) an equivalent number of birds made up of equal numbers of adults and juveniles in the postbreeding harvest scenario (solid line), and (3) a density-dependent (D-D) harvest that describes what happens if adults and juveniles are taken in proportion to their relative availability, based on the stable age structure in the population (dashed line).



of the wider knowledge matrix can *kereru* be retained within the forests of Te Urewera. Integrally linked to this cultural world view are the role of humans and the harvesting of forest resources. For the Tuhoe, the imposition of European laws removed *mana* for the *kereru* from the tribe, and the enforcement of wildlife protection orders restricted the harvest of *kereru.* As a result of the combination of these cultural limitations, *Tane Mahuta* (the God of the Forest) senses that the *kereru* have become superfluous to Tuhoe needs and consequently has removed the *mauri* of the *kereru* from the forest by not replenishing the population, which has caused the observed declines (Lyver et al. 2008*b*). As with the conceptions of human-animal relations held by North American hunters (Nadasdy 2007), New Zealand conservation agents typically treat the above explanations of wildlife declines as "cultural constructions," implying that they are symbolic or metaphorical, rather than methods for "ascertaining the truth" (see Povinelli 1995). Rarely, if at all, are these explanations used as a factual basis for wildlife management or conservation policy. Instead, managers trained in Western scientific principles attempt to integrate only those components of traditional knowledge that they perceive to be relevant, which often contributes to the extension of state power over aboriginal peoples rather than their empowerment (Nadasdy 2007). The restoration of the *kereru* in Te Urewera provides New Zealand with an opportunity to develop a management program that uses the full complement of Tuhoe knowledge, strategies, and understandings of the world, including the ontological assumptions, as its basis. Returning the Te Urewera National Park back to the Tuhoe would be a reinstatement of *mana*, and permitting a harvest would signal to *Tane Mahuta* that *kereru* are still highly prized by the people and that the *mauri* of the bird should be returned to the tribe to permit its recovery.

Respect for the prestige and essence of wildlife is a common conservation ethic observed in other hunter-gatherer cultures around the world, and disregard for the guidelines that govern respectful behavior is believed to manifest itself as a decline in, or unavailability of, the resource (Krupnik and Vakhtin 1997, Nadasdy 2007). For some Maori, their relationship with the environment is the basis for the strength, integrity, and ongoing potential of their culture and thus part of their sense of well-being (Moller 1996). The *kereru* still provides a significant source of cultural identification and a link to ancestors and traditional lore for the Tuhoe community. The Tuhoe observed that the decline in the *kereru* population over the last century (Lyver et al. 2008*b*) has paralleled the erosion of their traditional ecological knowledge (TEK) as well as practices related to the bird, its harvest, and its environment. Prohibitions in 1921 outlawed the harvest of *kereru* and forced Maori around New Zealand to suppress or modify their customary harvest and activities to avoid detection by government authorities. Continued interaction with, and harvesting of, a resource is often critical to the survival and expression of knowledge related to that particular resource, especially within cultures that have traditionally relied on oral transmission of information. The protection of indigenous wildlife harvesting rights within some cultures through the postcolonial era has maintained the mechanism and opportunity for the continued development and transfer of traditional knowledge (Beaton 1990, Skira 1990, Ferguson and Messier 1997, Taiepa et al. 1997, Lyver 2002). However, with approximately 81% of the Tuhoe now living outside of their tribal region, few will have been exposed to the customary teachings related to the *kereru* and its management. Efforts to rectify this trend have been attempted within the tribe through *wananga* (learning groups) and educational initiatives in local schools. However, the knowledge transfer mechanism that holds the most promise for maintaining and building on the traditional knowledge base is continued contact with the resource through harvesting.

Challenges to building traditional management strategies in conservation

For protagonists of TEK, gaining access to detailed knowledge and being in a position to understand and appreciate the full extent of the information imparted by elders are often some of the greatest challenges of working with indigenous communities in environmental management. Traditionally, knowledge was closely guarded within the Maori culture, with access to some components confined to only a few. Therefore, the release of information outside of the *iwi* or cultural boundaries is often conducted with some trepidation, if at all. Elders are generally reluctant to release knowledge to uninitiates who enter their cultural world without the appropriate apprenticeship in learning about the culture, history, cosmogony, customs, and language (Roberts et al. 1995). Superficially acquired knowledge has often led to misuse and even abuse when information has been taken out of its cultural context.

The naming of hunting locations and the use of signals enhanced linkages to, and authority over, the land and forest for the Tuhoe. The reconstruction of these etiquettes would initiate the process of putting traditional values back into the Tuhoe community and facilitate the resumption of authority over the *kereru.* This practice would also serve to identify the guardians of particular areas of forest, and the families or subtribes who would be responsible for the management or activities, e.g., any potential harvest, that occurred in those places. Achieving wider tribal consensus or agreement about management strategies for *kereru* has proven difficult. Historically, it was the smaller subtribal groups who had authority over and a vested interest in maintaining the integrity of the wildlife populations and forest ecosystems around their communities. For any conservation effort to succeed, management would need to come from the numerous family groups who make up the matrix of Tuhoe subtribes throughout Te Urewera. This way each specific community would see the benefits and own the outcomes of its management actions and strategies.

For the Tuhoe, the re-establishment of the right to harvest native birds is one way of expressing their identity, a desire driven as much, if not more, by the cultural, social, and spiritual significance of the practices associated with the harvests as by the actual need for food (King 1994, Kirikiri and Nugent 1995). As Kirikiri and Nugent (1995) pointed out, more ardent attempts to prevent harvesting might occur if tribes were given decision-making power over *kereru* and forest management because poaching would be recognized as interfering with traditional customs and the success of legitimate sustainable customary use. An example of such a commitment has existed in the South Island of New Zealand since 2000, whereby the recognition of the authority of the Ngai Tahu people under the Ngai Tahu Settlement Act (1999) spurred tribal-led conservation actions such as the Kuapapa Kereru Programme. The goals of this program are to increase the abundance and range of *kereru* on Banks Peninsula, Canterbury, by working with local communities to raise their awareness and appreciation of *kereru* and to provide information about *kereru* numbers, distribution, movements, and foods as a basis for improving habitat (Norton 2007). However, formal settlement of land claims and institutional recognition of *mana* is not always a prerequisite for restoration by the Maori, as demonstrated by the Kukupa Restoration Programme in which the subtribe of Ngati Hine led a co-management initiative with the Department of Conservation, Northland, to restore *kukupa* (a northern Maori dialectical variation of *kereru*) populations in the Motatau Forest (Innes et al. 2004, Lyver 2005). Whatever the political process, these examples demonstrate that some tribes have the desire and capability to initiate conservation programs and do not intend to use the change in policy or management authority to legitimize the immediate harvesting of *kereru.*

The Tuhoe used a range of social mechanisms to establish guidelines and procedures for the correct and appropriate use of biological resources and to avoid their depletion. In the past, the penalties for a breach of custom and protocol could be severe, and this was a strong disincentive to abuse a resource. *Tino rangatiratanga* (absolute authority) conferred upon Maori leaders the power to enforce customary practices for the promotion of the well-being of biological resources (Hodges 1994, Moller 1996, Millner and Sciascia 1997). Unlike the European system of hunting seasons, during which officers enforce compliance, the traditional concept of *ture* does not need enforcement, but rather the community naturally respects the customary lore and practice. The preservation and respect of *mana* is paramount to the Maori way of life, and Maoridom is very careful to preserve the many forms of *mana* it holds, in particular the prestige of environmental guardianship (Roberts et al. 1995). Compliance with these rules was based on respect, and reciprocity was enforced with fear of divine retribution or by human acts of enforcement or confiscation of resources (Roberts et al. 1995). The principal of reciprocity by which balance was achieved and maintained underlay and governed every aspect of tribal custom. However, with many of the Tuhoe living in an urban environment removed from the more traditional life-style, the challenge is how to maintain, transmit, and ensure respect for customary lore within the community. Questions remain about what a TEK system might look like, and how it might operate within the modern social-ecological environment.

Ecological basis of traditional management strategies

It is acknowledged that not all traditional management strategies evolved within a specific ecological framework or with conservation outcomes in mind. The strategy of not plucking *kereru* in the forest was focused around fostering respect for the prestige of the bird, rather than any direct conservation benefit. Much debate has centered on whether indigenous cultures actively conserved their resources with deliberate management strategies, or whether many strategies were driven by benefits to the hunters alone, and population benefits accrued purely by chance. Protection of the breeding portion of a species' life stage is a common strategy used by Maori around New Zealand. For example, Rakiura Maori in the south of New Zealand prohibit access onto the Muttonbird (Titi) Islands outside the harvest season to prevent the disturbance of breeding adults while mating, incubating, and initially rearing chicks (Lyver 2002). Scientific studies have shown that adult sooty shearwaters are highly prone to abandonment of burrows if disturbed during the incubation phase (Warham and Wilson 1982).

Harvesting juvenile cohorts rather than breeding adults from wildlife populations is a common traditional management strategy used by the Maori to promote sustainability in their harvests (Hunter et al. 2000, Lyver et al. 2008*a*). However, the alternate explanation for harvesting only the young is that this strategy is based on the fact that chicks are much fatter and more appetizing than adults, rather than a conscious decision to protect the breeding population. Tuhoe elders recognized that harvesting *kereru* between May and June in the postbreeding period meant that the availability of juvenile birds effectively buffered impacts on the adult breeding population to some extent. Unfortunately, they were not able to provide any indication as to the proportion of the historical harvest that was made up by juvenile *kereru*. It was also acknowledged that the harvest occurred when *kereru* were in peak condition and at their most palatable, but in years when *kereru* condition was poor or numbers relatively lower, the harvest was lighter or did not proceed. This suggests that the Tuhoe actively monitored the *kereru* population and the state of the forest, e.g., the fruiting of trees, and adjusted their harvest management strategies accordingly.

Our simulation models showed that harvesting a combination of adult and recently fledged *kereru* would be a more sustainable strategy for the population compared with harvesting adults only. The inclusion of juveniles in the harvest has the effect of diluting the impact on adults. The postbreeding harvest based on the stable age structure of the population demonstrated that the effects would be intermediatary to scenarios based on a 50:50 removal of adults and juveniles or the removal of adults only (see Fig. 2). The reproductive rates of many indigenous bird species in New Zealand, like the *kereru*, are intrinsically low (Moller 1996), but their typically high annual survival rates, coupled with the fact that older birds generally show higher reproductive success than younger breeders (Saether 1990, Forslund and Part 1995), confers a higher reproductive value on adult birds than on juveniles.

Adapting traditional management strategies to climatic uncertainty

One goal of our simulation model was to demonstrate how a potential climate-change-induced shift of the harvest to the prebreeding stage would have a relatively greater impact on the *kereru* population than harvesting during the earlier postbreeding phase because of the greater numbers of adults removed from the population. We were able to emphasize this point to the community using the model and facilitate discussions about what recent climate-induced changes to traditional management strategies might potentially mean for their harvest. Although it is unknown if *kereru* would delay or forego breeding in years of late *toromiro* fruiting, few *kereru* nesting attempts occurred during years in which there was little podocarp, e.g., *toromiro*, fruit present in one region of Te Urewera (Powlesland et al. 2003). This potentially could mean that adults would be at even greater risk of harvest in the following year because fewer juveniles would be present to buffer the harvest.

The ability to adapt to environmental variation is a key component of management strategies and survival in all cultures. The Inuvialuit in the Western Arctic dealt with natural unpredictability in their environment by having flexibility in seasonal cycles and switching species opportunistically (Berkes and Jolly 2001). However, the level to which indigenous cultures can adapt to, or compensate for, climate-change-induced variability in prey stocks and the physical environment remains to be seen. It is expected that the increased reliance on and availability of westernized foods and resources will buffer these effects to a certain extent, although probably at a further cost to cultural sustainability.

In the absence of a harvest, our deterministic model predicted that the *kereru* population would grow by approximately 9% each year. This is probably an optimistic estimate, given that some of the parameters that we used were based on those for a *parea* population that was undergoing a rapid recovery from the impacts of introduced mammalian predators (Flux et al. 2001). In spite of this, the growth rate of the unharvested population is within the limits described in reviews by both Russell (1999) and Saether and Engen (2002) for a range of avian species.

The differences between our simulated harvest strategies depend, in part, on the relative impacts on adult and juvenile *kereru*. Our assumption that equal numbers of both classes are removed in the postbreeding harvest scenario infers that juvenile birds, which make up approximately 20% of the population, are more vulnerable to harvesting than adults. Although there is neither published nor anecdotal evidence for this effect in *kereru* harvests, we suggest that this is a reasonable assumption because the greater susceptibility of juvenile birds to hunting has been documented for a large number of other harvested species (Bergerud 1970, Shupe et al. 1990, Sheaffer et al. 2004). The effect of harvest impacts on juveniles when more closely tracking their relative abundance would be to shift the postbreeding harvest curve closer to that for the prebreeding harvest scenario although, even with complete density dependence, the postbreeding harvest strategy would still lead to a lower PQE than the prebreeding harvest at all harvest levels, except for the very high and low extremes.

Tuhoe elders recognized that harvesting a combination of juveniles and adults at the postbreeding stage enhanced the sustainability of the population. Harvesting when *kereru* had large reserves of body fat and their flesh was flavored by *toromiro* fruit was perceived as *Tane Mahuta*'s way of directing the people to harvest at the appropriate time. However, it is unknown how the Tuhoe would adapt to a climate-change-induced delay in the fruiting of *toromiro,* and if they would shift their harvest to later in the year or cease harvesting altogether in affected years. Berkes and Jolly (2001) analyzed a range of short-term, i.e., coping, and long-term, i.e.,adaptive, responses to demonstrate the adaptive capacity of an Inuvialuit community to deal with climate change. However, the ecological effects of the climate-change-induced adaptations of Inuvialuit hunting strategies, e.g., harvesting goose eggs in seasons in which laying was late and egg numbers were down, were not considered at the wildlife population level. If the Tuhoe were to adapt to climate change by harvesting later in the year, it could have significant impacts on the long-term viability of *kereru* populations by increasing the relative impacts on breeding adults before newly fledged juveniles became available.

Although historically *kereru* numbers were large enough to absorb the harvest of an unknown proportion of the population by the Tuhoe (Lyver et al. 2008*b*), predation pressure, e.g. reduced productivity and adult survivorship, by introduced mammals coupled with habitat removal is widely believed to have placed the *kereru* harvest in the unsustainable category (Clout 1988, Atkinson 1993, Pierce et al. 1993). The Urewera ranges are characteristically rugged with dense high-canopy forest, which makes it notoriously difficult to obtain an accurate census of *kereru* and monitor their life-history rates. However, cultural indices of *kereru* numbers in Te Urewera indicate that the population has undergone a large-scale decline over the last 50–60 yr (Lyver et al. 2008*b*). Accordingly, our models must be viewed with this in mind. We do not infer any safe levels of *kereru* harvest at the present time because there are currently insufficient data on population abundance and vital life-history rates.

CONCLUSION

In carrying out this research on traditional knowledge we have endeavored to (1) emphasize the significance of the *kereru* to the Tuhoe and the role of specific traditional management strategies in its conservation, (2) investigate how climate change is affecting a forest ecosystem and potentially could induce adaptations of a traditional management strategy, and (3) explore what these strategy adaptations might mean for a theoretical *kereru* population. Our research provided evidence that the Tuhoe possessed a range of strategies for actively safeguarding the different life-history stages of the *kereru.* The majority of these governed the harvest-related behavior of community members, with one strategy designed to protect the breeding phase. Unlike many other research studies, this investigation endeavored to go one step further and predict how climate-change-induced modifications to customary harvest activities might have flow-on effects on the wildlife population being hunted. This study highlighted how a delay in the harvest could increase its impact on *kereru* by altering the proportion of adults being taken and potentially affecting the long-term viability of the population. Unexpected demographic or population feedbacks resulting from changes to harvest practices in other examples of customary harvest should be considered, especially if that species is under pressure from other environmental factors such as climate change.

A greater role for traditional knowledge in managing natural resources is a goal of many indigenous cultures, including the Tuhoe. Indigenous communities are undoubtedly important local sites of action for improving cultural-ecological resilience and natural resource management. The Tuhoe fiercely defend their local governance and identity, and the application of their TEK by their people would strengthen their commitment, action, and effectiveness when it comes to restoring and protecting resources. However, their isolation, small size, and lack of resources make local indigenous communities like the Tuhoe vulnerable to fragmentation and domination by centralized state agencies that have traditionally applied western models of resource management and research. The application of a "one size fits all" approach to legislation and a predominantly monocultural and institutionalized approach to resource allocation further weakens cultural-ecological resilience when national resources for local and indigenous management are severely limited. Commitment and vision are therefore required to redesign traditional and contemporary resource management structures that incorporate national and local strengths to simultaneously trigger improved environmental and cultural outcomes.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/vol14/iss1/art40/responses/

Acknowledgments:

The authors thank the Tuhoe elders who participated in this study and the Tuhoe Tuawhenua Trust for its directorship. We also acknowledge the elders who passed away over the period of this work. We appreciated Spady Kutia, Moehau Kutia, June Tihi, and Te Motoi Taputu for conducting, translating, and transcribing the interviews. Thanks also to Peter Newsome for designing the figure. The study was funded by the Foundation for Research, Science and Technology, Sustainable Indigenous Forest Grant (C09X0308). We benefited immensely from discussions and advice from Henrik Moller and editorial comments provided by Carl Folke (Editor-in-Chief) and two anonymous referees.

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