HAURAKI MAORI MATAURANGA FOR THE CONSERVATION AND HARVEST OF TITI, *PTERODROMA MACROPTERA GOULDI*

by Phil O'B. Lyver, Joe Davis, Liane Ngamane, Alice Anderson and Pauline Clarkin

(with one text-figure and two tables)

Lyver, P. O'B., Davis, J., Ngamane, L., Anderson, A. & Clarkin, P.2008 (31:x): Hauraki Maori Matauranga for the conservation and harvest of Titi, *Pterodroma macroptera gouldi*. *Papers and Proceeding of the Royal Society of Tasmania* 142(1): 149–160. https://doi.org/10.26749/rstpp.142.1.149 ISSN 0080-4703. Landcare Research, PO Box 40, Lincoln 7640, New Zealand (PO'BL*), c/o Hauraki Māori Trust Board, PO Box 33, Paeroa, New Zealand (JD, LN, AA, PC). *Author for correspondence. Email: lyverp@landcareresearch.co.nz

Hauraki Maori traditional knowledge (which the New Zealand Maori term matauranga) concerning the harvest of Titi, Grey-faced Petrel, *Pterodroma macroptera gouldi* (Hutton, 1869), on the islands adjacent to the Coromandel Peninsula was recorded and analysed. The harvest of Titi linked Hauraki individuals to culture, ancestors, individual well-being and tribal identity. It also maintained mana (prestige), kaitiaki (environmental guardian) responsibilities and matauranga systems. Harvest tallies of Titi chicks (and number of birders) declined from 15 000 chicks (and 100–150 birders) before 1950, to 1000–1200 chicks (10–20 birders) by the late 1980s, to < 100 chicks (5–10 birders) in 2007. Decline in harvest tallies was not due solely to fewer individuals harvesting because daily catch rates per birder also declined, in some circumstances by as much as 87%, over this time. Traditional resource management strategies for sustaining Titi populations included: selection of chicks in the intermediate stage of growth allowing those in a more advanced state to escape; harvesting chicks towards the end of the adult provisioning period to minimise disturbance; creating breeding space by splitting burrows; annual rotation of harvest around islands to enhance escapement in some years; assigning partial island refuges to enhance escapement; respecting the mana and mauri (life force) of the Titi by not leaving chick remains on the islands and causing abandonment; and designating a rahui (temporary harvest prohibition) on islands to rest colonies from harvest. Indigenous knowledge can provide valuable insights into population dynamics and strategies for managing a species, as well as to prioritise research to safeguard the population, traditional knowledge and cultural well-being of the harvesting community.

Key Words: Maori, Hauraki, Grey-faced Petrels, traditional knowledge, resource management strategies, *Pterodroma macroptera gouldi*, Titi, matauranga.

INTRODUCTION

Relationships between wildlife and indigenous peoples are important for subsistence economies, defining cultural identity, and providing links to history, ancestors, land, art and environmental philosophy (IIED 1994, Kirikiri & Nugent 1995, Moller *et al.* 2004). In many instances, traditional knowledge (herein referred to what Māori term *mātauranga*) underlies and guides these relationships (Lyver 2002). Unlike science-based systems, indigenous peoples' traditional knowledge depicts ecosystems as infused with spirit and life force and based upon reciprocal human–animal relationships (Krupnik & Vakhtin 1997, Tyrrell 2007). This is quite different from a scientific perspective which views ecosystems as mechanical, quantitative and quite distinct from people and feeling (Berkes 1999).

Recording traditional knowledge holds value in its own right, but can also inform research and management for a variety of ecological systems (Ohmagari & Berkes 1997, Lyver *et al.* 1999, Huntington 2000, Gilchrist *et al.* 2005). Moller *et al.* (2004) argued that traditional monitoring methods, albeit often imprecise and qualitative, are nevertheless valuable because observations are diachronic (knowledge developed over a long timeframe and from one locality), inexpensive, incorporate large sample sizes, invite the participation of harvesters as researchers, and sometimes incorporate subtle multivariate cross-checks for environmental change. Decision making about the management of wildlife populations benefits from an in-depth understanding of the species' abundance, demographics, movement and habitat use. For wildlife managers, understanding population trends is a critical first component in the sustainable management of wildlife harvests. Estimates of abundance using scientifically-based methodologies can often be expensive and time-consuming, frequently lack replication and have observer bias, often be run for less than a single generation of the species concerned, and often be only "relative indices" or accompanied by large confidence intervals (Moller 1996, Moller & Raffaelli 1998, Raffaelli & Moller 2000). For many wildlife populations there are often insufficient quantitative data (e.g., adult survival, immigration rates) to support scientific tools (e.g., trophic or stage-structured population models) and decision making. As a result, management decisions can be made in the absence of data, or by using data from related species to fill knowledge gaps. For many wildlife management challenges, and especially those involving indigenous people, there will be little robust scientific information available to guide sustainable harvesting. Also, indigenous communities will have little access to, or even little understanding of, the value of scientific information that could secure or enhance customary life-ways. Equally many wildlife scientists will have little appreciation of the power and utility of mātauranga.

Some indigenous knowledge systems have been eroded over the past 100–200 years. New Zealand Māori recognise that there has been a breakdown in transmission of mātauranga because of cultural assimilation with European culture (Tau 2001). Separation from natural resources through government land confiscations and harvest prohibitions, motivated by a predominantly preservationist conservation paradigm, has accelerated this loss. Even so, many *iwi* (tribes) assert that their mātauranga, which is largely based around an ethic of "resource conservation for

future use" (Kirikiri & Nugent 1995, Roberts *et al.* 1995, Moller 1996), can reliably inform wildlife management and conservation in New Zealand (Lyver 2002). The value of and need to include mātauranga has been supported and ratified under international agreements such as the Convention on Biological Diversity 1993 (UNEP 1993), to which New Zealand is a signatory.

Our study considered Hauraki mātauranga as a source of information to guide the harvest of a seabird breeding on New Zealand's offshore islands. For the Hauraki iwi, mātauranga forms the basis of their association with a culturally significant seabird species, the Tītī, Grey-faced Petrel, *Pterodroma macroptera gouldi* (Hutton, 1869). The customary take of Tītī chicks by Hauraki represents one of the three remaining petrel harvests permitted in Australasia (Skira 1990, Kitson 2004).

Tītī breed mainly on islands off the east coast of northern New Zealand, with the larger colonies on Rimariki Islands, Taranga (Hen Island), Mokohinau Islands, Ruamaahua (Aldermen) Islands, Moutohora (Whale Island) and Whakaari (White Island) (Wodzicki & Robertson 1959, Imber 1976, Imber *et al.* 2000). Recent estimates of numbers on the major breeding islands suggest the population is about 200 000–300 000 breeding pairs, indicating a total population in excess of a million birds (Taylor 2000). The Tītī is unusual among *Pterodroma* because it is a winter-time breeder and lays eggs during June and July, with its chicks fledging in early summer. On average, Tītī adults are 410 mm long and weigh approximately 550 g (Heather & Robertson 1996) while their chicks usually weigh less than 900 g.

Hauraki, Ngāti Awa and Ngātiwai, and other iwi groups around the upper half of the North Island of New Zealand traditionally harvested Tītī chicks annually from mainland and offshore island breeding colonies (e.g., Rimariki Islands, Ruamaahua Islands, Moutohora Island). However, in response to declining harvests during the 1960s Hauraki and Ngāti Awa implemented a *rāhui* (temporary harvest ban) and the harvest on their islands was mostly discontinued. Even so, a small-scale take persisted from the Ruamaahua Islands by a few individuals, and now there is a renewed interest by the iwi to reinstitute the customary practice.

The objectives of this paper were to understand the significance of Tītī and its harvest to Hauraki and determine long-term changes in the abundance and density of Tītī on their islands. We also reviewed *kaitiakitanga* (environmental guardianship) strategies used by Hauraki to manage the sustainability of their harvests. We argue that Hauraki did not harvest indiscriminately, but had ways of proactively managing the Tītī population and their breeding islands. Finally, we consider the role of Hauraki mātauranga in informing wildlife and harvest management for the Ruamaahua Islands.

METHODOLOGY

Interview process

An invitation to conduct this research was extended by the Ruamaahua Islands Trust, and sanctioned by the governing Hauraki Māori Trust Board and community at tribal meetings in Paeroa. Selection of interviewees was deliberately non-random. Those individuals who were approached for interviews were recognised by the community to have knowledge and experiences relating to the Tītī. Therefore, interviews were conducted with seven *kaumātua* (male elders; age range 50–88 years) of which five had >30 years birding experience; four *kuia* (female elders; age range 65–78 years); four birders with less than three years' harvest experience; and four Ruamaahua Islands Trust and working group members. Each of the interviewees had either direct or indirect involvement with Tītī through the historical or recently reinitiated harvest on the Ruamaahua Islands (fig.1) or through the current co-management of the islands with Department of Conservation (DOC). This either exposed interviewees directly to the birds, the islands, and harvest, or indirectly through knowledge collected about the system. Repeated ideas and patterns of knowledge that emerged over the course of the interviews indicated we had interviewed enough individuals for the information to be considered reliable.

Prior to commencing an interview, a project description and an oral history agreement governing information use and confidentiality were discussed with the interviewee. Semi-structured 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 & Garde 2006). Quite often interviewees would provide responses related to a particular topic without being specifically asked about it, so the interviewer would refrain from asking those questions.

Three interviewers were used over the course of the study, although one interviewer conducted 89% of the interviews. All the interviewees spoke English as either a first or second language, so all interviews were conducted primarily in English. The interviews were conducted between 1 July 2006 and 7 November 2007 and ranged from 0.75–2 hours in length. Fourteen of the interviews were conducted on a one-to-one basis, while on four occasions discussions were conducted with two interviewees present. All of the interviews were recorded on digital video and transcribed verbatim. The accuracy of transcriptions was checked by a second transcriber. Direct quotes are indicated by indentation below.

Interview questions were developed in conjunction with the Ruamaahua Islands Trust. For the purposes of this paper the interview was divided into four broad sections and addressed key themes about: (1) the significance of Tītī and its harvest to Hauraki; (2) observed changes in Tītī abundance and variation in burrow and chick densities; (3) cultural indicators used to gauge changes in Tītī abundance; and (4) traditional kaitiakitanga strategies used to manage the Tītī harvest and islands.

RESULTS

Harvest of Tītī

Interviewees reported that Tītī were usually harvested during the first two weekends in November. The first birding party would go out and harvest on the opening Saturday, and the second party on the following Saturday. Harvesting did not usually occur on the Sunday, although occasionally birders would overnight on the islands and return to the mainland the following day. Tītī chicks were only harvested from burrows during the day. Interviewees reported that if a chick was close to the burrow entrance, it could easily be caught

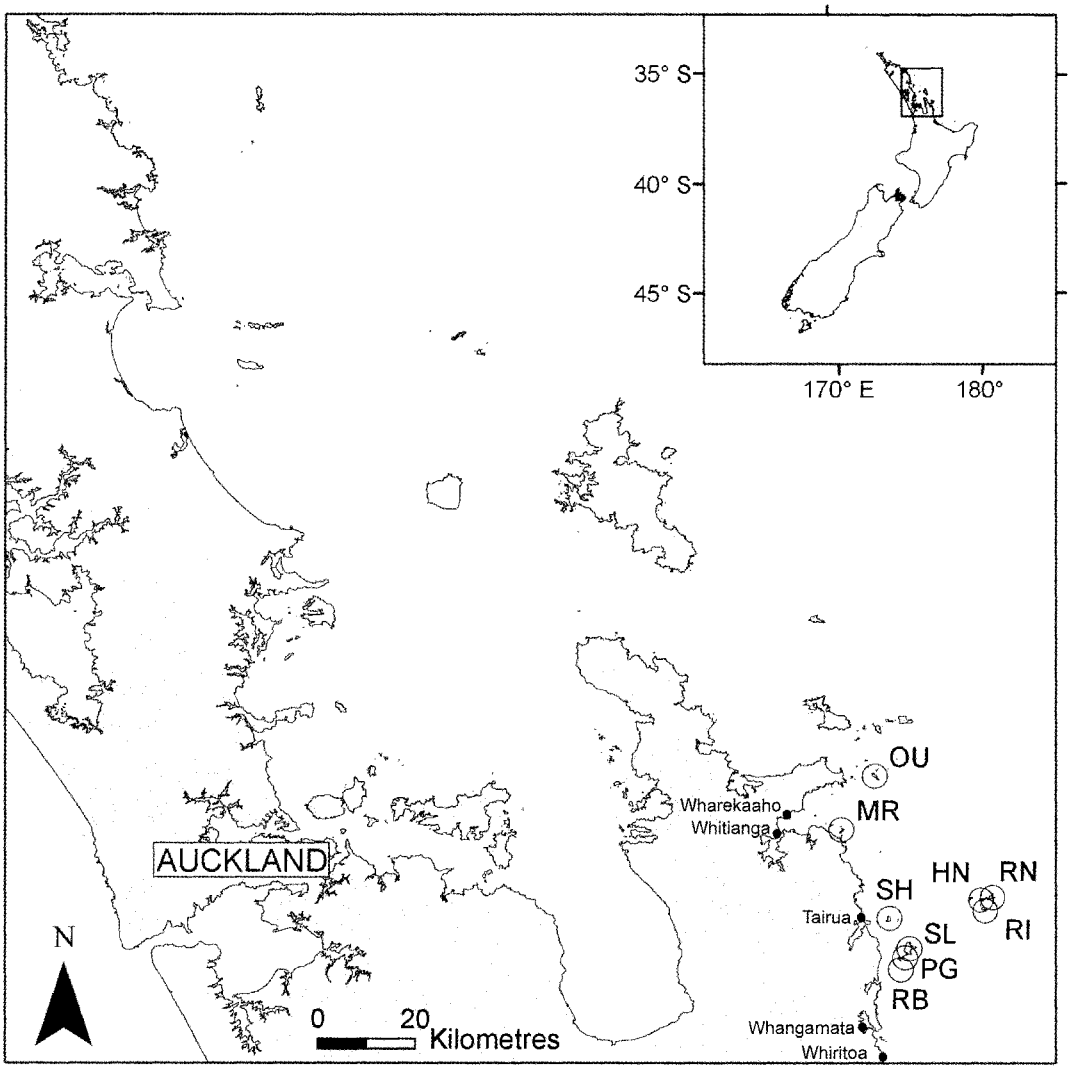

FIG. 1 — Hauraki communities and Tītī Islands harvested by Hauraki birders (Ruamaahua Islands [RN – Ruamaahuanui; RI – Ruamaahuaiti; HN – Hongiora]; OU – Ohinau; MR – Mahurangi; SH – Shoe Island; SL – Slipper Island; PG – Penguin Island; RB – Rabbit Island).

by hand. However, if a chick was beyond hand reach, a stick of mānuka, *Leptospermum scoparium*, J.R. Forst & G. Forst, or bracken fern, *Pteridium esculentum*, (G. Forst) Cockayne, between 0.5–1 m long with short prongs (~ 5 mm) protruding from the end would be inserted. Once birders could feel the chick pecking the stick or moving around in the burrow, they would twirl the end into the bird's down so it would become entangled. It would then be quietly eased up the burrow to a point where it could be reached and pulled out. Interviewees indicated that it was a skill that needed experience to be perfected.

Once the bird was in hand it was quickly killed by breaking its neck or crushing its skull. Before placing the dead chick into a sugar-bag, some birders would apply pressure on the bird's abdomen causing it to regurgitate its stomach contents, while others would pull or cut out its crop. Some birders indicated they just harvested the chicks and took them back to the mainland in their entirety and processed them at home.

The older birders recounted how before the 1970s, chicks were usually brought home and dipped in either the creek or a pot of hot water to assist with feather and down removal. Other birders indicated that their families would conduct the entire preparation process while out on the island. Burning candles or paper were also used occasionally by some to singe off down and pin feathers. After about 1968, many birders would partially pluck birds and then immerse them in molten wax. Once the wax had set it would be cracked and stripped away taking with it all the remaining down and pin feathers. Birds were mostly eaten fresh or frozen for later use. Only two birders remembered birds being salted or preserved in fat after especially large harvests.

Significance of Tītī to Hauraki

Interviewees explained the importance of Tītī harvest in terms of a spiritual association that the practice provided to culture and ancestors; it also provided individual well-being and iwi identity as a way of maintaining *mana* (prestige) and *kaitiaki* (environmental guardian) responsibilities and knowledge. They also acknowledged direct benefits of physical nourishment and nutrition from eating the bird (table 1).

One interviewee reported that there was an expectation from other iwi in Hauraki that his family would provide the traditional foods like Tītī or *kaimoana* (seafood) for occasions of cultural and social significance. It was emphasised that the

TABLE 1
Significance of Tītī and their harvest to Hauraki

No.	Explanation of significance
1	Desire to see Tītī (and seafood) back on the tables of our *koroua* (elder men) and *kuia* (elder women) here in Hauraki and at our *hui* (gatherings).
2	Having Tītī present on the table to eat on important occasions is very relevant for Hauraki. It partly identifies the Hauraki people or particular families within the *iwi* (tribe). It denotes where you come from.
3	Tītī are a traditional food source for Hauraki and have been a staple food item in the past. It is about continuing to have the taste of those traditional foods.
4	There is a level of expectation that certain *hapū* (subtribe) or *whānau* (family) will provide particular types of foods for occasions. There is a *mana* (authority and prestige) aspect to being able to put local wild food on the table for visitors at gatherings.
5	It is the customary right of Hauraki to harvest Tītī. Continuation of the harvest maintains that right and tradition.
6	The harvest of Tītī is a traditional practice passed down through the generations by Hauraki *tūpuna* (ancestors). Continuation of this practice maintains that link to the tūpuna.
7	Continuation of the harvest maintains the integrity of the *mātauranga* (Māori trandional knowledge) associated with the Tītī, the harvest and islands. Isolation from the harvest can disrupt the oral transfer of knowledge. The associated mātauranga is a living thing. It is an evolving thing.
8	Continuation of the harvest preserves the traditions and unity within and amongst the iwi, hapū and whānau.
9	Continuation of the harvest maintains the connection and the *kaitiaki* (guardian) relationship with the Ruamaahua Islands and the bird.
10	The Tītī is a special *kai* (food). It is a *rangatira* bird (a bird with chiefly status) and can not be replaced with other poultry like chicken. It is a special bird that nourishes not only your physical self, but also your spiritual well-being. It is a food that you crave.
11	Provision of your own food whether it is from the sea, forest or garden provides a sense of satisfaction that one does not get from store-bought food. There is a special feeling in eating the same foods that the old people ate.

ability to supply abundant and high-quality local food was an essential part of the *manaakitanga* (hospitality) customs and responsibility:

> *Whenever there was a tangi [funeral] on our [eastern] side of the [Kaimai] ranges we never had to worry about going to gather kaimoana or Tītī. However, when there was tangi or hui [gathering] or something over on the other side, the expectation from the people over there was that we would put kaimoana or Tītī on the table. From the time I was a little boy that would always happen.* (J.L. 2007)

Interviewees recognised that the knowledge pertaining to the *tikanga* (traditions and rituals) such as *karakia* (prayer); *pātere* (rhythmical chant); *waiata* (traditional song); *pepeha* or *whakatauki* (proverbs); *tohu* (signals or indicators) of the harvest and *kaitiaki* practices related to Tītī in the Hauraki community had become increasingly diluted over the past 30 years. Reasons suggested for the erosion of this knowledge included: (1) the perturbation to traditional Māori life brought about by colonisation over the past 100–150 years; (2) the relatively recent movement of Māori away from their traditional lands and resources into an urban environment; (3) a general decline in the practice of harvesting Tītī; and (4) that the knowledge was possessed by only a few families within the *iwi* over the past 50 years. Interviewees felt that the latter reason had made the mātauranga vulnerable to loss. Even so, one asserted that certain elders within the Hauraki iwi still possessed a robust understanding of mātauranga related to the Tītī, although acknowledged that few of these individuals remained. Most interviewees agreed that to reverse the loss of mātauranga, the knowledge had to be "lived once again". They urged that the Tītī harvest become an annual activity for the iwi and supported with new initiatives such as *hui* (gatherings) and elder–youth *wānanga* (learning groups).

> *In the earlier years, it was quite different. It [the harvesting of Tītī] was part of the lifestyle of our old people really. They lived their mātauranga. Our tūpuna [ancestors] used to go out to Ohinau (fig. 1) in October and November and stay there for weeks while they harvested the Tītī and planted the kumara crops. Then they would go again later after the first frosts had occurred on the mainland and harvest their kumara and another species of muttonbird [species not identified].* (R.B. 2006)

Changes in Tītī abundance

Birders identified a range of harvest-based indicators that they used to monitor Tītī population abundance. One interviewee whose family had historically harvested Tītī indicated that he and his father observed an initial decline in chick abundance on the Ruamaahua Islands during the late 1980s, with the scale of decline becoming very noticeable by 2003. The interviewee recounted his father making the comment in the late 1980s:

> *The birds don't seem to be here. They don't seem to be coming back to the islands like what they use too.* (V.T. 2007)

This particular interviewee felt that the harvest would never go back to the same level as it was 30 years ago because of the human and environmental pressures now facing the birds. He also reported that prior to 1990 it was usual for a birder to harvest two chicks from each burrow entrance. This was supported by interviewees from another family who referred to burrows in the past as "always being full" [of chicks]. However, they had also observed a decline in burrow occupancy during the early 1990s. Another interviewee reported that the number of burrow entrances on the Ruamaahua Islands has remained the same, but now you attempt about three holes and only get one chick.

> *In the past, when you got to the Aldermens [Ruamaahua Islands], it was just one mass of holes. You could sit in one place and stick your hand in. But you don't stick your hand in too far at the start because the bird up this end [of the burrow] will peck at it. You go in and pull it out, then another will be about a foot away, and another a bit further on until you clean it [the burrow] out. Then you move a bit. The softer the ground the deeper they [the birds] go. And you'll know if you get three or four birds from one entrance, then you know there are three or four different tunnels underneath.* (B.C. 2007)

The oldest interviewee recounted parties of 100–150 birders going out to the islands to harvest during the 1930s and 1940s and returning with around 15 000 birds. However, three interviewees reported that the size of the birding parties had shrunk to 10–20 birders by the late 1980s. Prior to this it was common for a birding party of 7–10 individuals to harvest about 1000–1200 chicks over a day (4–5 hours of birding). It was even possible for a single birder to harvest 250–300 birds in a day off the Ruamaahua Islands, but after 1990 an individual tally declined to about 50 chicks per day. Similarly, another interviewee who had birded on nearby Mahurangi (Goat) Island (fig. 1) recounted how in the early 1970s his two uncles and father could easily catch up to 120 chicks between them in the first hour of harvest. In contrast, records from 2005 and 2006 show that parties of between six and 10 birders harvested a combined tally of less than 100 chicks, although the majority of these individuals had little practical harvesting experience. The older birders linked the erosion of mātauranga indirectly to declines in the Tītī population. It was recognised that the optimal environment for passing this knowledge on between generations was during harvesting expeditions out to the islands. However, with the decline in bird abundance fewer people were harvesting and as a result knowledge was not being passed on. Unfortunately, in more recent times this knowledge loss has been exacerbated by the passing of the more experienced birders.

Variation in burrow density and chick quality

Birders were aware of the patchy distribution of Tītī burrows on some islands. They reported that Tītī burrows were most dense around the peripheries of inshore islands (e.g., Slipper and Rabbit islands; fig. 1), whereas burrow density was higher and more evenly distributed across the landscape on the Ruamaahua Islands. They attributed this difference to the greater abundance of birds and forest coverage on the Ruamaahua Islands. On Slipper and Mahurangi islands, where areas of forest had been removed for farming, burrow density was much lower in the grass areas, especially where ungulates such as goats, *Capra hircus* Linnaeus, 1758, were present. Birders were acutely aware of these differences because of the manner that they had to move around the islands. It was reported that on inshore islands, an individual could stand up and walk between burrows, whereas on the Ruamaahua Islands they were required to tentatively crawl around to avoid collapsing burrows. One experienced birder recognised a greater abundance of small seabird species on inshore islands (e.g., Shoe, Rabbit and Penguin islands; fig. 1) compared with the Ruamaahua Islands. He postulated that interspecific competition for nesting space was the reason for this, and that the larger, more abundant Tītī could outcompete the smaller burrowing seabird species for breeding space on the Ruamaahua Islands.

Birders also recognised spatial differences in the quality of Tītī around some islands. One reported that his family used to target the burrows on the southeastern slope of Ruamahuaiti because the chicks in these burrows were generally larger than those from other parts of the island. Similarly, two birders from a different family explained that their father taught them that larger chicks were usually harvested on the eastern sides of the islands. The suggested reason was that the sun rises in the east and warms the burrows and eggs during the incubation phase, so the eggs in these burrows tend to hatch earlier.

Of the five most experienced birders interviewed, four had observed differences in chick growth between years. It was noted that in years of poor chick growth, for every 150 burrows prospected approximately six entrances would have dead chicks present. Interviewees attributed years of poor growth to lower food abundance or availability brought about by overfishing of Tītī prey species (e.g., squid) or climatic perturbations. However, none of the birders indicated that years of poor chick growth had increased in frequency.

Hauraki resource management strategies

A range of traditional harvest management strategies used by Hauraki were identified by interviewees (table 2). One interviewee highlighted the importance of self-government and internal controls in caring for and managing the food grounds. She believed that Hauraki should determine who goes to the islands, and how they should conduct themselves while out there. The interviewee illustrated her point by explaining how her elders tended large vegetable gardens, and as children they were never permitted access to play for fear that they would damage the crops. Younger family members were tutored in how to tend and respect the gardens before gaining entry. She firmly believed that the same principles should apply to harvesting Tītī on the Ruamaahua Islands. Only once an individual has demonstrated the appropriate skill base and respect should they be granted access to the islands. Without this system of internal controls there will always be the very real potential of someone damaging and destroying the resource for the rest of iwi. Two interviewees reported that this happened when poachers accessed the islands to harvest Tītī. Without consideration for the tikanga, they were reported to have overharvested and indiscriminately collapsed breeding burrows.

The oldest interviewee described how his grandfather used to control the harvest and inform the people of the appropriate time to harvest the Tītī chicks each season. His grandfather would also determine the number of chicks that could be taken and the number of harvesters that should go out to the islands:

TABLE 2
Concepts and traditional resource strategies used by Hauraki muttonbirders to manage Tītī populations

Concept	Traditional management strategies
Respect for species and its habitat	Teachings and directorship of harvest should come from *kaumātua* (respected elders). You do not prepare or eat your food where you catch it.
Reducing the demographic impact	Vital life history stages (e.g., adults) are not harvested. Harvest at the appropriate development stages. To protect your future breeding population do not harvest well-developed chicks. Timing of harvest important to minimise disturbance, interference and desertion of adults.
Allowing for escapement	Harvest only occurs during a designated period. Rotation or resting of islands harvested each season. *Tohu* (environmental indicators) are used to determine whether harvest should proceed or not. Chicks are only caught while down burrows and never at night when they emerge later in the breeding season to fledge.
Protection of habitat	Access to populations controlled or limited to specific *iwi* (tribe) or individuals within an iwi. Digging should be minimised to avoid damage to burrows.
Enhancement of habitat	The digging of burrows can maximise and create breeding space which is advantageous to bird population.
Provision of refugia	*Tapu* (sacred rules) was used to restrict access or harvest to specific areas or islands.
Minimisation of waste	Do not harvest more of the resource than you can process effectively.

> *If there were birds everywhere, he would let the others [in the iwi] know and that's when they would take their young people out to teach them [how to harvest].* (B.C. 2007)

He also recounted how his grandfather would ensure that everyone received birds, including those families that could not go out to harvest. One experienced birder recognised that the timing of the harvest was important for maintaining the Tītī population. He maintained that chicks should not be harvested too early, even in seasons when they were well developed, because the adults will still be provisioning their young. He suggested that the adults will sense the premature loss of their chick and become discouraged from returning to the island to breed in the future. Therefore, the timing of the harvest, which begins on the first Saturday in November, is considered to be quite crucial.

All interviewees asserted that only the chicks were taken in the harvest. To kill adults was a serious transgression of tikanga. Two experienced birders explained that harvesting chicks at an inappropriate developmental stage could be detrimental to the population. They explained that underdeveloped Tītī chicks were poor eating and should be left to grow further, whereas chicks that were developmentally advanced, with more than half of their body covered by adult feathers, should not be harvested because they were the better-quality birds that are most likely to come back to the island and breed in the future. The interviewees felt it made sense to let these birds escape to ensure a future breeding population. The appropriate chick to harvest was one which still had down covering all of its body, but had adult plumage on its wings.

> *You will notice it when you're muttonbirding. You will see that the adult feathers are starting to show up on the chicks, but they still can't fly. If you were to harvest the more advanced chicks, the old people would say "hey you brought the bloody adults back", and they would give you hell. Its true, you have got to leave some of the better chicks so that the population replenishes itself.* (B.C. 2007)

Three interviewees indicated it was disrespectful to the bird and a violation of traditional teachings to pluck, clean or eat the Tītī on the islands where they were harvested. They explained that these protocols were also commonly applied to other food resources such as Pipi, *Paphies australis* Gmelin, 1791, and Green-lipped Mussel, *Perna canaliculus* Gmelin, 1791. Shellfish was never opened or eaten while you were still working in the inter-tidal zone. Interviewees believed that cutting out the oil-filled crops of chicks and leaving them in the entrances of burrows or plucking and cleaning the chicks on the island would deter the adult birds from breeding there in the future. As one interviewee recounted:

> *I remember my Aunty going off the deep end a couple of times because someone had gone out to the islands and harvested Tītī, then prepared the birds on the beach. That really annoyed her. All I can remember is her saying is that "they plucked the bloody things on the beach and cleaned them on the beach and just left the remains there. You don't eat kai [food] in the cupboard." She'd bring the whole bird back to her place and clean them all up at her place at Whiritoa.* (J.L. 2007)

Even so, another three interviewees reported cleaning and preparing the birds on the islands when they camped out overnight. All three interviewees described how the feathers or intestines of chicks were either buried on the island or disposed of in the ocean. No offal or feathers were left lying out around the birding grounds.

There was substantial division amongst interviewees regarding the collapse or digging of access holes through the roof of breeding burrows to facilitate the harvest of Tītī. Four interviewees felt strongly that collapse and the digging of burrows should be avoided at all costs because it would deter the adult birds from returning and using the burrow the following season. They believed if the burrow roof was damaged near or over the nest chamber, the burrow would leak and make it uninhabitable for the birds. One interviewee indicated that digging and repairing the burrows would be very time-consuming because of the friable substrate on the Ruamaahua Islands. In contrast, two birders described how shortening a burrow by digging at a point along its length was beneficial to the Tītī population because it increased the available breeding space on the island. They described how if a harvester could not reach a chick with their arm extended down a burrow (~ 1 m), then they would dig or punch through the burrow roof at the extent of their reach and reinsert their arm at the new opening to remove the chick. The soil from digging the hole was then used to create a back wall for the forward section of burrow, while the new opening was fashioned to form the entrance to the rear half of the burrow. The birders believed that this activity in effect created two burrows for the following season. They acknowledged that this technique only worked with burrows that were close to the surface.

Interviewees referred to the more recent conservation practice of reducing the exposure of Tītī to harvest by only having a short period of harvest on the islands (first two weekends in November). Minimising the time that chicks are exposed to harvest increases the likelihood that more birds will escape and return to breed in the future. The closure and rotation of harvest around different islands was another method used by Hauraki birders to rest populations and spread any potential impacts of harvest. One interviewee indicated that it was common practice for the Ruamaahua Islands to be closed and the inshore islands (e.g., Shoe, Slipper, Rabbit and Penguin islands – fig. 1) to be opened to harvest, or vice versa. However, he reported that in 1984, his mother had recommended to wildlife authorities that a rāhui be placed over the Ruamaahua Islands for a number of seasons because bird numbers had remained low. Two interviewees also indicated that Ruamaahuanui was rarely harvested because the island was harder to land on. They suggested this island acted as a partial refuge for the birds and a source of future breeders to the other islands in the group.

One interviewee referred to how *tohu* (signals or indicators) were likely to have been used to determine whether a harvest occurred or not in a year, or whether a harvest was large or small. The interviewee indicated that the old people had a particular time period for harvesting but that sometimes the weather was too rough and the birders could not get out to the islands. She believed her ancestors would have seen those conditions as a sign to stay home and not to go out to harvest, whereas today these links might not be made.

DISCUSSION

Re-establishing the relationship with Tītī

The harvest of Tītī has a key role within Hauraki tradition and identity. The ability to provide traditional foods reflects the mana of the iwi and their capacity to successfully manage their resources. It is considered by many Māori to be *whakama* (shameful) to receive visitors and not serve them a food sourced from the local area. This practice is fundamental in defining the iwi and/or individual as a kaitiaki for the resource. The Kererū, New Zealand Pigeon, *Hemiphaga novaeseelandiae novaeseelandiae* Gmelin, 1789, and Sooty Shearwater, *Puffinus griseus* (J.F. Gmelin, 1789), have similar cultural significance for the iwi of Tūhoe and Rakiura respectively (Taiepa *et al.* 1997, Lyver *et al.* 2008). The re-establishment of native bird harvests is seen by some Māori as the right to express 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 (NZCA 1994, King 1994, Kirikiri & Nugent 1995). The health benefits of traditional foods have become widely recognised with increases in diseases like diabetes amongst Māori in New Zealand (Cambie & Ferguson 2003, Bovell-Benjamin 2007). Therefore, there has been an increasing emphasis to move away from the current westernised energy-dense diet and include a greater proportion of traditional foods (Murphy *et al.* 2003).

It was recognised that community isolation from the Tītī harvest over the past 20–30 years has eroded the mātauranga and left just a few older individuals with the more comprehensive knowledge base. With the decline in Tītī and isolation from the resource, the ability of Hauraki to maintain and build on traditional harvest practices has diminished. The current iwi authorities (Hauraki Māori Trust Board and Ruamaahua Islands Trust) have expressed the desire to become more actively involved in the restoration of Tītī populations using the best information available to them through science and their own mātauranga. The restoration of a sustainable Tītī harvest would reflect favourably on the iwi's abilities and mana as a kaitiaki. It would also demonstrate to the wider conservation community that Māori have the capacity to manage their own resources. However, iwi face the internal issue of how a future harvest might be regulated. In the past, individual influential elders experienced in the practice of birding controlled the harvest process and who participated in it, but in their absence Hauraki need to determine what management structures might be appropriate for the current situation.

The protection of some indigenous wildlife harvest rights through the post-colonial era has maintained the mechanism and opportunity for the continued development and transfer of mātauranga within those cultures (Taiepa *et al.* 1997, Beaton 1990, Ferguson & Messier 1997). Gilchrist *et al.* (2005) reported that quality of mātauranga was better for wildlife species with which local Inuit peoples had greater familiarity through harvest or year-round contact, or both. Similarly, the development and intergenerational transfer of Rakiura mātauranga continues through their participation in an annual harvest of Sooty Shearwater chicks on islands adjacent to Stewart Island. As one Rakiura informant stated:

> *In life there is muttonbirding, and then there is everything else.* (S. Bull pers. comm. 2005)

Even so, it is important to point out that indigenous peoples have extensive knowledge of species that they may not harvest and that all cultures are intellectually curious about the environment around them and that extends beyond direct connections to seemingly utilitarian matters like "knowing your food" (Nabhan 2000). Hauraki acknowledge that Rakiura have a healthy knowledge base that they can potentially learn and benefit from. However,

they also highlighted subtle differences in the way the harvest was conducted in the Hauraki region, and asserted how it is essential for them to preserve their own mātauranga and tikanga. Only then will the Tītī harvest, and the identity and mana that comes from this harvest, remain with Hauraki. It was also recognised that a combination of traditional and contemporary methods may need to be employed to ensure the persistence and communication of the knowledge within the iwi. Central to this process must be the transmission of knowledge across generations. New transmission techniques might include hui and wānanga, while re-establishing the harvest under the guidance of *tohunga* (experts) or kaumātua will ensure the persistence and growth of the mātauranga.

Understanding changes in wildlife populations

Most current seabird harvesting goes scientifically unmeasured (Moller 2006). However, monitoring population baselines and trends in harvest rates and prey abundance can be an important component of mātauranga (Usher 2000, Kitson 2004, Moller *et al.* 2004, Gilchrist *et al.* 2005, Lyver *et al.* 2008). Through harvest-based indicators Hauraki birders were able to provide insights into the decline of the Tītī on the Ruamaahua Islands over a 50–60-year timeframe. The birders' understanding of breeding patterns was sensitive enough to detect that declines had occurred in chick occupancy, but not burrow density. This understanding is corroborated by burrow density surveys conducted in 1972 and 2006/07 (Fogarty & Douglas 1973, Jones *et al.* 2008), which show that, on average, burrow densities have not changed, and may have even increased slightly. In addition, preliminary evidence from recent burrow occupancy surveys suggests that chick occupancy is significantly lower on the Ruamaahua Islands than on other islands that have only Tītī present (e.g., Moutohora – Lyver *et al.* unpubl. data; Bethalls Beach – G. Taylor pers. comm. 2007).

In this case study, no scientific monitoring program had measured or detected the decline in Tītī populations on the Ruamaahua Islands. All evidence and reports of a decline had come from the Hauraki birders. Similar examples can be found in the Canadian Arctic where two cases of dramatic population declines (Common Eider, *Somateria mollissima sedentaria* (Linnaeus, 1758); Ivory Gull, *Pagophilia eburnea* (Phipps, 1774)) were brought to the attention of the federal wildlife management agency, the Canadian Wildlife Service, by local Inuit hunters (Gilchrist *et al.* 2005). Few, if any, scientific monitoring programs can provide population trend information over two to three generations for a long-lived seabird like the Tītī. At the very least, the Hauraki mātauranga can: (1) describe historical carrying capacity levels; (2) provide goals for restoration; or (3) be used as a prioritisation tool for focusing intensive research studies.

As low Tītī numbers persisted, Hauraki birders began to observe the effects through declining catch rates and lower annual tallies. To some degree Hauraki birders were able to buffer their harvest against initial declines in Tītī abundance by targeting islands, or areas on islands, of high burrow density. This scenario typifies the curvilinear relationship that often exists between catch-per-unit-effort (CPUE) and population abundance when a hunter is faced with a declining resource (Moller *et al.* 2004). By using mātauranga and technological advances to harvest at times and places of high prey concentration, the hunter can buffer the decline in their CPUE, even when the population is declining at a greater rate. Rakiura birders had a much greater opportunity to buffer the declines in their harvests of Sooty Shearwater chicks by harvesting in areas of high chick density and when chicks were aggregated above ground (Lyver *et al.* 1999, Lyver 2002). Even so, the rate of decline reported by Hauraki birders may be an underestimate of the true population decline. Birders recognised areas on islands (e.g., island edges and slopes with an eastern aspect) as having better quality and greater densities of chicks, and by targeting these areas buffered their harvests against decline. Surveys conducted on the Ruamaahua Islands in 1972 showed that burrow densities were most concentrated on gentle slopes under high canopy with little undergrowth (Fogarty & Douglas 1973).

Years in which Tītī chicks have experienced poor growth have not increased in frequency indicating that food supply in most years has not affected the provisioning of chicks and recruitment in later years. Rakiura birders also linked changes observed in harvest patterns to declines in titi abundance. Rakiura mātauranga predicted that years with larger and fatter chicks will have greater chick abundance; however, over the past 15 years birders reported years that chicks were fat, but there were fewer in the burrows than expected (Lyver 2002). This suggested to the birders that food was still available, and that some other factor(s) were causing declines. A similar scenario was faced by Hauraki birders.

Higher species diversity of smaller burrowing seabirds (e.g., Fluttering Shearwaters, *Puffinus gavia* (J.R. Forster, 1844); Little Shearwaters, *Puffinus assimilis haurakiensis* Gould, 1838; Diving Petrels, *Pelecanoides urinatrix urinatrix* (J.F. Gmelin, 1789); White-faced Storm-Petrels, *Pelagodroma marina* Latham, 1790) on some inshore islands (e.g., Penguin Island, Rabbit Island) compared with the Ruamaahua Islands was attributed to fewer Tītī present on these islands. However, the lower chick occupancy on the Ruamaahua Islands detected in recent surveys suggests that the historical harvest of Tītī chicks from the islands may have in some way benefited these other burrowing seabird species that breed later in the year (e.g., freeing up of breeding space), and potentially contributed to a change in species composition on the islands. If species composition has changed then any recovery of the Tītī population may not be straightforward. The rapid expansion of the Buller's Shearwater, *Puffinus bulleri* Salvin, 1888, (which are ~100 g smaller than Tītī) population on Aorangi, Poor Knights Islands, after Wild Pig, *Sus scrofa* Linnaeus, 1758, eradication (S. Bartle pers. obs. 1968) was at the expense of other petrels, including Tītī and Fluttering Shearwaters (Harper 1983).

Mātauranga limitations to detect changes in meta-populations of seabirds

Traditional methods used by Hauraki to detect changes in the Tītī meta-population on the Ruamaahua Islands were largely harvest-based. Unlike in earlier years (pre-1900s), when people would stay for extended periods (4–6 weeks at a time) on some birding islands, recent contact with the Tītī population has been limited to 2–4 days per year and is mainly restricted to daytime observations. This has meant that impressions and hypothesis generation formed about the resource by Hauraki birders have come from only a small window in the birds' life history. The nocturnal and subterranean breeding habits and the large at-sea component of the Tītī's life history also

compound these efforts. In contrast, some Rakiura birders can spend up to 10–11 weeks living on the birding islands and use a wider suite of indicators – e.g., (1) numbers of adults returning to the islands at night; (2) smell of the islands; (3) level of noise of adults returning to and leaving the island each day; (4) amount of trampling caused by the birds along tracks; (5) catch rates; (6) condition of chicks; (7) emergence time of fledglings; and (8) changes in overall burrow densities around the islands – to evaluate the status of the Sooty Shearwater population (Lyver *et al.* 1999, Newman & Moller 2005, H. Moller pers. comm. 2008).

By using only harvest-based information to monitor populations it is difficult to interpret anything about non-harvested (control) populations. It could be possible that Tītī colonies on non-harvested islands are not in decline but Hauraki would have no way of knowing this without using non-harvest-based sampling techniques. A similar scenario confronted Rakiura birders. Declines in the Sooty Shearwater population over the past 15 years were detected by Rakiura through their harvests (Lyver *et al.* 1999); however, studies of beach patrol records and a non-harvested population on the Snares Islands, located 200 km south of the Rakiura Tītī Islands, corroborated these observations (Scofield & Christie 2002, Miskelly *et al.* 2001). Evidence pointed to a climate-based mechanism that could be potentially impacting adult Sooty Shearwater survival (Lyver *et al.* 1999, Bragg *et al.* 2007).

It is very difficult to differentiate between harvested- and non-harvested-related factors impacting a seabird population. It would be highly likely that there are feedback loops related to harvesting behaviour and the natural demographic patterns of Tītī (Newman & Moller 2005). Interviewees postulated that removing chicks from breeding burrows at the wrong time could increase the risk of colony abandonment by the adult birds. If harvest is in some way linked to Tītī ecology, then changes to harvest rates will affect the bird's ecology making it very difficult to disentangle the process. In addition, differential movement rates between harvested and non-harvested meta-populations may remove evidence of harvest effects.

Resource benefits of Tītī harvest strategies

Interviewees acknowledged that absolute protection of adult Tītī was paramount under Hauraki customary lore and regulation. This included not harvesting adults or disturbing adults in any way through the breeding season. This concept is widely supported by many seabird studies which have shown that small changes in adult survival have a large impact on population growth rates (λ) (Hamilton & Moller 1995, Hunter *et al.* 2000). Also, a long-term Tasmanian study of Short-tailed Shearwaters, *Puffinus tenuirostris* (Temminck, 1835), has demonstrated that repeated researcher disturbance of the colony contributed to the decline of the colony, increased burrow desertion, and decreased breeding success and recruitment of young adults (Serventy & Curry 1984). Selective harvesting of chicks at certain stages of development could also reduce harvest impact. The Hauraki practice of leaving the more advanced birds to fledge indicates their understanding of the relationship between chick quality and recruitment. A similar strategy is also employed by "Nessmen" that harvest 2000 Northern Gannet, *Morus bassanus* (Linnaeus, 1758), chicks from Sula Sgeir, an islet some 90 km north of the Isle of Lewis in the Outer Hebrides (Beatty 1992). Younger downy gannet chicks and the slimmer, developmentally more advanced individuals (with mostly adult plumage) are left to fledge, while chicks in the intermediate stage of development are harvested. In contrast, Rakiura muttonbirders prefer larger and more developed chicks, which have a higher survival and probability of recruitment (Sagar & Horning 1997, Hunter *et al.* 2000). However, the contribution of chick survival to λ is small so harvest selectivity may have little demographic impact unless the harvest is very intense or it is coupled with elevated adult mortality (Hunter & Caswell 2005). It is possible that the declines in the Tītī population on the Ruamaahua Islands could be largely driven by extrinsic factors impacting crucial demographic phases (e.g., adult survival) away from the islands. If survival rates of adult Tītī have decreased over the past 50 years, the removal of chicks at historical levels could be forcing the harvest into a state of unsustainability, and reducing the effectiveness of traditional breeding-based conservation strategies.

Harvesting too early or leaving the remains of chicks on the birding grounds were deemed to be serious transgressions of Hauraki harvesting tikanga because they were believed to lead to burrow abandonment and higher rates of emigration by adults from the islands. Moller (2006) also postulated that disturbance of breeding by harvesting could exacerbate impacts of simple additive mortality by promoting increased emigration in pre-breeders. This could quite easily apply to the breeding population as well. Violation of customary lore or a display of disrespect towards a species is commonly used by indigenous cultures to explain declines or disappearances in wildlife. Tūhoe perceived that the recent practice of plucking kererū in the forest was partly cause for declines in its population because leaving the bird's feathers scattered around the forest signalled disrespect. This value-belief ethos is also evident in other indigenous cultures, such the Siberian Yupik, where the belief that an animal (especially a sea mammal) killed, butchered, consumed and disposed of according to specific respectful practices would ensure the animal would follow the eternal cycle of revival and availability to the people (Krupnik & Vakhtin 1997).

The protection of burrows from collapse and digging by some was perceived to be a critical component of managing the Tītī population. Reduced productivity at seabird colonies caused by humans collapsing burrows and compacting substrata is a recognised threat on the Rakiura Tītī Islands (Moller 2006). The reasoning behind splitting existing burrows in two is that it creates additional breeding space and releases the population in part from density effects (e.g., interference competition) leading to increased egg, chick and juvenile survival, and a higher carrying capacity on the islands. Alternatively, if done wrongly it could damage burrow structure and have quite the opposite effect. If inexperienced birders were going out to the islands to harvest unsupervised, they could cause irreparable damage by either harvesting chicks in the wrong developmental stages or collapsing burrows indiscriminately. This was supported by a number of interviewees who felt that the core part of Hauraki's management strategy for the islands needed to include a rigorous tuition process for all new birders going out to the islands. A study with Rakiura birders found that 94% (n = 17) of interviewees that had harvested chicks from burrows referred to the protection of burrows as a "very important form" of their traditional management (J. Kitson unpubl. data). Rakiura tikanga dictates that if a hole is dug over a nest chamber or burrow passage to reach a chick, it must be plugged. However, the plugging

of burrows occurs on some islands only once burrows have been shortened to maximise breeding space (H. Moller pers. comm. 2007).

Rāhui is one of the core attendant management practices used by Māori to serve the environmental ethic of "conservation for human use" and ensure resource sustainability (Roberts *et al.* 1995). Hauraki utilised a form of rāhui by adopting a harvest rotation policy whereby Tītī meta-populations on islands were "rested" from harvest every second year or so to reduce the impacts of harvest (e.g., adult disturbance, chick removal). A similar strategy is used by Cree stewards who use their knowledge of changes in beaver numbers, size of colonies, size of litters and frequency of abandoned or new colonies to direct the intensiveness of hunting within their territories (Feit 2004). Partial refuge islands (e.g., Ruamaahuanui), where harvest occurred infrequently, were also used by Hauraki to provide recruits to support harvested populations on the nearby islands (Hongiora and Ruamaahuaiti). Island refuges is a relatively common concept that has been implemented in the Seychelles, Indian Ocean, to safeguard a Sooty Tern, *Onychoprion fuscata* (Linnaeus, 1766), population by providing recruits for the neighbouring harvested colonies of Desnoeufs and Îlot Fregate (Feare 1984). The resource management strategies presented provide evidence that Hauraki harvesters were able to synthesise and interpret their diachronic observations in a population context. In doing so, it also opened up the possibility of understanding how these demographic components could be influenced by environmental parameters across a range of temporal and spatial scales.

CONCLUSION

Our study illustrates the way Hauraki mātauranga can understand and hypothesise about complex island ecosystem effects that have important management implications. Mātauranga, by its holistic nature, provides multi-species and community-level information even where the primary focus is on a key species. Hauraki mātauranga has proven to be a useful tool for highlighting trends in the Tītī population and management options that promote (1) the provision of refuge; (2) habitat protection; (3) spatial spreading of impact; (4) escapement;;(5) minimising of disturbance; and (6) harvesting of life-stages that have minimal demographic impact. Addressing the relationships between these strategies and demographic outcomes, and their potential benefit in the current environment, can now be the focus for future research and analysis. Consideration of the demographic effect that each strategy or combination of strategies has had on the Tītī population can also guide decision making about harvest management on the Ruamaahua Islands.

ACKNOWLEDGEMENTS

The authors thank the Hauraki interviewees who participated in this study and the Ruamaahua Islands Trust for its directorship. We appreciate the contribution of Frank Waitai, Damien Waitai and Bettina Yockney in conducting and transcribing the interviews, and Ellen Cieraad for designing the figure. The study was funded by Ngā Pae o te Māramatanga (RF-14-04) and the Foundation for Research, Science and Technology (C09X0509) grants. Thanks also to Henrik Moller, Anne Kendrick and Margaret Davies for reviewing and editing this manuscript.

REFERENCES

Beaton, E. 1990: The muttonbirders. Making a tough living off millions of extremely punctual birds. *Geo* **12**(2): 21–31.

Beatty, J. 1992: *Sula. The Seabird Hunters of Lewis.* Penguin, London: 143 pp.

Berkes, F. 1999: *Sacred Ecology, Traditional Ecological Knowledge and Resource Management.* Taylor & Francis, Philadelphia, PA, USA: 209 pp.

Bovell-Benjamin, A.C. 2007: Sweet potato: a review of its past, present, and future role in human nutrition. *Advances in Food Nutrition Research* **52**: 1–59.

Bragg, C., Clucas, R., Fletcher, D., Mckecknie, S., Moller, H., Newman, J. & Scott, D. 2007: Sustainability of Tītī harvesting by Rakiura Māori. A report to Rakiura Māori for community peer review. University of Otago, Dunedin, New Zealand: 118 pp.

Cambie, R.C. & Ferguson, L.R. 2003: Potential functional foods in the traditional Maori diet. *Mutation Research* **523–524**: 109–117.

Feare, C.J. 1984: Seabirds as a resource: use and management. *In* Stoddart, D.R. (ed.): *Biogeography and Ecology of the Seychelles Islands.* Junk, The Hague, The Netherlands: 593–606.

Feit, H.A. 1995: Hunting and the quest for power: The James Bay Cree and Whitemen Development. *In* Morrison, B.R. & Wilson, C.R. (eds): *Native Peoples: The Canadian Experience*, Oxford University Press, Ontario, Canada: 101–128.

Ferguson, M.A.D. & Messier, F. 1997: Collection and analysis of traditional ecological knowledge about a population of Arctic tundra caribou. *Arctic* **50**: 17–28.

Fogarty, S.M. & Douglas, M.E. 1973: The birds of the Aldermen Islands. *Tane* **19**: 31–39.

Gilchrist, G., Mallory, M. & Merkel, F. 2005: Can local ecological knowledge contribute to wildlife management? Case studies of migratory birds. *Ecology and Society* **10**(1): 20. http://www.ecologyandsociety.org?vol10/iss1/art20/

Hamilton, S., & Moller, H. 1995: Can PVA models using computer packages offer useful conservation advice? Sooty shearwaters in New Zealand as a case study. *Biological Conservation* **73**: 107–117.

Harper, P. 1983: Biology of the Buller's shearwater (*Puffinus bulleri*) at the Poor Knights Islands, New Zealand. *Notornis* **30**: 299–318.

Heather, B.D. & Robertson, H.A. 1996: *The Field Guide to the Birds of New Zealand.* Penguin, Auckland, New Zealand: 440 pp.

Hunter, C. & Caswell, H. 2005: Selective harvest of sooty shearwater chicks: effects on population dynamics and selectivity. *Journal of Animal Ecology* **74**: 589–600.

Hunter, C.M., Moller, H., & Fletcher, D. 2000: Parameter uncertainty and sensitivity analysis of a population model: setting research priorities for shearwaters. *Ecological Modelling* **134**: 299–323.

Huntington, H.P. 2000: Using traditional ecological knowledge in science: Methods and applications. *Ecological Applications* **10**: 1270–1274.

IIED (International Institute for Environment and Development). 1994: *Whose Eden? An Overview of Community Approaches to Wildlife Management.* IIED, London: 124 pp.

Imber, M.J. 1976: Breeding biology of the Grey-faced Petrel *Pterodroma macroptera gouldi. Ibis* **118**: 51–64.

Imber, M., Harrison, M. & Harrison, J. 2000: Interactions between petrels, rats and rabbits on Whale Island, and effects of rat and rabbit eradication. *New Zealand Journal of Ecology* **24**: 153–160.

Jones, C., MacLeod, C.M. & Lyver, P.O'B. 2008: Mauriora ki nga oi. Safe-guarding the sustainable harvest of oi (*Pterodroma macroptera gouldi*). Unpublished Field Report 2007, Landcare Research, Lincoln, New Zealand: 1–13.

King, M. 1994: Should the harvest go on hold? *Mana* **5**: 27–28.

Kirikiri, R. & Nugent, G. 1995: Harvesting of New Zealand native birds by Māori. *In* Grigg, G.C., Hale, P.T. & Lunney, D. (eds): *Conservation Through Sustainable Use of Wildlife*. Centre for Conservation Biology. The University of Queensland, Brisbane, Australia: 54–59.

Kitson, J. 2004: Harvest rate of Sooty Shearwaters (*Puffinus griseus*) by Rakiura Maori: a potential tool to monitor population trends. *Wildlife Research* **31**: 319–325.

Krupnik, I. & Vakhtin, N. 1997: Indigenous knowledge in modern culture: Siberian Yupik ecological legacy in transition. *Arctic Anthropology* **34**: 236–252.

Lyver, P.O'B. 2002: Use of traditional knowledge by Rakiura Māori to guide sooty shearwater harvests. *Wildlife Society Bulletin* **30**: 29–40.

Lyver, P.O'B., Moller, H. & Thompson, C. 1999: Changes in Sooty Shearwater (*Puffinus griseus*) chick production and harvest precede ENSO events. *Marine Ecology Progress Series* **188**: 237–248.

Lyver, P.O'B., Taputu, M., Kutia, S.T. & Tahi, B. in press: Tūhoe Tuawhenua mātauranga of kererū (Hemiphaga novaseelandiae novaseelandiae) in Te Urewera. *New Zealand Journal of Ecology* **32**(1).

Miskelly, C.M., Sagar, P.M., Tennyson, A.J.D. & Scofield, R.P. 2001: Birds of the Snares Islands, New Zealand. *Notornis* **48**: 1–40.

Moller, H. 1996: Customary use of indigenous wildlife – Towards a bicultural approach to conserving New Zealand's biodiversity. *In* McFadgen, B. & Simpson, P. (comps): *Biodiversity: Papers from a Seminar Series on Biodiversity, hosted by Science & Research Division, Dept of Conservation, Wellington, 14 June – 26 July 1994*. Department of Conservation, Wellington, New Zealand: 89–125.

Moller, H. 2006: Are current harvests of seabirds sustainable? *Acta Zoologica Sinica* **52**(Supplement): 649–652.

Moller, H. & Raffaelli, D. 1998: Predicting risks from new organisms: The potential of community press experiments. *In* Fletcher, D.J., Kavalieris, L. & Manly, B.F.J. (eds): *Statistics in Ecology and Environmental Monitoring 2: Decision Making and Risk Assessment in Biology.* Otago Conference Series No. 6, Dunedin, University of Otago Press: 131–156.

Moller, H., Berkes, F., Lyver, P.O'B. & Kislalioglu, M. 2004: Combining science and traditional ecological knowledge: monitoring populations for co-management. *Ecology and Society* **9**(3): 2. [online]: http://www.ecologyandsociety.org/vol9/iss3/art2

Murphy, E., McAuley, K.A., Bell, D., McLay, R.T., Chisholm, A., Hurley, R., Story, G., Mann, J.I., Thomson, R. & Williams, S.M. 2003: A new approach to design and implement a lifestyle intervention programme to prevent type 2 diabetes in New Zealand Maori. *Asia Pacific Journal of Clinical Nutrition* **12**: 419–422.

Nabhan, G.P. 2000: Interspecific relationships affecting endangered species recognised by O'Odham and Comaac cultures. *Ecological Applications* **10**(5): 1288–1295.

Newman, J. & Moller, H. 2005: Use of mātauranga (Māori traditional knowledge) and science to guide a seabird harvest: Getting the best of both worlds? *Senri Ethnological Studies* **67**: 303–321.

NZCA (New Zealand Conservation Authority). 1994: Maori Customary Use of Native Birds, Plants, and other Traditional Materials. Department of Conservation, Wellington, New Zealand: 1–13.

Ohmagari, K. & Berkes, F. 1997: Transmission of indigenous knowledge and bush skills among the Western James Bay Cree women of subarctic Canada. *Human Ecology* **25**: 197–222.

Raffaelli, D. & Moller, H. 2000: Manipulative field experiments in animal ecology – do they promise more than they can deliver? *Advances in Ecological Research* **30**: 299–338.

Roberts, M., Norman, W., Minhinnick, N., Wihongi, D. & Kirkwood, C. 1995: Kaitiakitanga: Māori perspectives on conservation. *Pacific Conservation Biology* **2**: 7–20.

Sagar, P.M. & Horning, D.S. 1997: Mass-related survival of fledgling sooty shearwaters *Puffinus griseus* at the Snares, New Zealand. *Ibis* **140**: 329–339.

Scofield, R.P. & Christie, D. 2002: Beach patrol records indicate a substantial decline in Sooty Shearwater (*Puffinus griseus)* numbers. *Notornis* **49**: 158–165.

Serventy, D.L. & Curry, P.J. 1984: Observations on colony size, breeding success, recruitment, and inter-colony dispersal in a Tasmanian colony of Short-tailed Shearwaters *Puffinus tenuirostris* over 30-year period. *Emu* **84**: 71–79.

Skira, I.J. 1990: Human exploitation of the short-tailed shearwater (*Puffinus tenuirostris*). *Papers and Proceedings of the Royal Society of Tasmania* **129**(1): 77–90.

Taiepa, T., Lyver, P., Horsley, P., Davis, J., Bragg, M. & Moller, H. 1997: Co-management of New Zealand's conservation estate by Māori and Pākehā. *Environmental Conservation* **24**: 236–250.

Tau, T. 2001: The death of knowledge. Ghosts on the plains. *New Zealand Journal of History* **35**: 131–152.

Taylor, G. 2000: Action plan for seabird conservation in New Zealand. Part B: Non-threatened seabirds. Threatened Species Occasional Publication 17, Department of Conservation, Wellington, New Zealand: 1–435.

Telfer, W.R. & Garde, M.J. 2006: Indigenous knowledge of rock kangaroo ecology in Western Arnhem Land, Australia. *Human Ecology* **34**: 379–406.

Tyrrell, M. 2007: Sentient beings and wildlife resources: Inuit, beluga whales and management regimes in the Canadian Arctic. *Human Ecology* **35**: 575–586

UNEP (United Nations Environmental Programme). 1993: The Convention on Biological Diversity. http://www.cbd.int/convention/default.shtml

Usher, P.J. 2000: Traditional ecological knowledge in environmental assessment and management. *Arctic* **53**: 183–193.

Wodzicki, K. & Robertson, F.H. 1959: White Island. Birds, with a note on the mammal *Rattus exulans* (Peale). *DSIR Bulletin* **127**: 70–84.

(accepted 5 August 2008)