Return to previous file: drds303

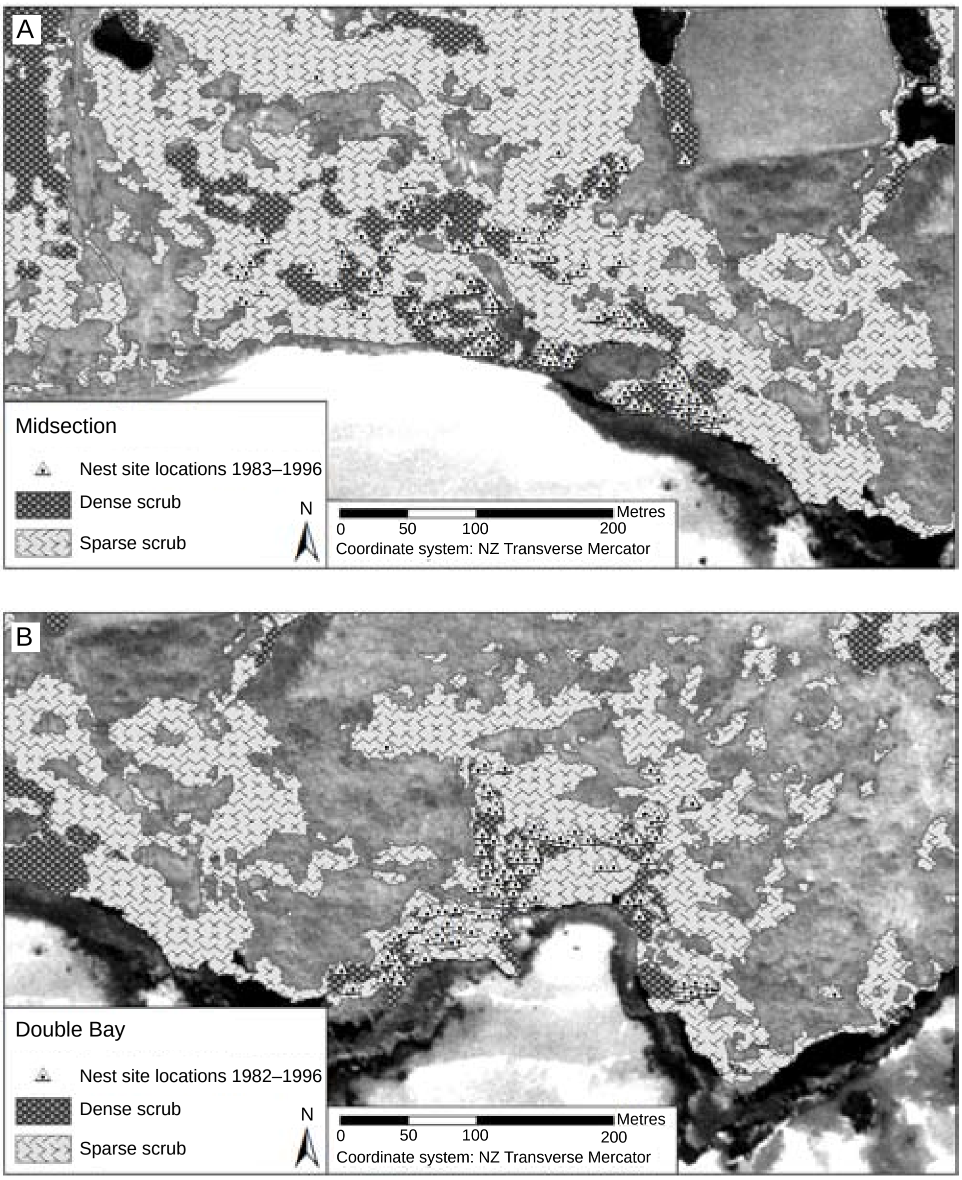

Figure 6. The estimated geographic locations (recorded in the NZTM geographic coordinate system) of yellow-eyed penguin (*Megadyptes antipodes*) nest sites (triangles) for the years 1983–1996 at A. the Midsection nesting area and B. the Double Bay nesting area of Boulder Beach, Otago Peninsula. The nest site locations are overlaid on the dense and sparse scrub habitat classes, which were the only two classes of the habitat map that nest sites were found to occur in. Some of the nest site locations are not visible because of overlap between nest sites that occurred in the same location in two or more years.

2.3 UPDATING THE YELLOW-EYED PENGUIN GIS

A secondary objective in the construction of the yellow-eyed penguin GIS was to make it possible to update the nest site shapefile dataset with a minimal amount of effort and error. This required the creation of a simple interface data entry form that would standardise the process of entering new data and remove the need to directly access the nest site shapefile.

The interface form was created using Visual Basic for Applications (VBA), which is an embedded programming environment in ArcGIS® 9 used for automating, customising and extending applications. The structure of the interface was designed to follow the format of the current DOC yellow-eyed penguin nest site field data collection form. With this structure, data from the DOC form could be transferred (i.e. typed) directly into the interface without the need to first organise and/or convert the data in a separate spreadsheet. As part of creating a standardised data entry process, combination boxes, or pick-lists, were used for some fields of the interface to provide guided input when entering data. For example, the choices for nest site vegetation cover were presented in a drop-down pick-list to ensure that spelling mistakes and inconsistencies were minimised. In addition, as a form of quality control, some data restriction (e.g. date format, and a maximum number of eggs and chicks) and validation are allowed before updating the nest site shapefile. The final interface form is presented in Fig. 7.

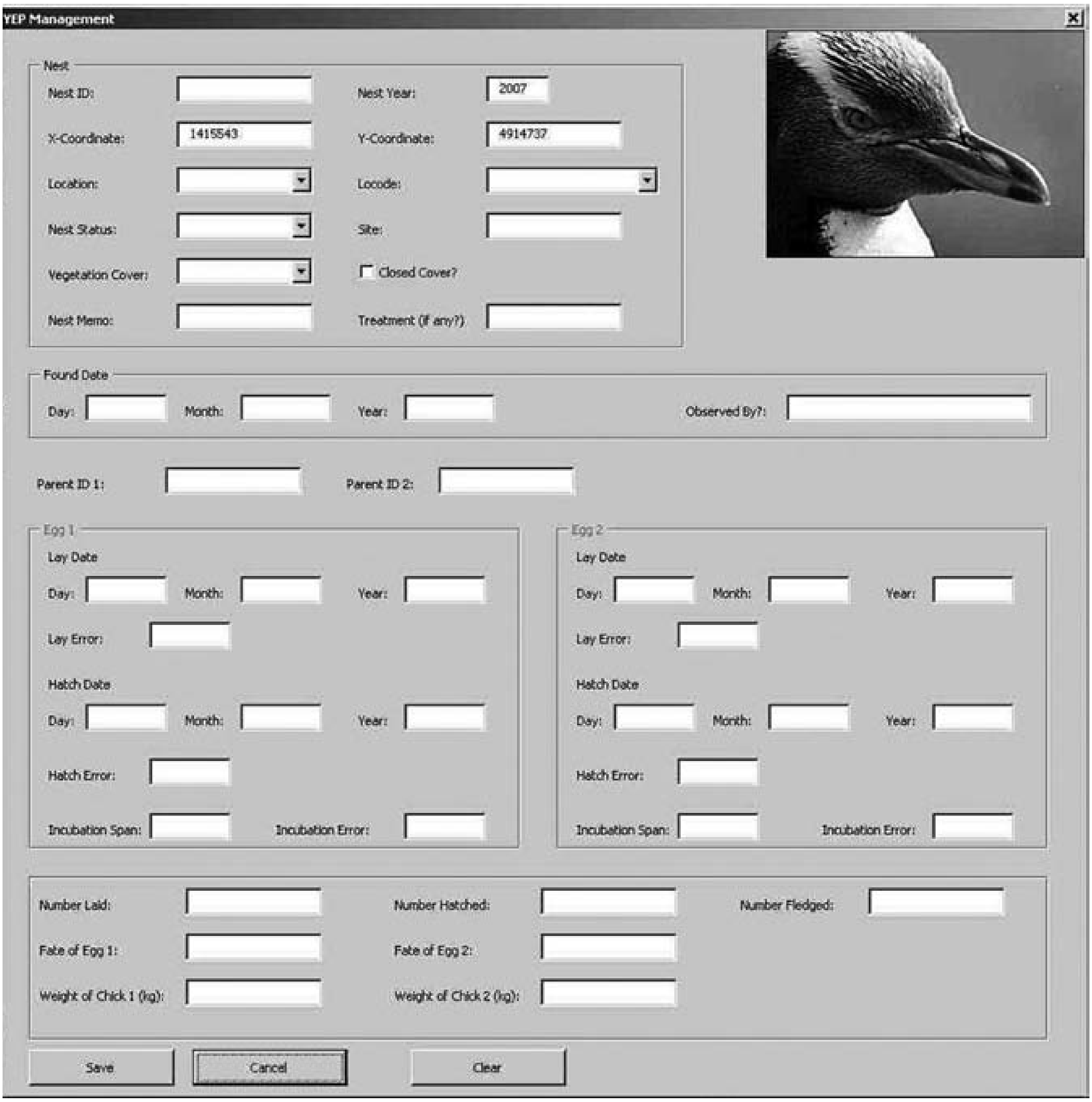

Figure 7. The graphical interface form for entering new data into the nest site shapefile in the yellow-eyed penguin (*Megadyptes antipodes*) GIS (described in section 2.4).

3. Uses of the yellow-eyed penguin GIS

3.1 SPATIAL ANALYSIS

A GIS designed for ecological research or wildlife management purposes is often used to quantify habitat selection and use (Manly et al. 2002). Such analyses generally involve the computation of statistics describing different landscape features that exist at recorded geographic locations of individual animals or related biological/ecological units (e.g. nest sites). For example, the mean elevation of nest sites at Midsection and Double Bay between 1982 and 1996 was 35 m and 43 m, respectively; and the mean slope was 27° and 31°, respectively. While these figures suggest that yellow-eyed penguins may not be averse to nesting well above sea level or on steep slopes, it is likely that there are other landscape features that impose a greater influence on nest site selection.

By overlaying the nest site shapefile on the habitat map, the relationship between nest site locations and habitat classes became clearly visible (see Fig. 6), and it appeared that nest sites occurred more often in dense scrub than in the other habitat classes. To confirm and quantify this relationship, a process called a 'spatial join' in ArcMap™ was used to incorporate data from the habitat map into the attribute table of the nest site shapefile. This process added a field to the nest site attribute table that defined the habitat class that each nest site was placed in for each year (i.e. 1983–96 for Midsection and 1982–96 for Double Bay). Summary statistics of the updated nest site data were then computed, revealing that nest sites were found only in either dense or sparse scrub habitat. This summary information was then entered into an Excel® spreadsheet to run a statistical test that compared the average number of nest sites in dense v. sparse scrub habitat for the years 1983–96. A simple one-way ANOVA revealed that, for the years 1983–96, the average number of breeding yellow-eyed penguins selecting dense scrub was significantly greater than those selecting sparse scrub for the placement of nest sites in both Midsection ($F = 41.79$, $P < 0.01$) and Double Bay ($F = 41.59$, $P < 0.01$) (Fig. 8).

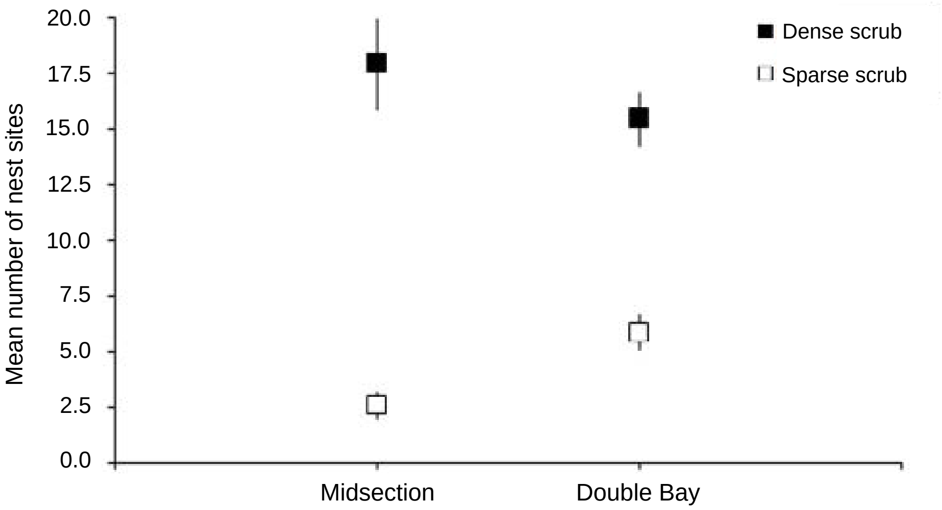

Figure 8. The annual mean number of yellow-eyed penguin (*Megadyptes antipodes*) nest site locations that occurred in dense scrub and sparse scrub habitat at the Midsection and Double Bay nesting areas of Boulder Beach, Otago Peninsula. The mean was calculated for nest site records from 1983–96. Error bars represent ± 1 standard error of the mean.

The tendency for yellow-eyed penguins to select well-concealed nest sites in dense vegetation has long been observed throughout much of their breeding range (Richdale 1957; Darby 1985; Lalas 1985; Seddon & Davis 1989; Moore 1992). In addition, higher nest densities have been observed in habitat patches that contain greater densities of vegetation (e.g. Seddon & Davis 1989; Moore 1992). The density of individuals and/or nest sites in relation to different habitat classes, or to other landscape features, is often an important measure in the analysis and monitoring of a species' habitat use and population trends. Population and/or nest site densities can easily be calculated and spatially represented in a GIS.

The density of yellow-eyed penguin nests in dense scrub was compared with that in sparse scrub between the years 1994 and 1996. These years were selected for analysis because the vegetation cover present at that time was likely to have been similar to that represented in the 1997 Boulder Beach image. The areal extent (in m^2) of each habitat class in Midsection and Double Bay was easily calculated in ArcMap™ and, not surprisingly, the density of nests in dense scrub was found to be significantly greater than in sparse scrub for both areas (Midsection: $F = 9.14$, $P < 0.05$; Double Bay: $F = 18.56$, $P < 0.01$; Fig. 9). However, due to natural changes in the extent of vegetation cover over time, the error associated with these trends may have increased with each year prior to 1997 (i.e. the amount of error may have been greatest for the 1994 nest sites).

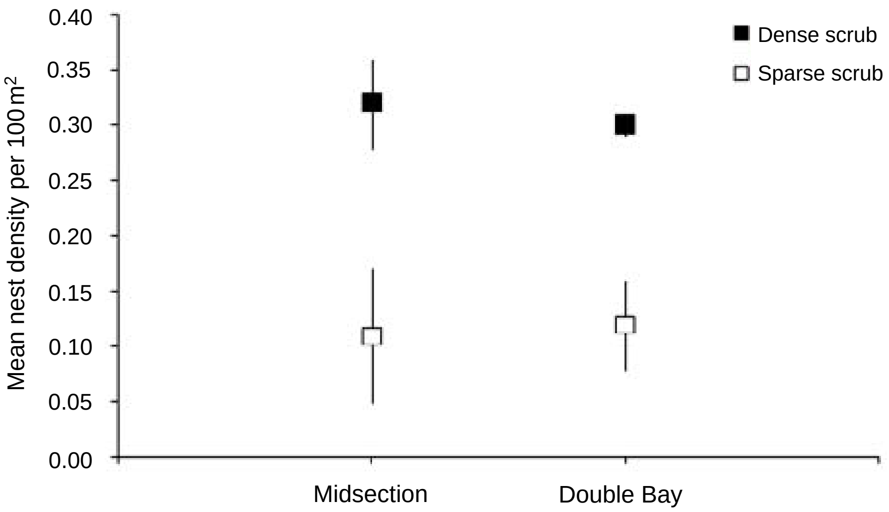

Figure 9. The annual mean density of yellow-eyed penguin (*Megadyptes antipodes*) nest sites that occurred in dense scrub and sparse scrub habitats at the Midsection and Double Bay nesting areas of Boulder Beach, Otago Peninsula. The mean density was calculated for the years 1994–96. Error bars represent ± 1 standard error of the mean.

3.2 OTHER POTENTIAL USES

The analyses described above are just the 'tip of the iceberg' of ways in which a GIS could be used to examine the relationship between yellow-eyed penguins and their habitat. Given the variety of attributes collected for each nest site (see Appendix 2), many different analyses, both spatial and non-spatial, are possible. Some examples include tracking the movements of breeding adults to different nest sites or nesting locations between years; linking trends in egg laying, hatching or chick fledging dates to geographic patterns; and examining geographic trends in nest success (i.e. the average number of chicks per nest that successfully fledged). Analyses like these could help determine the extent and pinpoint the source of problems such as disease outbreaks, predation or effects of human disturbance. Expanding on these examples, one possible use of the GIS for management purposes could be to determine the sections of yellow-eyed penguin breeding areas that are most affected by predation, and to use this information to design a predator control strategy.

A GIS could also be useful for yellow-eyed penguin habitat restoration and tourism management. This report has described how the preferred vegetation cover for nest sites can be easily determined with a GIS. This information could be valuable for determining the type, amount and spatial layout (i.e. distribution and density) of vegetation that should be used in habitat restoration programmes, as well as for predicting the potential placement or distribution of nest sites for a given year in a breeding area given the habitat types available (along with other topographical parameters) (Clark 2008). By comparing the sections of a nesting habitat used by yellow-eyed penguins with those visited by tourists and other users, public access could be managed in ways that minimise disturbance to breeding birds. Lastly, a GIS could be used to monitor and evaluate the spatial consequences of virtually any management intervention, such as changes in the locations of nest sites or nest site densities in response to the erection of fencing or signage, or the effects of habitat protection or restoration work, which could be used to help adapt and improve management strategies.

3.3 BEYOND YELLOW-EYED PENGUINS

The type of GIS described in this report could easily be applied to many other types of ecological or wildlife management and research. There is a broad range of examples, both in New Zealand and other countries, where GIS similar to that presented here for the yellow-eyed penguin have been used to predict species distributions and/or the availability of suitable habitat for different plant and animal species (e.g. McLennan 1998; Guisan & Zimmerman 2000; Greaves et al. 2006; Mathieu et al. 2006). Some studies have also shown how this type of GIS may be valuable for predicting habitat use by reintroduced or translocated species (e.g. Michel 2006). Aside from being helpful in the analysis of habitat use and in designing conservation strategies for threatened species and habitats, the type of GIS outlined in this report can also be used to track and analyse the movements of introduced predators, which can be useful in the development of effective predator control programmes (Shanahan et al. 2007). Thus, there is great potential for GIS in virtually any aspect of wildlife research and management.

4. Error and uncertainty

For any project that involves data collection, analysis and interpretation, there exists some amount of error and uncertainty. These terms can be considered synonymous (i.e. a large amount of error can be seen as a large amount of uncertainty); however, in this report uncertainty is defined as any amount of error that cannot be quantified or accounted for. Generally, error and uncertainty can increase proportionally with the amount and variety of data collected, as well as with the types of analyses used (Stine & Hunsaker 2001). In a GIS, it is possible to produce additional error and uncertainty through processes such as the derivation of new data layers from pre-existing datasets (e.g. the extraction of the DEM of Boulder Beach from the 1997 imagery). Consequently, it is imperative that, wherever possible, all potential sources of error and uncertainty are accounted for and minimised, if not eliminated.

Among the potential sources of error and uncertainty in the yellow-eyed penguin GIS, the most significant were the sketch maps of historical nest site locations at Midsection and Double Bay. Because of the inconsistent scale and detail of these hand-drawn maps, and the fact that they were not originally intended for the purpose for which they were used in this study, they were not an ideal source for determining the accurate geographic locations of the historical nest sites. Nevertheless, these sketch maps were the only source of information available for estimating the historical nest site locations. Every effort was taken to minimise the amount of error associated with the georeferencing of the sketch maps and the collection of NZTM coordinates of nest site locations in the field. However, since there were no references available other than the sketch maps, it was not possible to check the accuracy of the estimated geographic locations of the nest sites against an independent source. Therefore, the error associated with the nest site locations was based primarily on the accuracy of the georeferencing of the sketch maps, which meant that nest site locations were estimated to within ± 5–30 m of their correct position.

Another primary source of error and uncertainty was the creation of the habitat map. Uncertainty is inherent in thematic mapping techniques such as object-oriented classification, where class definitions must be discrete (i.e. there cannot be overlap between classes). This means that local (i.e. within class) habitat variation or detail can be lost. In addition, the process of defining the different habitat classes is at least partially subjective, which can result in inaccurate representations of the true landscape. However, these issues are irrelevant if, as in this study, local habitat variation is not important and class definitions are thorough and distinct. Uncertainty in the classification of land cover data extracted from imagery can also arise from natural topographical variation, which can produce shadows that are captured in the imagery, as well as areas of the same type of land cover that have different reflectance intensities, both of which may result in misclassification. The uncertainty present in the habitat map derived from the 1997 Boulder Beach imagery was primarily due to the number of shadowed areas. This was particularly relevant to Double Bay, where some steep cliffs exist. The habitat map was corrected as much as possible with manual editing, which was supported by other aerial photographs of Boulder Beach, and with photographs taken on the ground during a field survey. Since the habitat map was not validated with an independent set of field data, it was not possible to quantify the amount of error in the map. However, although the accuracy of the final habitat map was ultimately uncertain, it was still considered suitable for use in the analyses in this project.

A GIS can be a powerful tool for producing useful information for management purposes, but it can also produce misleading information (Monmonier 1991). The ability to use a GIS to produce visually appealing outputs can mislead users into believing that the GIS is more accurate than the data it represents (Bailey 1988). Ultimately, the errors, uncertainties and potential for misleading information associated with GIS emphasise the importance of carefully collecting appropriate data that meet the accuracy and quality required for the intended purpose, and for designing quality control protocols. Unfortunately, these aspects of GIS are often not considered because addressing them may require additional costs and resources.

5. Conclusions and recommendations

When used appropriately, a GIS can be a valuable tool for ecological or wildlife management and research. However, when constructing and using a GIS, the potential for error and other limitations must be clearly addressed and minimised. The yellow-eyed penguin GIS described in this report has demonstrated three main capabilities of GIS that could be beneficial for the management of virtually any plant or animal species or habitat.

The first and foremost capability of GIS is the broad scope provided for organising and storing a variety of potentially large datasets, and for comprehensive and efficient spatial and temporal analyses. While the accuracy of some of the derived data layers and associated analyses of the yellow-eyed penguin GIS were unknown (as described in section 4), the methods used to achieve them were robust. Furthermore, given that GPS and remote sensing technologies are improving and becoming more available and commonly used to collect data on nest site locations and other habitat features, the accuracy of future analyses based on up-to-date data will undoubtedly be much improved.

The second capability of the GIS described in this report is the ability to incorporate historical data for spatial analysis and interpretation. Wildlife researchers and managers should take care when working with historical data, as the level of accuracy, or amount of error, can be indeterminable. Nevertheless, with improvement, the methods outlined in this report for incorporating historical data can be quite useful, especially for comparing spatial patterns in historical data with current data to reveal changes and trends that have occurred over time.

Finally, the third main capability of GIS, as demonstrated in the construction of the yellow-eyed penguin GIS, is the creation of a simple, easy-to-use interface form that provides a standardised protocol for updating datasets such as the nest site shapefile. The main benefits of using a protocol such as this for entering data are that errors and inconsistencies can be minimised and routine manipulation of data should be easily understood and completed in a consistent format. In addition, a standardised procedure that is well designed and easy to use can help to overcome some of the difficulties associated with integrating ecological knowledge and technical GIS expertise.

The primary intention of this report was to provide a comprehensive yet simple guide to the construction and use of a GIS for collating, analysing, updating and managing data in wildlife management or research projects, using the spatial analysis of yellow-eyed penguin nest site data as an example. Wildlife managers, researchers and other users are encouraged to modify and update the structure of the GIS described in this report as necessary, and it is recommended that future studies incorporate current data as much as possible to ensure improved accuracy in analyses and other GIS output. Ultimately, as GIS technology improves, so will its effectiveness and value as a management and research tool.

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8. Glossary

The following definitions have been taken from the Environmental Systems Research Institute's (ESRI) Support website: http://support.esri.com (viewed 3 August 2008). Definitions of additional terminology relating to GIS can also be obtained from this site.

Aspect The compass direction that a topographic slope faces, usually measured in degrees from north.

Attribute Information about a geographic feature in a GIS that is usually stored in a table and linked to the feature by a unique identifier. See 'non-spatial attribute data' and 'spatial attribute data'.

Base map A map depicting background reference information such as landforms, roads, landmarks and political boundaries, onto which other thematic information is placed.

Classification The process of sorting or arranging entities (or data) into groups or categories.

Data layer (or layer) The visual representation of a geographic dataset in any digital map environment. Conceptually, a layer is a slice or stratum of the geographic reality in a particular area, and is more or less equivalent to a legend item on a paper map. On a road map, for example, roads, national parks, political boundaries and rivers might be considered different layers.

Database (or geodatabase) One or more structured sets of persistent data, managed and stored as a unit and generally associated with software to update and query the data. A simple database might be a single file with many records, each of which references the same set of fields. A GIS database includes data about the spatial locations and shapes of geographic features recorded as points, lines, areas, pixels or grid cells, as well as their attributes.

Differential correction A technique for increasing the accuracy of GPS measurements by comparing the readings to two receivers, one roving and the other a fixed base station.

Digital elevation model (DEM) The representation of continuous elevation values over a topographic surface by a regular array of *z*-values, referenced to a common datum. DEMs are typically used to represent terrain relief.

Feature A representation of a real-world object on a map.

Feature class In ArcGIS®, a collection of geographic features with the same geometry type (such as point, line or polygon), the same attributes and the same spatial reference. For example, highways, primary roads and secondary roads can be grouped into a line feature class named 'roads'.

Geographic coordinate system A reference system that uses latitude and longitude to define the locations of points on the surface of a sphere or spheroid (which represents the surface of the Earth). A geographic coordinate system definition includes a datum, prime meridian and angular unit.

Geographic Information System (GIS) An integrated collection of computer software and data used to view and manage information about geographic places, analyse spatial relationships and model spatial processes. A GIS provides a framework for gathering and organising spatial data and related information so that it can be displayed and analysed.

Georeferencing Aligning geographic data to a known coordinate system so it can be viewed, queried and analysed with other geographic data. Georeferencing may involve shifting, rotating, scaling, skewing, and in some cases warping, rubber sheeting or orthorectifying the data.

Global Positioning System (GPS) A system of radio-emitting and -receiving satellites used for determining positions on the Earth. The orbiting satellites transmit signals that allow a GPS receiver anywhere on Earth to calculate its own location through trilateration.

Image/imagery A representation or description of a scene, typically produced by an optical or electronic device, such as a camera or a scanning radiometer. Common examples include remotely sensed data (e.g. satellite data), scanned data and photographs.

Land cover The classification of land according to the vegetation or material that covers most of its surface, e.g. pine forest, grassland, ice, water or sand.

Nearest neighbour A technique for resampling raster data whereby the value of each cell in an output raster is calculated using the value of the nearest cell in an input raster. Nearest neighbour assignment does not change any of the values of cells from the input layer; for this reason, it is often used to resample categorical or integer data (e.g. land use, soil or forest type), or radiometric values, such as those from remotely sensed images.

Non-spatial attribute data Non-spatial information about a geographic feature in a GIS usually stored in a table and linked to the feature by a unique identifier. For example, attributes of a river might include its name, length and sediment load at a gauging station.

Orthorectification The process of correcting the geometry of an image so that it appears as though each pixel was acquired from directly overhead. Orthorectification uses elevation data to correct terrain distortion in aerial or satellite imagery.

Parallax The apparent shift in an object's position when it is viewed from two different angles.

Photogrammetry The science of making reliable measurements of physical objects and the environment by measuring and plotting electromagnetic radiation data from aerial photographs and remote-sensing systems against land features identified in ground control surveys, generally in order to produce planimetric, topographic and contour maps.

Pixel The smallest unit of information in an image or raster map, usually square or rectangular. Often used synonymously with cell. In remote sensing, the fundamental unit of data collection. In a remotely sensed image, a pixel is represented as a cell in an array of data values.

Planimetric Two-dimensional; showing no relief. A two-dimensional map that serves as a guide for contour mapping, usually prepared from aerial photographs.

Polygon On a map, a closed shape defined by a connected sequence of x and y coordinate pairs, where the first and last coordinate pairs are the same and all other pairs are unique.

Projected coordinate system A reference system used to locate x, y and z positions of point, line and area features in two or three dimensions. A projected coordinate system is defined by a geographic coordinate system, a map projection, any parameters needed by the map projection, and a linear unit of measure.

Projection A method by which the curved surface of the Earth is portrayed on a flat surface. This generally requires a systematic mathematical transformation of the Earth's graticule of lines of longitude and latitude onto a plane.

Raster data A spatial data model that defines space as an array of equally sized cells arranged in rows and columns, and composed of single or multiple bands. Each cell contains an attribute value and location coordinates.

Relief Elevations and depressions of the Earth's surface, including those of the ocean floor. Relief can be represented on maps by contours, shading, hypsometric tints, digital terrain modelling or spot elevations.

Remote sensing Collecting and interpreting information about the environment and the surface of the Earth from a distance, primarily by sensing radiation that is naturally emitted or reflected by the Earth's surface or from the atmosphere, or by sensing signals transmitted from a device and reflected back to it. Examples of remote-sensing methods include aerial photography, radar and satellite imaging.

Resolution The detail with which a map depicts the location and shape of geographic features. The larger the map scale, the higher the possible resolution. As scale decreases, resolution diminishes and feature boundaries must be smoothed, simplified or not shown at all; for example, small areas may have to be represented as points. Also defined as the dimensions represented by each cell or pixel in a raster.

Resampling The process of interpolating new cell values when transforming rasters to a new coordinate space or cell size.

Root mean square error (RMSE) A measure of the difference between locations that are known and locations that have been interpolated or digitised. RMSE is derived by squaring the differences between known and unknown points, adding those together, dividing that by the number of test points, and then taking the square root of that result.

Scale The ratio or relationship between a distance or area on a map and the corresponding distance or area on the ground, commonly expressed as a fraction or ratio. For example, a map scale of 1/100 000 or 1:100 000 means that one unit of measure on the map equals 100 000 of the same unit on the Earth.

Shapefile In ArcGIS®, a vector data storage format for storing the location, shape and attributes of geographic features. A shapefile is stored in a set of related files and contains one feature class.

Slope The incline, or steepness, of a surface. Slope can be measured in degrees from horizontal (0–90) or percent slope (the rise divided by the run, multiplied by 100). The slope for a cell in a raster is the steepest slope of a plane defined by the cell and its eight surrounding neighbours.

Spatial analysis The process of examining the locations, attributes and relationships of features in spatial data through overlay and other analytical techniques in order to address a question or gain useful knowledge. Spatial analysis extracts or creates new information from spatial data.

Spatial attribute data Information about the locations and shapes of geographic features and the relationships between them, usually stored as coordinates and topology.

Spatial join A type of table join operation in which fields from one layer's attribute table are appended to another layer's attribute table based on the relative locations of the features in the two layers.

Stereopair Two aerial photographs of the same area taken from slightly different angles that produce a three-dimensional image when viewed together through a stereoscope.

Thematic data/map Features of one type that are generally placed together in a single layer. A map designed to convey information about a single topic or theme, such as population density or geology.

Topography/topographic map The study and mapping of land surfaces, including relief (relative positions and elevations) and the position of natural and constructed features. A map that represents the vertical and horizontal positions of features, showing relief in some measurable form, such as contour lines, hypsometric tints and relief shading.

Transformation The process of converting the coordinates of a map or an image from one system to another, typically by shifting, rotating, scaling, skewing or projecting them.

Triangulation Locating positions on the Earth's surface using the principle that if the measures of one side and the two adjacent angles of a triangle are known, the other dimensions of the triangle can be determined.

Uncertainty The degree to which the measured value of some quantity is estimated to vary from the true value. Uncertainty can arise from a variety of sources, including limitations on the precision or accuracy of a measuring instrument or system; measurement error; the integration of data that use different scales or that describe phenomena differently; conflicting representations of the same phenomena; the variable, unquantifiable or indefinite nature of the phenomena being measured; or the limits of human knowledge. Uncertainty is often used to describe the degree of accuracy of a measurement.

Vector data A coordinate-based data model that represents geographic features as points, lines and polygons. Each point feature is represented as a single coordinate pair, while line and polygon features are represented as ordered lists of vertices. Attributes are associated with each vector feature, as opposed to a raster data model, which associates attributes with grid cells.

Appendix 1

EXTERIOR ORIENTATION PARAMETERS AND TRIANGULATION RESULTS

As described in section 2.2.2, the exterior orientation parameters of the stereopair of aerial photographs of Boulder Beach taken in 1997 were calculated using the space resection by collinearity technique in Leica Photogrammetry Suite V8.7 software program. Details about this technique and the procedures utilised in the software program are outlined in Leica Geosystems (2003). Using least squares adjustment techniques, the six exterior orientation parameters associated with each image were automatically calculated by the software program. The accuracy of these parameters is listed below. The summary of the root mean square error (RMSE) of the GCPs on the ground and in the two images are also listed.

Exterior orientation parameters

Image ID	X	Y	Z	OMEGA	PHI	KAPPA
1	0.0677	0.0178	0.4073	0.0672	0.2023	0.0599
2	0.0176	0.0113	0.0936	0.1677	0.1780	0.0600

Summary RMSE (in metres) for GCPs on ground (number of observations in parentheses)

```
Ground X: 0.1859 (12)
Ground Y: 0.1157 (12)
Ground Z: 0.1593 (12)
```

Summary RMSE (in pixels) for GCPs on image (number of observations in parentheses)

```
Image X: 0.3449 (12)
Image Y: 0.2147 (12)
```

Appendix 2

ATTRIBUTES INCLUDED IN THE YELLOW-EYED PENGUIN NEST SITE DATASET

ATTRIBUTE	DESCRIPTION	EXAMPLE
Nest year	Year of the particular breeding or nesting season.	1996
Location	Name of the breeding area.	Double Bay
Locode	Two-letter code for location name.	DB
Site	Specific code or ID for each nest site.	10
Nestid	Full nest site ID. Includes Nestyear and Locode.	1996DB10
P1	Band or ID number of first parent observed at nest. Left empty if number is never read or parent is unbanded.	10094
P1id	Same as P1, except for the few cases where old band numbers are replaced.	10094
P2	Band or ID number of second parent observed at nest. Left empty if number is never read or parent is unbanded.	9914
P2id	Same as P2, except for the few cases where old band numbers are replaced.	9914
Vegetation	Primary type of vegetation immediately surrounding nest site.	Flax
Cover	Whether nest site is covered or not (i.e. closed or open).	Closed
Date found	Date the nest site was first found.	9/25/1996
Nest status	Whether nest site is active (i.e. eggs laid or not).	Eggs laid
Treatment	Any actions taken by DOC personnel or researchers.	Chick taken into captivity
Lay date e1	Estimated lay date of the first egg.	10/1/1996
Lay error e1	Estimated error of Lay date e1.	3
Lay date e2	Estimated lay date of the second egg.	10/5/1996
Lay error e2	Estimated error of Lay date e2.	3
Hatch date e1	Estimated hatch date of the first egg.	11/15/1996
Hatch error e1	Estimated error of Hatch date e1.	2
Hatch date e2	Estimated hatch date of the second egg.	11/15/1996
Hatch error e2	Estimated error of Hatch date e2.	2
Incub span e1	Estimated number of days of incubation of the first egg.	46
Incub error e1	Estimated error of Incub span e1.	0
Incub span e2	Estimated number of days of incubation of the second egg.	42
Incub error e2	Estimated error of Incub span e2.	0
Nlaid	Number of eggs laid.	2
Nhatched	Number of eggs hatched.	2
Nfledged	Number of chicks fledged.	1
Fate egg1	Fate of the first egg (fledged, predated, etc.).	Fledged
Fate egg2	Fate of the second egg.	Hypothermia
Nest memo	Comments, memos or notes of interest about the nest site.	
Easting*	Easting coordinate of nest site in NZTM.	4914556.76
Northing*	Northing coordinate of nest site in NZTM.	1415518.42
Who	Surname of person who found nest site.	Clark
C1kg	Weight of first chick prior to fledging.	5.5
C2kg	Weight of second chick prior to fledging.	
VegClass*	For Midsection and Double Bay, the habitat class that a nest site was located in based on the habitat map derived from 1997 imagery of Boulder Beach.	Dense Scrub

* These attributes were added to the dataset when constructing the GIS as described in this report.

Appendix 3

SKETCH MAPS OF YELLOW-EYED PENGUIN NESTING HABITAT AREAS

Additional examples of the sketch maps of the Midsection and Double Bay yellow-eyed penguin (*Megadyptes antipodes*) nesting habitat areas at Boulder Beach, Otago Peninsula.

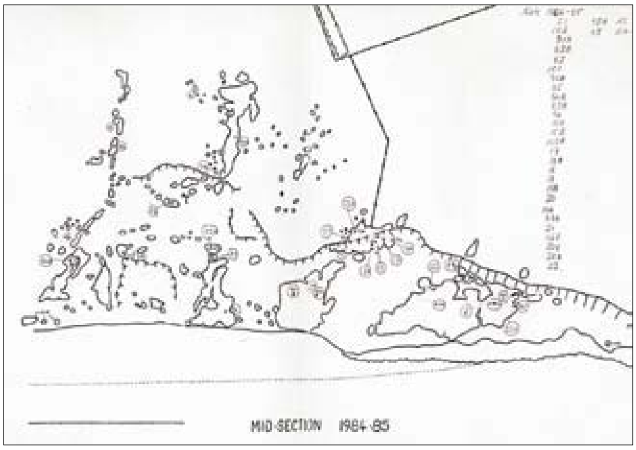

Figure A3.1. Midsection 1984–85.

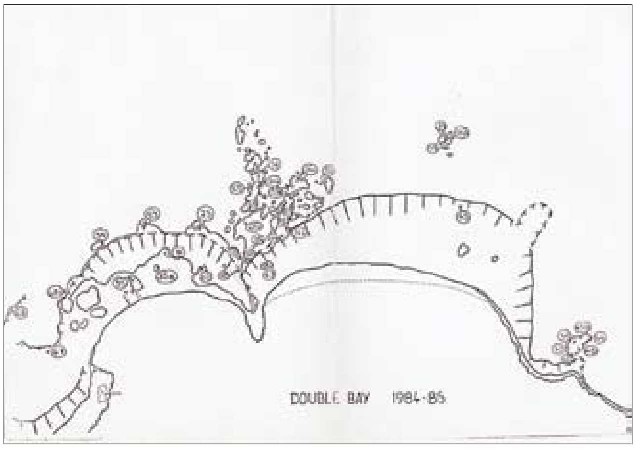

Figure A3.2. Double Bay 1984–85.

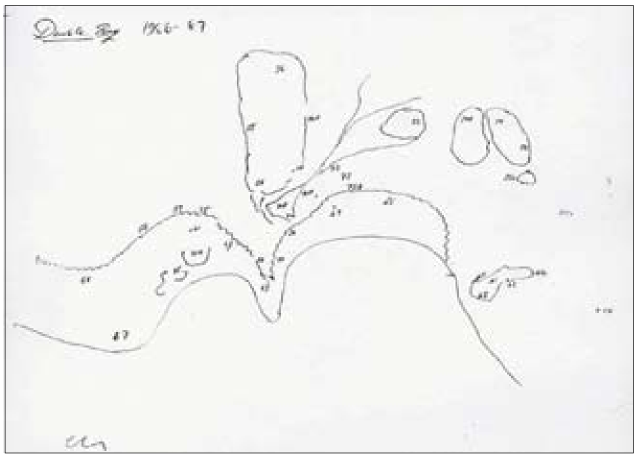

Figure A3.3. Double Bay 1986–87.

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