Saving Endangered Species: The Application of Computer-Based Radio Coverage Modelling to Wildlife Telemetry Systems

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ABSTRACT
The research described in this paper is aimed at improving wildlife telemetry systems by the use of computer-based radio frequency (RF) visualization and planning, and enhancing RF coverage by adoption of improved techniques and tactics. The use of a computer-based modelling application has proved to be of benefit in the area of visualisation and planning. Use of this tool and other work in this area has led to the identification of opportunities to improve field practice, including staff training in RF techniques and tactics, selection of optimum receiver sites, improved receive antenna systems, and better planning for airborne monitoring and tracking.

Keywords: Information systems, information systems applications, wildlife telemetry

INTRODUCTION
Kiwi – a New Zealand national icon – is one of several endangered species subject to national conservation and recovery programmes. This paper describes research conducted for the kiwi recovery program of the NZ Department of Conservation (DOC) (Bank of NZ, 2005). During 2004, the author spent some time working as a volunteer with DOC staff at the Moehau[1] kiwi sanctuary, mainly assisting in the location of kiwi to enable the annual change of telemetry transmitter, undertaken because of limited battery life. This process is normally undertaken in the May-June period each year.

While engaged in this work, two issues became apparent. Firstly, the terrain of the Moehau area is very rugged: the northern part of the Coromandel Peninsula is only about 10 km wide, and the main mountain range rises to a height of nearly 1000m. Most of the area is clad with dense primary bush or secondary-growth scrub. The terrain means that vehicle movement is mainly restricted to one road around the coast, foot movement is difficult and radio coverage, which is in the very high frequency (VHF) band (30-300 Mhz) and limited to radio line-of-sight, is also problematical.

Secondly, the majority of work involving monitoring and tracking of birds utilizing telemetry involves long periods of time in the field for relatively few detections. (For example, in one day that the author was out with a DOC team, only one bird was located, and that was found by a trained kiwi dog, rather than using the telemetry system.) Although monitoring and tracking by aircraft is possible (and actually undertaken once or twice a year) the cost makes regular use prohibitive, and the rugged nature of the terrain creates problems even for this mode, as will be outlined later in the paper.

As a result of these experiences, an informal research question was formulated: can improvements (that are cost-effective and practicable to implement) be made to the telemetry system, to enhance the effectiveness of endangered species management and research?

The approach taken to the problem was one of incremental and piecemeal improvement: that is, visualizing the problem, formulating ideas for improvement and then evaluating these ideas from the points of view of functionality improvement potential, economic feasibility and practicality. Lack of resources within DOC meant that a "big bang" approach to upgrade or replace the current system is just not feasible. This paper summarizes work to date - albeit still at an early stage. The results are applicable to any wildlife telemetry scenario that uses RF techniques, not just the kiwi recovery program. The majority of the work can be considered as being in the category of *critical research*: "… the specific purpose of a critical IS research project ranges from creating knowledge as a catalyst for change … to playing an active role in transforming IS practices …" (Cecez-Kecmanovic, 2005). A variety of methods have been employed, including the positivist methods of laboratory and field experiments (Galliers, 1994) and the critical research method of *participatory action research* (Baskerville, 1999).

RADIO COVERAGE MODELLING
Wildlife telemetry has gained increasing prominence in NZ conservation management and research over the past two decades (e.g. Thomas, 1982, Taborsky and Taborsky, 1995, Gibbs and Clout, 2003, Seddon and Maloney, 2004). There is good general coverage of wildlife telemetry systems in the literature (e.g. Mech, 1983, Kenward, 1987, Priede, 1992, Geers et al., 1997, Government of British Columbia, 1998, Mech and Barber, 2002). Most of these references give a high-level overview of RF technology (e.g. frequency bands and their propagation characteristics, and antenna types and characteristics) but there is no in-depth coverage of RF techniques or tactics.[2] Nor does the main wildlife telemetry literature mention the use of RF coverage modeling (either manual or computer-based) to assist in improving detection rates in the field, an approach which could also lead to savings of time and resources.

On the basis that, often, a good start point for solving a complex problem is being able to visualize the problem, the initial step was to carry out some radio coverage modelling over the Moehau Sanctuary area. The first intention was to use an orthodox geographic information system (GIS) application such as ESRI ArcInfo or ArcView. However, these applications support only optical line-of-sight coverage modeling and the incorporation of RF coverage capabilities would have required significant programming effort. Therefore, an off-the-shelf RF coverage planning tool was identified – the *Radio Mapper* application developed for military tactical radio planning at the University of NSW.

Radio Mapper requires Digital Terrain Elevation Data (DTED) to provide the terrain model base for radio coverage modelling. DTED is a well-known topographic data standard that essentially represents terrain as a set of (x,y,z) coordinates. There are three levels, representing different coverage granularities: level 0 has horizontal cell widths of 1 km, level 1 has cells of 90m and level 2 has cells of 25m. An approach was made to the NZ Defence Force Joint Geospatial Support Facility at Devonport Naval Base, who agreed to supply DTED level 2 coverage of the Coromandel area. After assembling the necessary application software, data and hardware, modeling activities commenced in early March 2005.

The initial use of Radio Mapper was to assist in problem visualisation. This is consistent with the use of computer models or simulations in orthodox decision support applications (e.g. Turban and Aronson, 1998 77). However, the tool proved to be far more effective and useful than originally envisaged, and probably offers the following lessons for IS designers (and educationalists):

- A decision support application can sometimes be utilised successfully in a problem domain significantly different from that for which it was originally intended.
- The use of Radio Mapper, in this instance, has contributed far more to the problem domain than could possibly have been imagined at the outset. In that regard, the tool can be thought of as a key element in a learning process and can be equated to what Papert terms *objects to think with* (Papert, 1993 11).

INITIAL RESULTS AND OBSERVATIONS

Radio Mapper is a radio communications path-planning tool that assists planners in predicting performance using both point-to-point and area coverage calculations. Parameters which can be varied include transmitted frequency and power, antenna and antenna feeder gains or losses, receiver sensitivity, ground type (e.g. wet, dry, urban) and transmit and receive antenna heights above ground level (AGL). Modelling can be conducted for any area for which a DTED data set is available. Examples of outputs from Radio Mapper are shown at Figures 1 and 2 below.

As Radio Mapper displays only include terrain-related information (i.e. horizontal coordinates and height), it was discovered that toggling between Radio Mapper and another digital mapping application (in this case TUMONZ[3] was used) allowed selection of likely sites taking into account natural and artificial features such as streams, roads, tracks, built up areas etc not shown on Radio Mapper. At a later stage of the work, Radio Mapper coverage diagrams were able to be geo-referenced, imported into a GIS, and displayed as overlays to topographic maps.

By varying the site locations and other non-constant parameters such as receive antenna height, a "profile" of the sanctuary area was compiled. It was notable that raising the receive antenna height to around 100m had a large effect on coverage - of the order of 7-8 times that obtained at 1.5m, the typical height of a hand-held antenna. This is shown in Figure 3. This result has a bearing on techniques and tactics which could be adopted to improve coverage – some of these are discussed in following sections.

Another interesting result is that Radio Mapper predicts that the whole of the sanctuary area could be covered by five carefully sited receivers, provided the antennas were 100m AGL.

Practical validation of the RF coverage modeling results has been undertaken to a limited extent; for example:

- The tool predicts that receivers active on the high points of the main Moehau Range should be able to pick up transmitters operating on Great Barrier Island (some 25 km to the north east of Moehau) and from the Hunua Ranges (some 50 km south west of Moehau). Practical results have confirmed that that is the case.
- The selection of a migration monitoring site, described in the next section, also confirmed the predictions of Radio Mapper.
- Field trials were conducted over a three day period in the Moehau Sanctuary area. These compared actual radio telemetry coverage with that predicted using Radio Mapper, and very close correspondence was obtained.

Although only limited in-field validation has been conducted, results are sufficient to give a reasonable degree of confidence in the coverage predictions. Validation will be extended as time permits.

Figure 1. Radio mapper display showing selected radio sites

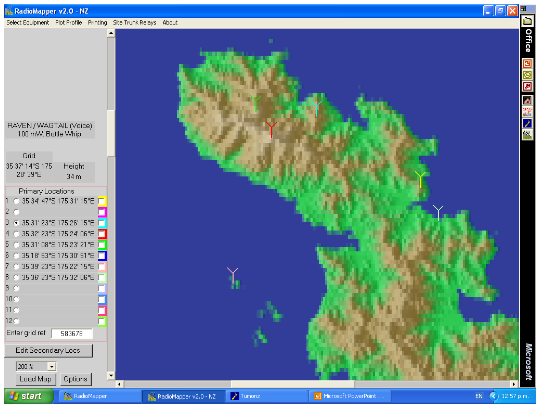


Figure 2. Predicted coverage from a single site

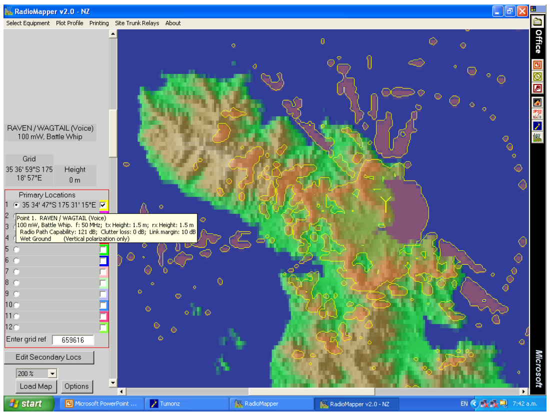
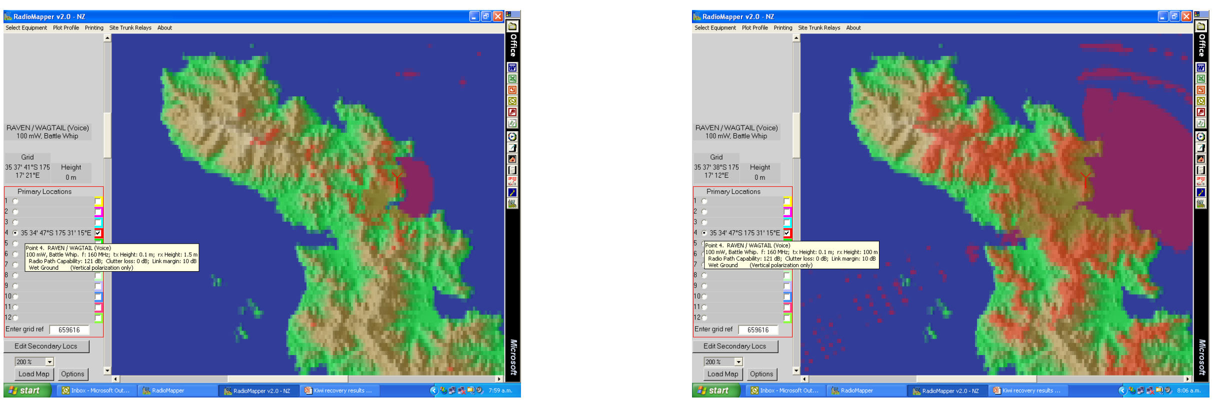


Figure 3. 1.5m receive antenna height (on left) compared with 100m receive antenna height



SOME PRACTICAL APPLICATIONS OF RADIO COVERAGE MODELLING

Following presentation of initial results of this work at the national kiwi recovery conference in March 2005, DOC staff met with the author and suggested a number of tasks that could make use of the RF coverage modeling capability:

- Selection of a radio receiver site at the southern end of the sanctuary area where a receiver/data logger could be installed to monitor transmitter-equipped kiwi entering or leaving the sanctuary area.
- Investigation, design and construction of prototype elevated antennas, to improve telemetry coverage.
- Predictions for the best altitude and track to fly while undertaking airborne monitoring.
- Analysis of the telemetry monitoring sites currently used by staff in the sanctuary area, to identify gaps in coverage and possible identification of better sites.
- Enhancing staff tracking performance, by appropriate training in RF techniques and tactics.

Progress has been made in all five of these areas. However, due to space limitations, only the first two are described in this paper. Work was carried out commencing late- 2005 and continues in 2006. The results are reported in the remainder of this section.

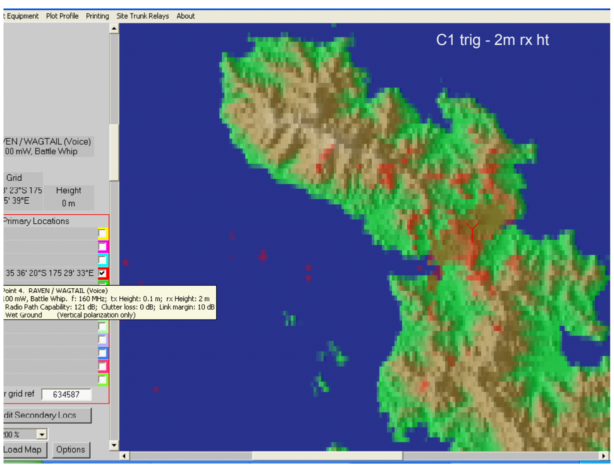
SELECTION OF A MIGRATION MONITORING SITE

The aim of this task was to determine if there are suitable site(s) where a receiver/data logger system could be installed to monitor, on a long-term basis, transmitter-equipped birds entering or leaving the sanctuary area. Experimentation with Radio Mapper identified four possible sites – one to the north of, and three to the south of, the Colville-Port Charles road. Figure 4 below shows predicted coverage from one of these sites. In April 2005, the author and a small group of DOC staff and volunteers undertook a site survey of the three southern sites, to assess their suitability, in terms of access, security, space to erect antennas etc. All three sites proved to be suitable from a practical point of view.

A communications test was also performed from one of the sites. Two people were equipped with telemetry transmitters tied to their bootlaces and they walked from the selected site down to the sea on each side (about 5 km each way). On the hill, staff were able to receive the signals continuously, down to the sea on each side. This demonstrated that the location is viable as a migration monitoring site, and also reinforces confidence in the Radio Mapper tool.

The use of Radio Mapper in the selection of this site and the subsequent communications test indicate that there should not be a significant issue of "false negative" results. That is, transmitter-equipped birds should not be able to move through the monitoring zone undetected, unless there is a failure of the receiver/data logger equipment, which is a separate management issue.

Figure 4. Predicted coverage from selected migration monitoring site



A significant issue, however, is likely to be "false positives" – that is, detection of birds at high points on the main range that are within the coverage of the selected site, who are not actually emigrating from the area. It is considered that this risk can be managed – over time, such birds will be detected within the sanctuary area during normal monitoring operations, indicating they have not emigrated. Similarly, any birds that immigrate would be transmitting on channels not allocated within the Moehau area, so should be able to be located and identified once in the sanctuary area.

During the second half of calendar year 2005, detailed planning, funding approval, system selection and acquisition, installation, and commissioning of the system took place. The telemetry system selected was the Telonics TR5 with the data acquisition option enabled (see Telonics Inc, undated). Funding was provided jointly by the author's university and DOC. The system was installed by DOC volunteers during a weekend in December 2005 and the system went live in early January 2006. Initial results are promising, with up to 10 birds being detected and logged in each 24 hour period. Some of these had not been detected in their normal range for some months, probably indicating they were "wanderers", or in the process of emigrating from the sanctuary area.

At this early stage, careful interpretation of the results is required to avoid false positives – that is, to identify birds that are actually migrating, and not just resident within the coverage area of the receiver. Future enhancements to ease this problem could include things such as: reducing the receive antenna height, or the use of directional antennas oriented east and west, to avoid repeated detection of birds resident in the main sanctuary area.

ELEVATED ANTENNA SYSTEMS

Also in the area of improved techniques, as previously mentioned, Radio Mapper graphically demonstrates the effect of increasing the height of the receive antenna. (Obviously, increasing the height of the transmit antenna would have the same effect, but is not feasible in a wildlife telemetry scenario.) For example, Figure 3 above demonstrates that a receive antenna at 100m AGL would have a coverage roughly 7-8 times that of an antenna at 1.5m AGL. This effect could be exploited by a number of initiatives, for example:

- Investigate the feasibility of mounting a receive antenna under a tethered balloon or in an unattended airborne vehicle (UAV). Limited by payload, the most likely antenna configuration is something simple such as a half-wave dipole or quarter-wave monopole. Bosak (1992 p. 93) provides a design for a lightweight, improvised Yagi that could be mounted on the side of a balloon – the ability to roughly "steer" the balloon by tether ropes at either end could allow a rudimentary direction-finding capability.
- Investigate the feasibility of a quick-erect (e.g. by pneumatic means) antenna mast mounted in the back of a truck or utility vehicle. This would allow utilization of good reception sites accessible by vehicle. This concept is widely used in military tactical communications.
- Design and develop a range of cheap, lightweight, antennas that could be hoisted into tall trees at key reception sites and left there, so that staff could move to them and connect to their receiver on arrival. This concept is also widely used in military tactical communications, particularly for jungle operations. The improvised Yagi design by Bosak (1992) may be viable, and therefore provide a direction-finding capability.

During the second half of calendar year 2005, some research funding was obtained to investigate the third option; namely cheap, lightweight antennas that can be installed around the sanctuary area and left in position. A small number of trial antennas were designed and constructed, mainly consisting of half-wave dipoles, Yagis based on Bosak's design and the commercial Yagi currently used by DoC, elevated by various means.

Limited laboratory testing was undertaken, using the RF laboratory of the author's university, in the absence of an anechoic chamber. The laboratory results demonstrated that the antennas constructed exhibited expected properties: particularly gain (relative to each other) and frequency response.

A field antenna testing range (ATR) was selected in the Moehau area, due to the availability of telemetry equipment from the Moehau Kiwi Sanctuary. The terrain was selected by Radio Mapper modelling, physical reconnaissance and telemetry coverage tests. The actual antenna test site had to have tall trees to achieve appropriate elevation for the antenna under test (AUT), and the terrain ideally had to provide intermittent coverage over a distance of 5-10 km along a traversable route radiating away from the antenna test site.

Antennas were set up at the test site and a research assistant equipped with a telemetry transmitter moved on foot along the chosen route. Other staff at the antenna test site monitored the RF signals using Telonics TR4 telemetry receivers. Up to three antennas were tested at a time. When a change occurred (e.g. signal was lost or regained) instructions were radioed to the surrogate "kiwi" to change position (e.g. back-track 50m). When it became apparent that a change had actually occurred, the "kiwi" was instructed to take a GPS waypoint of that position and then proceed along the route.

The results were recorded on TUMONZ by plotting the GPS waypoints, which were then linked up by line to show pictorially the coverage achieved for each AUT. The results are shown at Figure5 below. The field results graphically demonstrated the value of increasing receive antenna height to improve reception coverage. (The standard commercial Yagi, at 1.5m AGL, gave the worst performance of all the antennas tested.)

Other conclusions were as follows:

- The commercial Yagi, operated in an elevated mode, was quick to erect (of the order of 2-3 minutes) and provided superior performance, particularly over the same antenna when hand-held (the range obtained was of the order of four times greater, on the particular terrain where testing took place).
- Cheap, expendable dipoles could be erected and left in place in trees at key monitoring points, so that staff can connect to them on arrival. If RF signals are detected on significant channels, the standard commercial Yagi could be substituted for the dipole and hoisted into the tree if direction-finding is required.

The results have been passed to DOC with recommendations for further work and utilisation of the findings.

SUMMARY AND CONCLUSIONS

The research described in this paper is aimed at improving wildlife telemetry systems by means of computer-based RF visualization and planning, and improving RF coverage by adoption of enhanced techniques and tactics. The majority of the work can be considered as being in the category of *critical research.* A variety of methods have been employed, including the positivist methods of laboratory and field experiments and the critical research method of *participatory action research*.

The use of a computer-based modelling application – Radio Mapper – has proved to be of benefit in the area of RF visualisation and planning. It has been recommended that DOC consider acquiring a licence to operate Radio Mapper, or identify and procure a similar RF coverage modelling tool.

Use of Radio Mapper and other work in this area has led to the identification of opportunities to improve field practice: staff training in RF techniques and tactics, selection of optimum receiver sites, improved receive antenna systems, and better planning for airborne monitoring and tracking. It has been recommended that all DOC staff involved in field telemetry work undergo training (of the order of half a day is considered sufficient) in RF propagation techniques and tactics. In the kiwi recovery program, this could be run in conjunction with the annual national conference.

FUTURE WORK

There is considerable potential for further improvements to wildlife telemetry systems arising from the user of a radio coverage modeling tool and improved RF techniques and tactics. These include further work to improve conventional airborne tracking and monitoring (as mentioned in section 3.2); elevated antenna improvements, including vehicle- and ground-mounted masts; the use of alternative airborne platforms such as balloons and un-manned airborne vehicles (UAV); and investigation of automated space- and land-based detection and tracking systems.

REFERENCES

Bank of NZ (2005) *Kiwi Recovery Program website*, http://www.kiwirecovery.org.nz/Home/, Accessed 1 May 2005.

Baskerville, R. (1999) Investigating Information Systems with Action Research, *Communications of the Association of Information Systems,* 2.

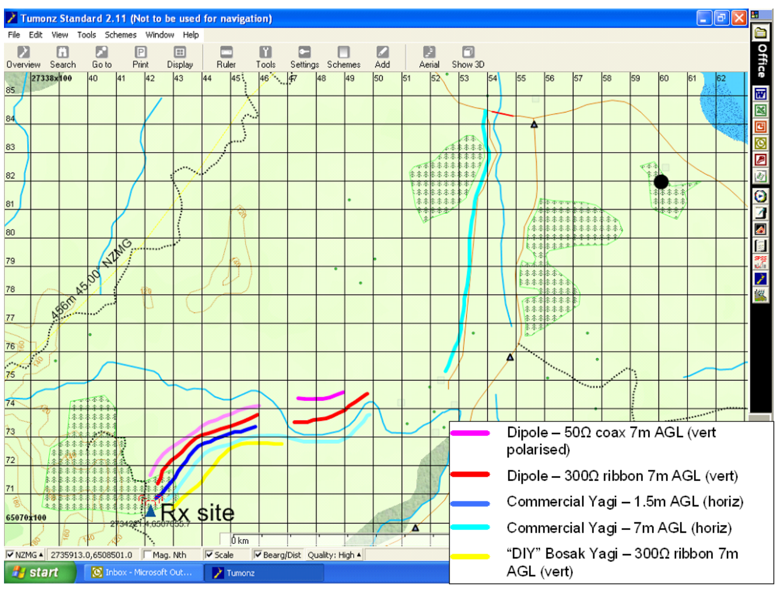
Bosak, A. (1992), "Some new design concepts for simple lightweight radio tracking equipment" in Priede, I. G. and Swift, S. M. (eds.) *Wildlife Telemetry: Remote Monitoring and Tracking of Animals*, Chichester.

Cecez-Kecmanovic, D. (2005) *Critical Approach in IS Research: the Differences that Matter*, 16th Australasian Conference on IS, Sydney.

Galliers, R. D. (1994), "Choosing Information Systems Research Approaches" in Galliers, R. D. (ed). *IS Research: Issues, Methods and Practical Guidelines*, Henley-on-Thames.

Geers, R., Puers, B., Goedseels, V. and Wouters, P. (1997) *Electronic Identification, Monitoring and Tracking of Animals,* CAB International, New York.

Figure 5. Antenna field test results



Gibbs, S. J. and Clout, M. N. (2003) Behavioural vulnerability of juvenile brown kiwi: habitat use and overlap with predators, *DOC Science Internal Series,* 102**,** 1-17.

Government of British Columbia (1998) *Wildlife Radio-telemetry: Standards for Components of British Columbia's Biodiversity No. 5*, http://srmwww.gov.bc.ca/risc/pubs/tebiodiv/wildliferadio.htm, Accessed 22 April 2005.

Kenward, R. (1987) *Wildlife Radio Tagging: Equipment, Field Techniques and Data Analysis,* Academic Press, London.

Mech, L. D. (1983) *Handbook of Animal Radio Tracking,* University of Minnesota.

Mech, L. D. and Barber, S. M. (2002) *A Critique of Wild-life Radio Tracking and its Use in National Parks*, http://www.npwrc.usgs.gov/resource/2002/radiotrk/radiotrk.htm, Accessed 3 May 2005.

Papert, S. (1993) *Mindstorms: Children, Computers and Powerful Ideas,* Harvester Wheatsheaf, Hemel Hempstead.

Priede, I. G. (1992) *Wildlife Telemetry - Remote Monitoring and Tracking of Animals,* Ellis Horwood, Chichester.

Seddon, P. J. and Maloney, R. F. (2004) Tracking Wildlife Radio-tag Signals by Light Fixed-wing Aircraft, *Department of Conservation Technical Series,* 30**,** 23.

Taborsky, B. and Taborsky, M. (1995) Habitat Use and Selectivity by the Brown Kiwi (Apteryx Australis Mantelli) in a Patchy Environment, *The Auk,* 112**,** 680-689.

Telonics Inc (undated) *Telonics TR5 Telemetry Receiver with Optional Data Acquisition System*, http://www.telonics.com/literature/tr-5/tr-5.html, Accessed 1 June 2005.

Thomas, M. D. (1982) A Radio Telemetry System for Animal Tracking in NZ, *NZ Journal of Science,* 25**,** 245-252.

Turban, E. and Aronson, J. E. (1998) *Decision Support Systems and Intelligent Systems,* Prentice-Hall, Upper Saddle River, New Jersey.

ENDNOTES

1. Located at the northern end of the Coromandel Peninsula, on the North Island
2. *Tactics*, in this context, are considered to be decisions or actions derived from in-depth knowledge of RF propagation characteristics that allow, for example, selecting the best receiver site(s) to cover a particular area.
3. The Ultimate Map of NZ: see URL http://www.tumonz.co.nz/ for details

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