Wildlife Population Analysis with GIS: Conservation Management of Royal Albatross

B.R. McLennan[1], M.K. Purvis[1] & C.J.R. Robertson[2]

[1]Department of Information Science, University of Otago, New Zealand.
[2]Conservation Sciences Centre, Department of Conservation, Wellington, New Zealand.

brmclennan@commerce.otago.ac.nz

Abstract.

This paper describes the use of a prototype spatial information system to facilitate exploratory analyses of 60 years of scientific observation data concerning a breeding population of royal albatrosses at Taiaroa Head, on the east coast of New Zealand's South Island. This system shall form the basis on an on-going data collection, management and analysis effort. Incorporation of breeding records with spatial and landscape data permits the investigation of spatial interactions between the location of nest sites and other phenomena. Three example analyses that explore these interactions are described and discussed.

Introduction.

Applications of geographic information systems (GIS) in the area of wildlife management are typically concerned with the assessment of habitat requirements and/or the prediction of areas of habitat that are suitable for a particular species (for examples refer to Agee *et al.* 1989; Ahearn *et al.* 1990; Lyon *et al.* 1987; Pereira and Itami 1991; Tomlin *et al.* 1987; Walker 1990; Yonzon *et al.* 1991). One approach to habitat assessment involves deductive prediction of the amount or extent of habitat that is

available for a target species based on a set of known habitat requirements. Alternatively, an inductive approach may be taken to establish habitat requirements by examination of the coincidence of habitat variables at known locations of the target species (Johnson and Host 1991). Both approaches may be implemented using the overlay and reclassification operators that are standard features of raster GIS, but the inductive approaches necessitate observational data concerning the target species. This focus on habitat arises because (a) it is an important determinant of species presence or absence (Griffiths *et al.* 1993) and (b) populations are rarely mapped (Johnston 1993), either due to the time and expense constraints in undertaking such a task or due to the dynamic nature of many wildlife populations. Understanding habitat preferences and developing programs for its protection are often the best means of protecting a species (McNeely *et al.* 1990).

The adoption of GIS for ecological applications on the other hand is not so evident in the literature. Ecology is concerned with the interactions between organisms (e.g. predation and competition) at differing levels of organisation (Emmel 1973) and traditionally has focused on those interactions that affect the number of organisms and temporal changes in those numbers (Johnston *op. cit.*). Spatial interactions between organisms were either simplified or ignored (Johnston 1989) due to a lack of tools for effectively handling spatially referenced data and a paucity of spatial ecological concepts and theory (Aspinall 1994). One other reason for the slow uptake of GIS is the lack of spatial analytical tools for the analysis and description of spatial pattern that is necessary in ecological studies (Kemp 1992). Organisms do have spatially related interactions with their environment, however, and landscape ecology studies the effects

of such spatial and temporal interactions between landscape characteristics and the spatial distribution of organisms (Bridgewater 1993). As a result, there is a requirement for large volumes of multi-source spatially referenced data (Michener *et al.* 1994) that are amenable to treatment with GIS. GIS also offer capabilities for spatial analysis that, even with the weaknesses stated above, are of use in the identification and visualisation of relationships that may exist between spatial data.

This paper investigates the use of a spatial information system to record and manage a conservation database of spatial and attribute data regarding a breeding colony of royal albatross at Taiaroa Head, New Zealand. The purposes of this system are two-fold: integration of breeding records within an information system leads to improved data management and reporting, and the analytical capabilities commercial GIS provide allow exploratory analyses to be undertaken in order to gain new or improved understanding and visualisation of spatial and temporal relationships among phenomena at Taiaroa Head. A better understanding of relationships should lead to better conservation management of the colony. Three examples of exploratory analysis that investigate albatross interaction with slope and visibility, and the dispersion of offspring within the population are described and discussed in the following sections.

Taiaroa Head

The royal albatross colony at Taiaroa Head is unique and important from a conservation perspective, because it is the only mainland breeding colony of any albatross species in the world. It is even more unusual due to its being located just 35 kilometres from the centre of the City of Dunedin (though it is still within the city boundary - see Figure 1)

on a site that has been and still is the focus of a great deal of human activity (Purvis *et al.* 1993). The total breeding population at Taiaroa Head is presently 27 pairs. Although this is a small number compared to the world population (estimated to be between 6,500 - 7,000 pairs in 1995). The remaining population breeds almost exclusively on three small islands in the remote Chatham Islands group 800 kilometres east of New Zealand at 44°S latitude. The total land area of these colonies is approximately 30 hectares. Therefore the colony at Taiaroa Head is important due to its accessibility for humans and because it has been the subject of continuous monitoring and protection that began with the efforts of Richdale in the late 1930s (Richdale 1939) and continues today with the colony being protected as a nature reserve that is administered by the Department of Conservation under the Reserves Act 1972.
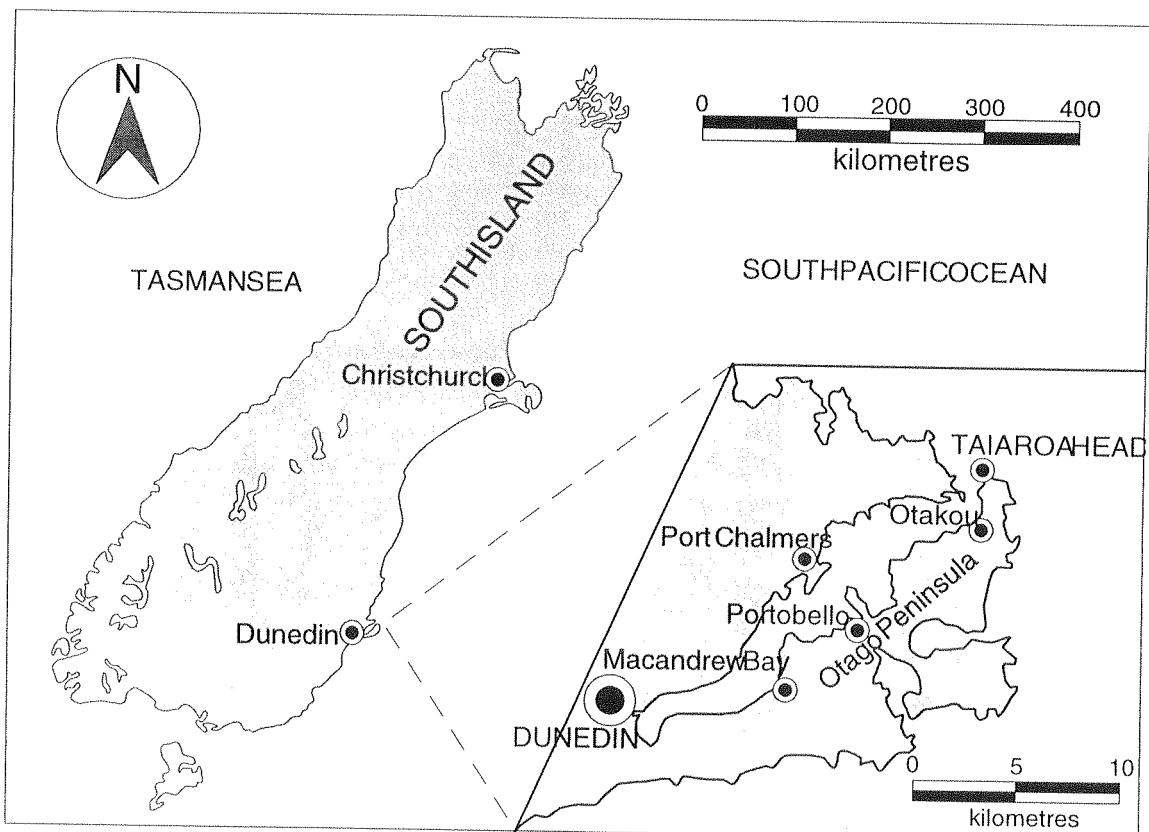

Figure 1. Location of Taiaroa Head

This ease of access for human visitors combined with the striking appearance of the birds has also resulted in the colony's increasing popularity as a tourist destination (DoC 1992b), with almost 100,000 tourists visiting the Trustbank Royal Albatross Centre at Taiaroa Head in 1995 which has implications concerning the conservation management of the colony. Of these, some 30,000 - 40,000 people annually take guided tours to observe the nesting birds from an observatory located within the reserve (see Figure 3). Tourist numbers are placing some strain on existing observation facilities however, as well as, it is suspected, causing some disturbance to breeding birds. In recent years there has been an observed pattern of birds selecting nest sites that are not within the public's gaze (DoC 1992a; Robertson 1995), a pattern that is particularly evident in those birds that were raised within view of the observatory.

Taiaroa Head Information System.

The information system that is used in the experiments described in this paper has been developed using Genamap version 6.2 by the Department of Information Science at the University of Otago in a collaborative effort with the Department of Conservation, New Zealand. Its primary purpose is to provide a system for the storage and management of breeding data that has been collected over the last 60 years as well as incorporating new data as it is collected. The current database consists of spatial physiographic, cultural (i.e. manmade), and natural feature data collected from aerial and global positioning system (GPS) surveys (McLennan et al. 1994), digitised paper maps of annual nest locations, and breeding attribute records that are kept by the Department of Conservation. The breeding records have been compiled from a number of sources,

which reflects the amount of scientific interest in the colony, and provides an almost complete record of albatross breeding activities from 1935 to the present day. They are compiled from daily observations and provide annual 'snapshots' of the chicks raised at the colony, their parentage, milestones in their development and records of management practices such as fostering and hand-rearing. Integration of these data within a spatial information system also permits queries, analyses and visualisations to be carried out that were not feasible with the manual methods used in the past.

Exploratory Analysis of Spatial Data.

One capability of GIS that is of interest with regard to the conservation management of the colony is the ability to conduct exploratory spatial analyses with the database. Haining (1994, p.45) defines spatial analysis as a *"collection of techniques for analysing geographical events where the results of analysis depend on the spatial arrangement of the events."* One aim of spatial analysis is the exploration of the patterns exhibited by geographic phenomena (which may be followed by quantitative description), and the relationships that may exist between them (Haslett *et al.* 1990) with a view to developing hypotheses about the processes that give rise to them (Openshaw *et al.* 1990). An exploratory approach to spatial analysis is applicable to the Taiaroa Head database, because although some patterns are evident in nest site distribution, the nature of the patterns and the reasons for them are in all likelihood complex. At this stage the problem is one of 'finding the questions' (Everitt and Dunn 1983) for the relationships between data that can be extracted from the database and visualised.

The remainder of the paper describes three example analyses that illustrate the types of 'data trawling' exercises that have been carried out to date. The first two examples explore interactions between slope and visibility landscape characteristics and the albatross population. The third examines the dispersion of the progeny of a single female known as 'Grandma' in an attempt to visualise the spatial relationships between the nest sites this bird used and those of her descendants.

Slope Analysis.

An investigation of slope was undertaken to determine the influence terrain slope has on the location of nest sites. It is known that royal albatrosses prefer to nest in generally flat areas and one study (Mills 1990) included measurement of slope as a factor in nest site selection. However, it had not been possible in the past to carry out an exhaustive analysis of slope, as this information had not been recorded and relocating historic nest sites from paper maps for remeasurement is unreliable and time consuming. An inductive analysis was carried out to determine the range of slopes that are suitable for the location of nests, followed by prediction of area within the nature reserve that fall within this range.

Six slope maps were constructed from a gridded elevation model by varying the computation method and matrix size parameters for comparison against a control set of slopes recorded at 20 nest sites during the 1989/90 breeding season for Mills' study. Slopes from each map were evaluated against the control set by paired t-test and the

most appropriate map was selected for further analysis. The slope of the terrain at all recorded nest sites since the 1968/9 breeding season[1] were extracted for statistical analysis and it was determined that the distribution of nest sites had a mean slope of 14.01° with a standard deviation of 6.43°. Figure 2 shows the areas within the nature reserve that meet these slope criteria; 52% (32,576m^2) of the reserve is suitable within one standard deviation *above* the mean (0 - 20.44°) and 66% (41,256m^2) is suitable within two standard deviations above the mean (0 - 26.87°). The latter describes the upper range of this habitat variable. A simple habitat suitability model based on one variable could certainly be refined to take into account additional parameters, but this example illustrates the process of developing an understanding of how organisms interact with their environment based on a comprehensive database of population observations. The slope data may also be integrated back into this database as a new attribute for subsequent analyses.

Visibility Analysis.

The large difference in the numbers of tourists passing through the Visitors Centre and those actually viewing the birds from the observatory is due to the observatory being used to its fullest capacity at peak times during the tourist season. In order to provide a more rewarding experience for the majority who do not go beyond the Visitors Centre, it is planned to install a number of video surveillance cameras within the colony that are

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[1] The paper maps used for recording location of nest sites were introduced at this time. The location of nest sites prior to this season were estimated from other observational data. For the purposes of this analysis, nest sites prior to the 1968/9 breeding season were excluded as being unreliable. 299 nest sites were included in the slope analysis.
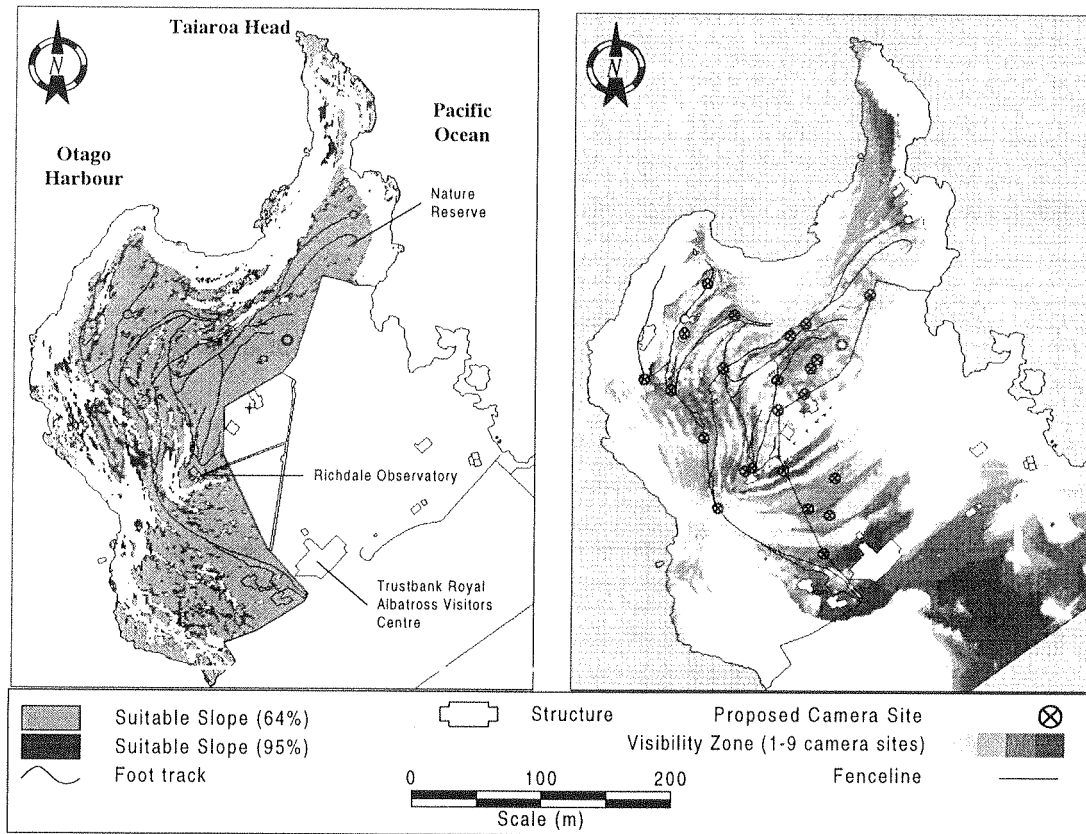
Figure 2. Slope Suitabliity Map

Figure 3. Visibility Map

connected to monitors at the Centre. Use of remote surveillance is expected to address two problems that are associated with tourism at Taiaroa Head: it should reduce the disturbance that is caused by public viewing facilities and it should also provide a more complete viewing coverage of the headland—only a small area of the reserve can be seen from the existing observatory and in any breeding season, there can be no guarantees that nesting albatrosses will be seen from it.

Given a number of proposed camera mounting sites, visibility analyses were carried out for each to determine the extent of the colony that would be covered. Visibility information may be derived from digital elevation models (Burrough 1986) that are of use for site selection purposes (Lee 1991). The map in figure 3 shows a composite of 23

viewsheds from proposed sites; the shading in the visible area represents the number of sites visible from the pixel.

Population Dispersion.

One question of particular interest to wildlife managers is the relationship between the sites where a chick was raised and the sites it selects when it returns as a breeding adult. For this experiment the descendants of one 'seed' bird known as "Grandma", were traced. "Grandma" was one of the first recorded birds to successfully raise a chick at Taiaroa (Robertson 1993). Her nest records and those of the five generations of her progeny account for 161 of the 500 or more nest sites recorded at the colony to date.

The method of analysis involved an iterative process that retrieved all nest records attributable to Grandma or her progeny, including those sites where a chick was successfully raised to fledging as well as those nest sites that failed. Successful progeny were searched in the attribute database to determine whether they returned to the colony to breed. The process was repeated for those birds that did return. Once all descendants had been identified, the co-ordinates of their nest sites (that are represented by point features) were retrieved from the spatial database. New layers were constructed that relate natal sites with descendant sites for successive generations, with the spatial relationships being formed by connecting line features which have start and end nodes constructed from the co-ordinates of the natal and descendant sites.
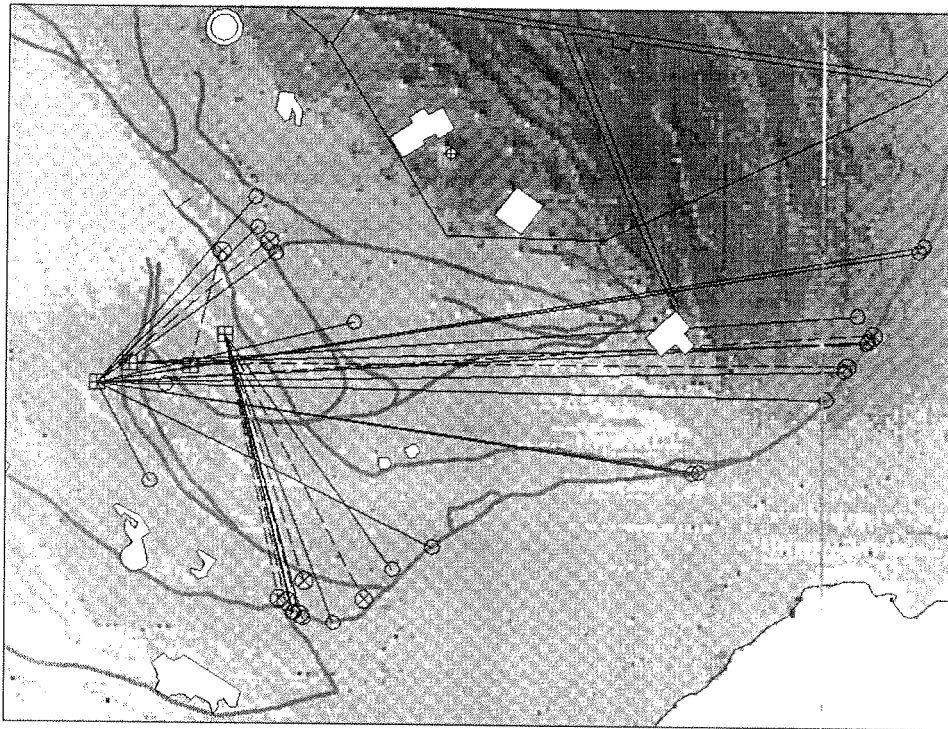
Figure 5. Second Generation Dispersion

Legend:

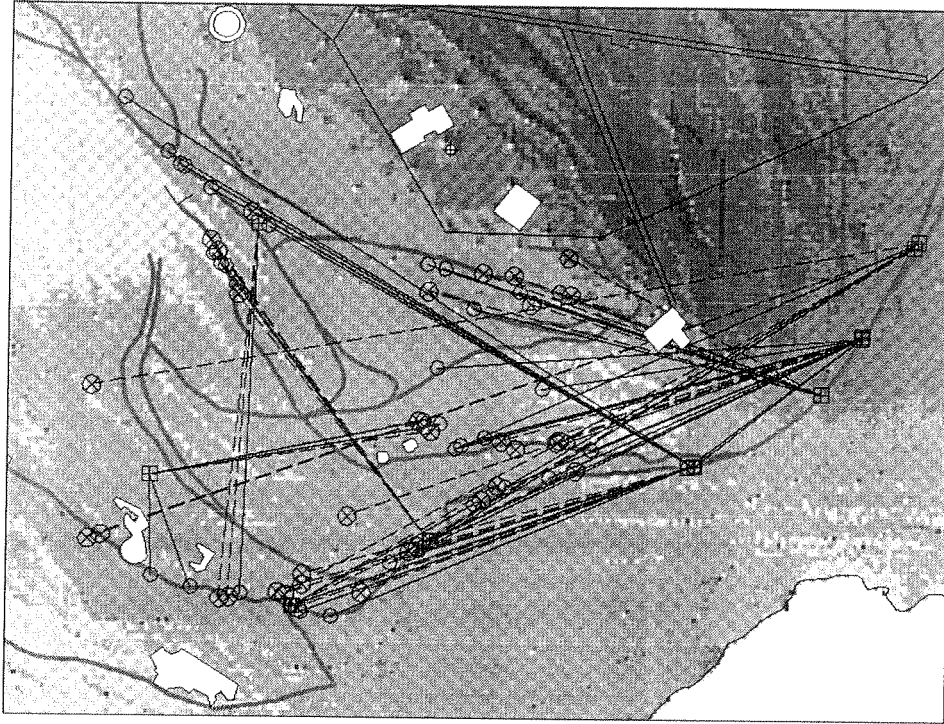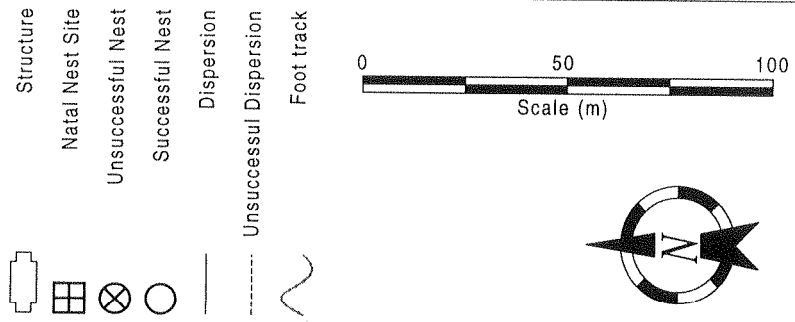| Symbol	Label
(rectangle)	Structure
(crossed square)	Natal Nest Site
(crossed circle)	Unsuccessful Nest
(circle)	Successful Nest
(solid line)	Dispersion
(dashed line)	Unsuccessul Dispersion
(wavy line)	Foot track

Scale (m)

0   50   100

N

Figure 4. First Generation Dispersion

Displaying these layers allows users to assess the pattern of dispersion visually in terms of direction and magnitude. The line features themselves may be queried to quantify the dispersion. Figures 4 and 5 show two maps that depict the dispersion between first and second generation progeny; natal sites are depicted by a crossed square, successful progeny sites by an open black circle and unsuccessful sites by a crossed circle.

This analysis proved to be useful for visualising trends in the nesting pattern, but it was observed that this is most effective if only a single generation is displayed. Any trends become confused if the dispersion of more than one generation is displayed. The line features themselves represent dispersion in only two dimensional cartesian space and care should be taken when attempting to interpret the processes they represent. The nature of the dispersion of nest sites is perhaps more a result of the complex physiography of Taiaroa Head and the location of courtship and pair-bonding activities that are also important factors in the location of nest sites. Also, the temporal nature of dispersion was not considered in this analysis.

A period of three to six years normally passes between the time a chick fledges and when it returns to the colony as an adolescent. Adolescents normally return for several years before pair formation and breeding and, in the case of Grandma, may have a breeding life in excess of 50 years (Robertson 1993). For the purposes of this experiment the temporal relationships were secondary to the spatial relationships between progeny. One interesting temporal pattern that emerges between figures 4 & 5 is the effect of public viewing. Nest sites in the south east sector of the reserve that were used by first generation birds are all dated prior to 1972 when the observatory was

constructed and controlled public viewing began. Access to the observatory is via a footpath that passes very close to this area. Second generation offspring have abandoned this area and no other birds have moved into it.

Conclusion.

The information system described in this paper provides a useful tool for the on-going collection and management of albatross breeding data and their spatial analysis. Even considering the experimental nature of the analyses carried out to date, the results have produced information that has proved useful in visualising the basis of the processes that influence the distribution of nest sites at Taiaroa Head. In addition, the system has been used for the production of maps that are now used as the basis for the on-going data collection effort. Future plans include the possibility of incorporating GPS as a means of automating this process and the incorporation of observational data concerning the activities of non-breeding adolescent birds that visit the colony.

Acknowledgements.

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