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FOREWORD

This edition of Ecological Management differs from previous issues in that it covers a single subject, the survey and monitoring of threatened species. It contains edited versions of presentations given at two workshops organized by the Threatened Species Unit in November 1995; one at Pureora in the North Island and one in the South Island at Cass.

The primary aim of the workshops was to provide the Department's regional conservancies with quality advice on the design of survey and monitoring programmes for threatened plants and animals. Birds and mammals were excluded in recognition that there is already considerable expertise and agreed methodologies for survey and monitoring of threatened birds, and that work on threatened bats is proceeding under the guidance of the bat recovery group.

The workshops included a day devoted to each of plants, invertebrates and reptiles/amphibians, with a shorter session on freshwater fish. Though each workshop covered the same topics, different tutors were involved in the North and South Island workshops. For the purposes of this publication, and to avoid unnecessary duplication, a single author in some cases synthesized the material from more than one workshop presentation. The cooperation of workshop tutors in agreeing to this approach is acknowledged.

Since the application of appropriate and standard survey and monitoring techniques is pre-requisite for all ecosystem management projects, I hope this publication will be of value to Project Managers as a resource document

N.B. Presentations on reptiles were based on already-published material and are not reproduced here. Readers are referred to the following:

Whitaker, A.H. 1994a. New Zealand lizards: their ecology and conservation. *Ecological Management* 2: 1-7, Department of Conservation, Wellington.

Whitaker, A.H. 1994b. Survey methods for lizards. *Ecological Management* 2: 8-16, Department of Conservation, Wellington.

Alan Saunders

Manager, Threatened Species Unit

The identification of plant specimens

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ABSTRACT

Procedures for the identification of plant specimens are described. Sources of Key reference material and locations of herbaria collections are also given.

INTRODUCTION

Every field biologist faces the problem of identifying organisms. This paper outlines various ways of obtaining names for unknown plants, from consulting the experts to using books. However, to learn those names, there is no substitute for identifying the plants yourself, then using the name regularly.

If the unknown plants are species which resemble other species, a reference collection of pressed pieces should be kept. For example, build up a pressed collection of small-leaved shrubs (or just *Coprosma*), or grasses, or sedges and rushes, or ferns, or whatever the problems are to you in the area where you work. A small number of specimens can be mounted in a hard-backed field notebook; larger numbers would need a loose-leaf folder of blank sheets or some similar system. Growing a collection of plants you wish to learn is an excellent way of coming to recognize them in the field.

IDENTIFICATION METHODS

Figure 1 describes the main options available for putting names on plant specimens. The numbered notes below refer to numbered sections of the flow diagram shown in Figure 1.

Explanatory Notes on Flow Diagram

1. Before you attempt to identify an unknown plant, it is desirable to be able to classify it as:

(a) native or exotic to New Zealand, and

(b) a member of a broad plant group, e.g., fern, conifer, grass, sedge, orchid, shrub daisy.

This enables you to narrow your options. For example, if the plant is definitely a pasture grass then there are books specifically on such plants, or you may find that a local farmer or farm advisory officer can help you. However, books written about New Zealand's pasture grasses do not usually include native grasses, among which a number of species can be found in "unimproved" pasture at times. If you have no feeling as to whether the mystery plant is native or not, or about its taxonomic group, then there may be little point in trying to identify it yourself.

2. You will find from experience that you will get an answer more rapidly from some sources than others. If you post a specimen to a place where there is only one person able to help, remember that that person may be on an extended field trip.

Specimens sent to herbaria for identification will normally be added to the collection, not returned to you, so keep a duplicate piece of the plant yourself to match against the name which the herbarium may give you.

Specimens are best pressed in newsprint and dried before sending. Partly dried, pressed specimens travel well also. Post in a folder of newsprint with cardboard or plywood either side. For each specimen give details on geographical location, type of plant community it was in, date collected, collector's name, and any details lost in pressing (e.g., flower color, fruit shape, size of the whole plant). An ideal plant specimen would include roots, stem, leaves, flowers and fruit but this may be impracticable, if not impossible, for most species on a single visit. Use your discretion about how much of the plant you collect, especially if you suspect that the species is threatened.

Fresh material can be posted in the case of many species: the specimen should be dampened then shaken almost dry and put in a sealed plastic bag, inside a box. Mark "live plant material" (or similar) on the outside of the parcel near the address label, so that it is opened at the address of the recipient, even if the addressee is not there. Very wet specimens, particularly of soft or aquatic plants, rot inside a plastic bag in two or three days. If there is a delay between your collecting a plant and posting it fresh, deterioration can be slowed by putting the slightly dampened plant in a plastic bag in a refrigerator (not freezer).

3. There is an abundance of good books on certain plant groups and almost none on others. Most public libraries have a selection of titles, as have universities and some SOEs such as Landcare Research and FRI. Each DoC Conservancy office will have some useful reference books for identifying some plants. The first, and often most difficult step is to decide which book to use. This comes back to the fact that all books cover a restricted range of species, e.g.,

Native trees (e.g., Salmon 1980; Eagle 1982)

Wetland plants (Johnson & Brooke, 1989)

Native trees and shrubs (e.g., Poole and Adams 1980)

Alpine plants (e.g., Mark and Adams 1974)

Exotic pasture grasses (e.g., Lambrechtsen 1972)

Clovers and related plants (Healy 1982)

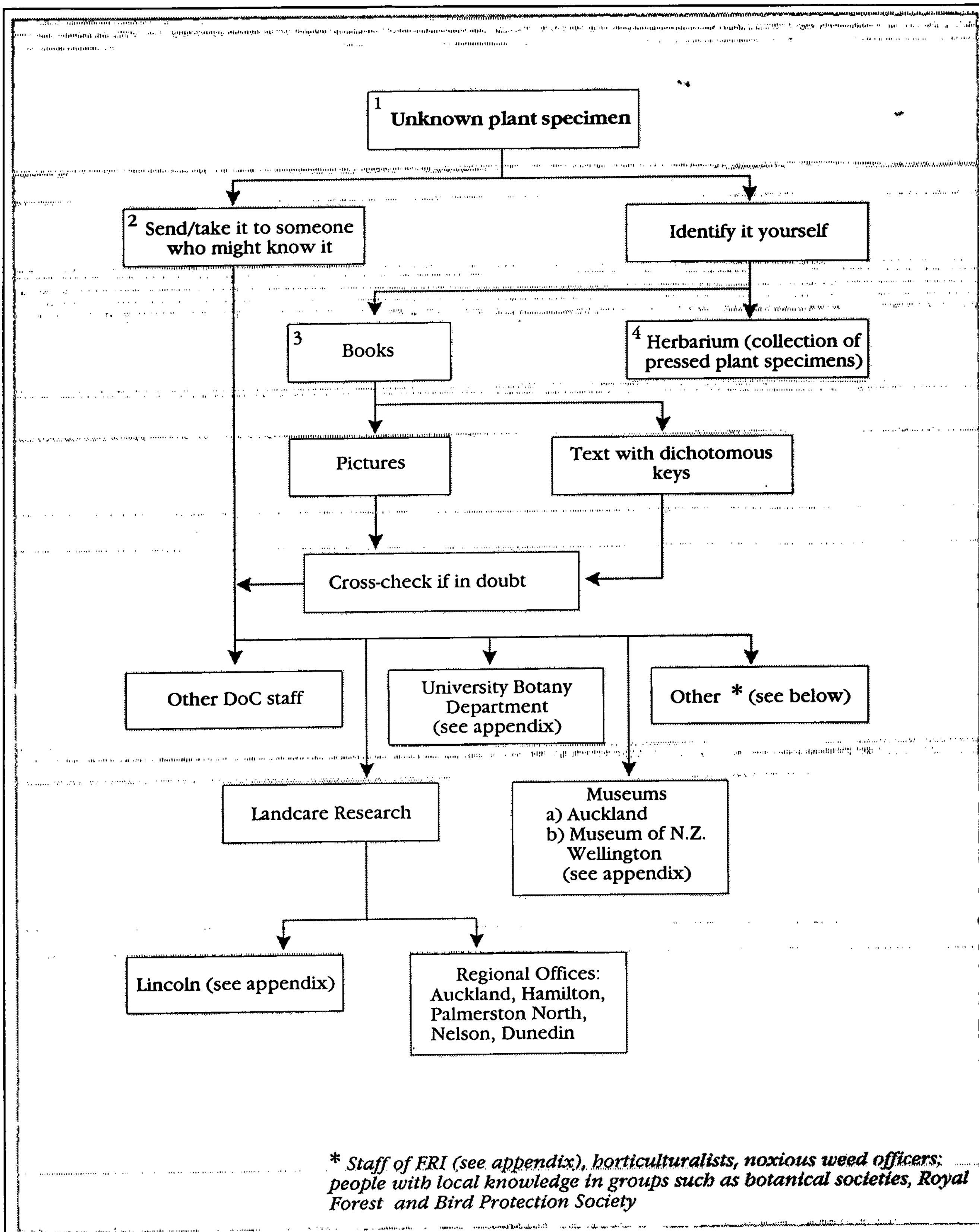

FIGURE 1. SOME METHODS OF IDENTIFYING UNKNOWN PLANT SPECIMENS.

A list of titles is appended to this paper, many of which are still in print. In certain respects, the most useful books are the two regional floras by Wilson (1978, 1982), since these illustrate **every** known flowering plant, conifer, fern and fern ally (and also some mosses, liverworts, lichens, and algae) within Mt Cook National Park and Stewart Island respectively. While the usefulness of both books decreases with distance beyond those regions, they are a valuable source of sketches of a lot of plants which occur quite widely in New Zealand and have not been illustrated by other authors.

4. Different organisations (Appendix) have different attitudes to allowing free use of their collections of pressed plants (herbaria) for doing your own identification. Many such specimens are quite old and fragile and will not stand unlimited amounts of handling. Anyway, you would need to have a fair idea of your unknown plant's formal (botanical) name before trying to find a matching specimen in a large herbarium, and if you take a specimen to an herbarium at, say, a museum, botany department at a university, Forest Research Institute, or Landcare Research then the curator of the herbarium would almost certainly want to do the searching.

REFERENCES

Some of the references listed below may have later editions than the ones cited.

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Salmon, J.T. 1980. The native trees of New Zealand. Reed.

Webb, C.J; Sykes W.R; Garnock-Jones, P.J. 1989. *Flora of New Zealand IV.* DSIR publishing .

Wilson, C.M. and D.R. Given 1989. Threatened plants of New Zealand. DSIR publishing.

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Wilson, H.D. 1982. Field guide. Stewart Island plants. Field Guide publications, Christchurch..

Wilson, H.D. and T. Galloway 1993. Small-leaved shrubs of New Zealand. Manuka Press, Christchurch.

Wright, A.E. 1984. New Zealand herbarium resources. *N.Z Journal of Botany* 22: 323-35.

APPENDIX 1

New Zealand herbarium resources (summarised from Wright 1984)

Auckland

Auckland Institute & Museum
Private Bag 92018
Auckland 1

Botany Department
University of Auckland
Private Bag
Auckland

Mount Albert Research Centre
Landcare Research NZ Ltd
Private Bag
Auckland

Christchurch

Botany Department
University of Canterbury
Private Bag,
Christchurch

Landcare Research NZ Ltd
P O Box 69
Lincoln

Lincoln University, Canterbury

Dunedin

Botany Department
University of Otago
P O Box 56,
Dunedin

Hamilton

Department of Biological Sciences
University of Waikato
Private Bag,
Hamilton

Palmerston North

Plant Biology Biotechnology Department
Massey University
Private Bag 11222
Palmerston North

Rotorua

Forest Research Institute
Private Bag 3020
Rotorua

Wellington

Museum of NZ
P O Box 467
Wellington

Botany Department
Victoria University of Wellington
Private Bag
Wellington.

Use of a dichotomous key for identification of plants and animals

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ABSTRACT

This paper describes the use of a dichotomous key for the identification of plants and animals. An example of using a key to identify a specimen of *Nertera* is given.

INTRODUCTION

Once we know to which **group** (e.g. genus or family or order) an unknown plant or animal belongs, then one of the most common ways of determining its specific name is through the use of a formal text or paper dealing with the species in that genus or family or order. Simply comparing the specimen with pictures or written text can be laborious and, probably, a rather hit-and-miss method.

Taxonomic publications include dichotomous keys to rationalise and speed up the process of getting to the "right" name. A dichotomous key requires us to make choices from alternative statements, choosing the one which best matches the unknown specimen, then to move down the table of choices until we reach a name for the species. This sounds quite simple, but there are pitfalls. As an example, botanical keys are notorious for using flower characters when your specimen has fruit only, or vice versa.

The shortcomings of dichotomous keys become obvious after trying to use one, but if you understand the jargon which seems to pervade many keys, and your specimen has all the features needed, then a dichotomous key can be very useful.

USING A KEY

To illustrate the working of a dichotomous key, a key to the native species of *Nertera* (a group of herbaceous plants related to *Coprosma*) is given below. This should allow us to identify the species of *Nertera* illustrated in Figure 1.

Method:

Begin at the first pair of statements (1). Examine the picture (or a piece of real *Nertera*, if you have one), and decide which of the two choices best fits the specimen. This will lead us to a new pair of statements, either (2) or (3). In either case, examine the specimen again in the light of the two choices offered. If we decide the plant was hairless at (1), then the choices at (2) will give us a specific name.

If possible, this name and the plant specimen should be compared against a full description and/or illustrations of the plant in some other reference. Factors such as the known distribution and habitat of the plant should also be used to decide whether the name we get from the key is likely or unlikely to be the "right" answer.

If we decided that the plant was hairy at (1), then the choices at (3) will enable us to decide whether it is *N. setulosa* or some other hairy species (in which case we proceed to the choices in (4), and so on).

Key to the New Zealand species of *Nertera* [1]

(Solution given on next page)

1. Plant hairless in all parts 2
   Plants distinctly hairy, in at least some parts of leaves and stems 3

2. Fruit pear-shaped .... *N. balfouriana*
   Fruit spherical, sometimes flattened on top .... *N. depressa* (including *N. cunninghamii*)

3. Hairs on stems and leaves, those on stems being markedly different from those on leaves (stem hairs fine, soft, matted on stem surface; leaf hairs coarse, straight, erect from leaf surface or edges) .... *N. setulosa*
   Stem hairs absent, or, if present, similar to leaf hairs in size and form 4

4. Leaf stalk (petiole) and plant stem obviously hairy; upper surface of leaf sometimes hairy 5
   Leaf stalk, plant stem, and upper surface of leaf with few or no hairs (leaf hairs are mostly confined to the leaf margins) .... *N. ciliata*

5. Leaf heart-shaped with a rounded leaf tip .... *N. scapanioides*
   Leaf not heart-shaped; leaf blade tapers back to the leaf-stalk (petiole); leaf tip pointed 6

6. Straight hairs on leaf surface .... *N. villosa*
   Hooked hairs on leaf surface. .... *N. dichondrifolia*

1. AP Drice's unpublished list "Indigenous higher plants of New Zealand" (1992 revision) includes two unnamed species of *Nertera* which do not appear in this key. He gave them the tag names of "*N. aff. depressa*" and "*N. balfouriana globose*". I know nothing of either species.

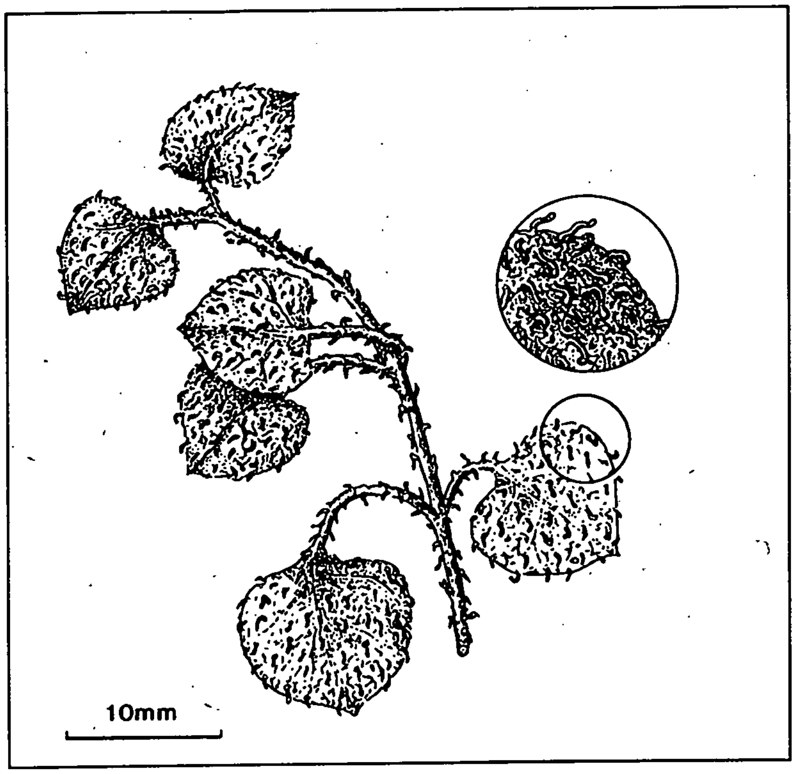

FIGURE 1. SAMPLE SPECIMEN OF *NERTERA*.

Solution from p.8; Identity of the illustrated *Nertera*

Using the key, you should have made the choices, in order, of 1.....3; 3.....4; 4......5; 5.......6; 6......*N. dichondrifolia*.

Grasses, sedges and rushes: their structure and differences

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ABSTRACT

A description of vegetative and floral characters useful for the identification of grasses, sedges and rushes.

CLASSIFICATION

Grasses, sedges, and rushes are all monocotyledons ("monocots" for short), i.e. one of the two great divisions of flowering plants, those having a single seed leaf (one cotyledon), leaf veins that are parallel, and flower parts in threes or multiples of three. Family statistics of these groups are given in Table 1.

Grasses comprise the grass family Poaceae ("po-ay-see"), also known by the less formal name Gramineae. [In recent years there has been a move by botanists to adopt family names derived by international convention from the first-named genus, in this case Poaceae after the grass genus *Poa*. A few other common families are also known by both "old" and "formal" names, e.g. the daisy family Asteraceae (Compositae); mint family Lamiaceae (Labiatae); carrot family Apiaceae (Umbelliferae); pea family Fabaceae (representing part of Leguminosae). It is perfectly valid to use either family name.] The grass family includes numerous genera that are weeds in New Zealand, such as *Cortaderia, Eragrostis, Nassella, Pennisetum, Stipa, Zizania*.

Sedges comprise the sedge family Cyperaceae ("sigh-per-ay-see"), named after the genus *Cyperus*, which has some weedy members in New Zealand. Other weedy genera include *Scirpus* and *Carex* (the cutty "grasses").

Rushes belong in the rush family Juncaceae ("junk-ay-see"), named after the genus *Juncus*. The term "rush" is applied mainly to this genus, although there are other rush-like plants elsewhere in the family, and also in other monocot families.

TABLE 1. FAMILY STATISTICS OF GRASSES, SEDGES AND RUSHES.

FAMILY	GRASSES (POACEAE)	SEDGES (CYPERACEAE)	RUSHES (JUNCACEAE)
Species in the world	10,000	4,000	400
Native genera in NZ	30	18	4
Native species in NZ	179	172	38
Naturalised species in NZ	255	41	35

VEGETATIVE CHARACTERS

The **stems** of grasses, sedges, and rushes are usually quite short, being found down near ground level. Some grasses do have obvious long-lived aerial stems, bamboos being an extreme example. Secondly, stems may take the form of a **rhizome** (an underground stem, usually horizontal, often a storage organ) or a **stolon** (running along the ground surface, able to take root and form a new offset plant). Thirdly there are the flowering stems which we call **culms** in these three groups of plants (Table 2). A culm will bear an inflorescence at or near the top and usually have some leaves arising from the lower portion, although these may be very reduced in size (and are then called **bracts**). On grass stems in particular we can usually distinguish the **nodes** (swollen knobs where the leaves or bracts are inserted). The intervening lengths of stem between the nodes are called **internodes**. An illustration of the vegetative structure of grasses is shown in Figure 1.

Table 2. Description of the cross-section shape of culms in grasses, sedges and rushes. The structure of culms varies within the three groups.

		grasses	sedges	rushes
Shape:				
Terete	○	usually	sometimes	often
Oval	⬭		often	often
Triangular	△		often	
Square	□		sometimes	
Inside the culm:		hollow	solid	hollow or pithy

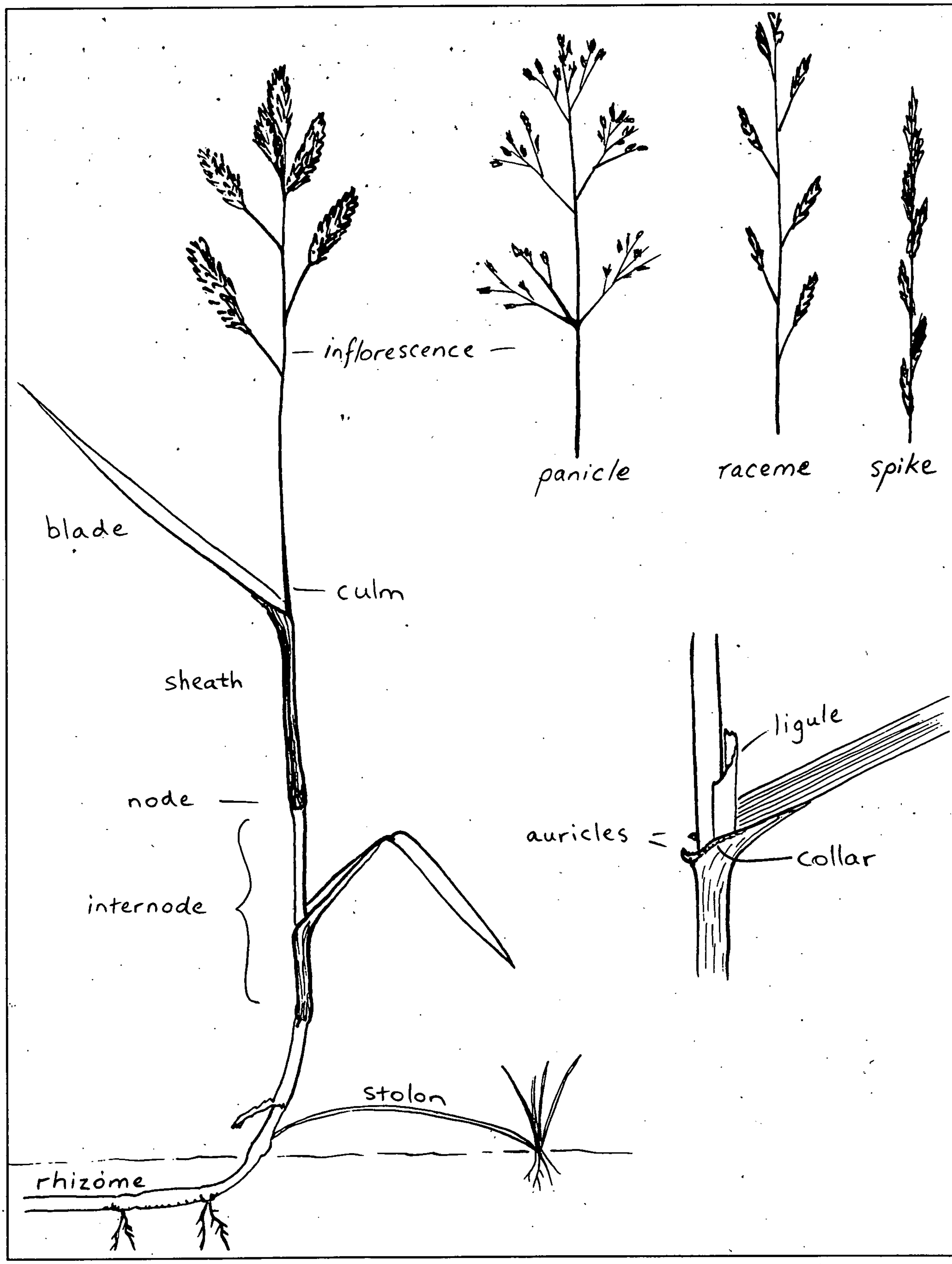

FIGURE 1. GRASS VEGETATION STRUCTURE AND INFLORESCENCE.

Growth form of grasses, sedges, and rushes is related to the length of the basal stems and their mode of branching. In grasses, the term **tiller** is used to describe each stem and its associated leaves. In **tussock** (bunched) grasses it is the tillers which form the construction modules of the whole plant. The basal stems of tussock grasses are very short, and new branches grow up within the leaf sheaths of the parent tiller and closely against it (intravaginal branching). In the alternative situation (**extravaginal branching**), the new shoots push out laterally from among the parent leaf sheaths, to produce a plant of more open habit: a loose tuft, mat, or turf growth habit, or even an extensive sward if rhizomes are present.

The **leaves** of grasses, rushes, and sedges are typically long and narrow, and comprised of two main portions: a **sheath** which clasps onto the stem, and a **blade** (or **lamina**) which angles away from it. Many rushes and sedges are effectively leafless, the leaf being reduced to not much more than the sheath, and the bulk of the plant then being made up of stems which are green and which carry out the photosynthetic functions in lieu of proper leaves.

Leaf blades vary greatly in their shape in cross section, and these differences can be of some help in distinguishing the three groups (Table 3).

TABLE 3. DIFFERENCES IN SHAPE OF LEAF BLADES AMONG GRASSES, SEDGES AND RUSHES.

O = often, s = sometimes

		grasses	sedges	rushes
Flat		O	O	s
Channelled, V-shaped		O	O	
Folded		O	s	s
Double-folded		s	O	
Inrolled		O	s	
Plano-convex		s	O	s
Triangular			s	
Tubular				O
Laterally flattened				s
Reduced to bracts			O	O

You may come across the terms **abaxial**, and **adaxial** to precisely describe the upper and lower surfaces of leaves. When we are considering leaves that are held erect or which are inrolled or rounded in cross-section, the concept of "upper" and "lower" surface can become confusing. So, **abaxial** means the side facing towards the axis.

Grass leaves are arranged in two ranks; those of sedges and rushes are usually in three ranks (rarely two) or else spirally arranged.

Leaf margins can be of some help in distinguishing grasses, sedges, and rushes. Grass leaves can have smooth margins although some, like pampas and toetoe have razor-sharp saw-toothed edges. Many sedges have coarse, cutting leaf edges, hence the common name "cutty grass" for species of *Carex* and *Gahnia* (The term sedge is derived from the Latin "seco", I cut). But many sedge leaves have smooth leaves (e.g. *Isolepis*), or if leafless (e.g. *Eleocharis*) they have smooth culms. Rush leaf edges are always smooth, or at least non-cutting to the fingers.

Several important distinguishing features are to be found where the leaf blade joins the sheath. To see these clearly it is often necessary to bend and pull the blade slightly away from the culm. A small flap termed the **ligule** may be found at the base of the blade, on the upper surface of the blade, and facing the stem, where its function is partly to help prevent rain from running down inside the sheath. In grasses the ligule is usually an obvious upstanding flap of membranous tissue, or else a row of fine hairs. In sedges the ligule is almost fused to the leaf blade. In rushes there is no ligule. Also at the junction of blade and sheath there may be a **collar**, shaped as its name suggests, and helping to give some stiffness to the structure. In addition there may be a pair of **auricles**, pointed ear-like extensions to the collar, that may clasp the culm.

FLORAL CHARACTERS

It comes as a surprise to many people that grasses, sedges, and rushes have flowers. They are not conspicuous and coloured as we might expect of flowers, for they are not trying to attract insects or other animals as pollinators. Instead they are wind-pollinated. Their strategy instead is to have numerous small flowers, held aloft to waft and shimmer in the air currents, and to produce copious amounts of pollen. (Much pollen is effectively wasted by this method; a lot of the excess is a major contributor to hay fever).

Floral characters (those of the flowers) are the most constant features that enable classification of plant families in general. Grass, sedge and rush flowers share some similarities such as small size, greenish-brown colour, lack of obvious petals, and being enclosed within chaffy or membranous bracts called **glumes**. Beyond that they really start to differ from each other, although the differences may be difficult to observe in the small, densely crowded flower heads (Figure 2).

Rush flowers are the most convenient to consider first, because they more readily exhibit features we might expect from our familiarity with more typical monocot flowers. They have a radial symmetry rather than being flattened or one-sided like sedge and grass flowers. Rush flowers still have distinguishable sepals and petals - three of each, although the six members all look so similar that we use the embracing term **tepal** to describe them. Within the cup of six tepals we usually find three or six **stamens**, plus a single **ovary** having feathery **stigmas** on the top (most rush flowers are hermaphrodite, containing both stamens and ovary). The ovary ripens to a dry **capsule** containing many seeds that are released by the folding back of the capsule valve tips.

Sedge flowers have no tepals, although some members have a remnant set of bristles or scales instead. Each sedge flower is hidden within a single enclosing glume (compared with 2 in grasses) and all the glumes are similar. Stamens (usually 3) and a single ovary are again present but often in separate flowers (the unisexual condition). In *Carex*, for example, male flowers are often aggregated at one end of the flower spikes or else in narrow, wholly male spikes at the top of the inflorescence. Sedge fruits are **nutlets**, single seeds enclosed by a hard wall. In *Carex* an extra thin but hard cover (the **utricle**) encloses the fruit, and in *Uncinia* (hook sedges) it is an elongation of the enclosing utricle which produces the familiar hook that catches a ride on socks and hairy legs.

Grass flowers are peculiar. The basic unit is the **spikelet**, a collection of small bracts in two rows on a central stalk. The two lower bracts (**glumes**) are empty, but the upper ones (**lemmas**) each contain another bract (the **palea**, visible on dissection) and a small flower (termed a **floret** on account of its reduced size). Each fertilised floret produces a single fruit (the grass **grain**, or **caryopsis**). In grass flowers a bristle-like **awn** may arise from the tip or back of either glume or lemma. The individual stalk of a spikelet is the **pedicel**.

Grass **inflorescences** come in many shapes. The main arrangements are as follows. A **panicle** is a repeatedly branched inflorescence with the individual spikelets on separate stalks. An open panicle is one with widely spreading branches; it can otherwise be closed and of linear shape, or compact if the stalks are short and hidden. In a **raceme** the spikelets are stalked but arranged singly along the main stem. A **spike** is similar to a raceme but the spikelets are not stalked.

Sedge flowers are typically borne either in a single spike, or else in various arrangements of several to many spikelets.

Rush flowers occur in clusters, either scattered along a branched inflorescence or within compact globular heads.

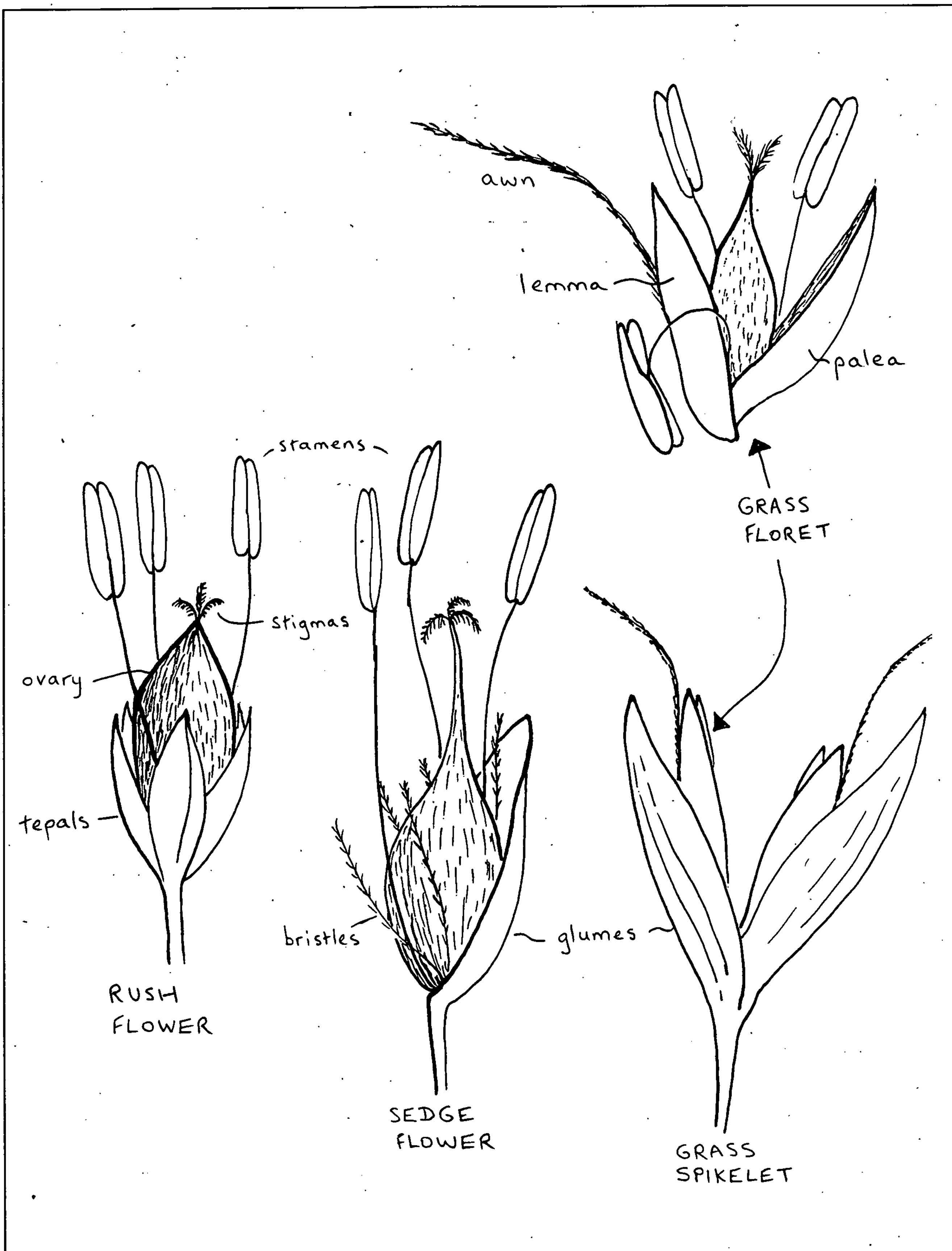

FIGURE 2. FLOWER STRUCTURE OF RUSHES, SEDGES AND GRASSSES.

Plant conservation in Wellington Conservancy

John Sawyer

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ABSTRACT

A description of essential questions addressed during the preparation of the Wellington Conservancy Plant Conservation Strategy.

INTRODUCTION

To identify, protect, manage and monitor plants of conservation concern in any Conservancy takes a lot of time and is a task that should not be underestimated. Plant conservation does not happen quickly. Many people have been involved in the Wellington Conservancy's plant conservation programme including Department of Conservation staff and others representing city councils, regional councils, local conservation agencies and private individuals. This paper reports on the questions that were addressed in formulating the Wellington Conservancy Plant Conservation strategy (Empson & Sawyer, 1995).

KEY QUESTIONS

1. Which plants in the Wellington Conservancy are threatened or of conservation concern?

A list of plants of conservation concern in the region was generated using the following criteria (criteria for selection shown in Table 1).

- Threatened species - nationally or regionally (work on regionally threatened plants was believed to be important because of our desire to conserve diversity where it is found. Just because *Gahnia rigida* is found elsewhere in New Zealand is no excuse for letting it disappear from the Wellington Conservancy).
- Susceptible species (species with particularly sensitive life history characteristics).
- Rare species (e.g. *Pseudopanax ferox*).
- Species that are not currently threatened but are believed to be in decline e.g. cabbage tree.
- Species about which we have very little information (for some of these we have found many more records and so these species are no longer of

conservation concern, for others however we still have very little information so they remain of concern).

- Species upon which the survival of other species of native wildlife depend e.g. the speargrass weevil on *Aciphylla squarrosa*.
- Local endemic species or varieties (i.e. species found only in the Wellington Conservancy) e.g. the *Brachyglottis campactus* var *monroi*.
- Species for which important populations occur in the Wellington Conservancy. For example, species whose largest population occurs in the Conservancy or whose southernmost or northernmost population occurs in the Conservancy, or species that are known to exhibit marked genetic differences between populations, or populations that are unique to certain ecological regions or districts). For example *Rhabdothamnus solandri* found in coastal lowland forest (especially streamsides) is believed to reach its southernmost occurrence in New Zealand at a site close to Wellington.
- Culturally important species e.g. flagship species or species known to have been significant medicinal plants and used by iwi e.g. pingao.

TABLE 1. CRITERIA USED TO IDENTIFY SPECIES AND PLANT POPULATIONS OF CONSERVATION CONCERN IN THE LOWER NORTH ISLAND, NEW ZEALAND.

SPECIES-LEVEL CRITERIA
- Threatened status (itself based on certain criteria - see Cameron et al. 1995)
- Susceptibility (e.g. due to sensitive life history features)
- Taxonomic distinctiveness (e.g. monotypic genera)
- Evolutionary uniqueness (e.g. species endemism)
- Potential for use as a resource species (e.g. medicinal plants)
- Genetic closeness to an economically useful or threatened taxa (e.g. analogue species)
- Cultural significance (e.g. a regional flagship species)
- Species of unknown or indeterminate status (e.g. species that may be threatened in status but about which there is insufficient information)
- Species that may be used as indicators (e.g. of ecosystem health)
- Key species (or umbrella species) to other species (i.e. essential for survival of other species)
POPULATION-LEVEL CRITERIA
- Largest or one of the largest populations of a particular taxa
- Populations at the distribution limits of a taxon
- Genetic variants at a population level
- Populations unique to certain ecological regions or districts
- Populations of species less likely to interbreed with each other
- Key populations upon which other wildlife (flora or fauna) is dependent (see also Key species criteria above)

2. Where will information about plants of conservation concern be stored as and when we collect it?

A threatened species database was developed in the Wellington Conservancy to store information about plants of conservation concern. The database was designed so that the information it contained would meet the needs of: field centre staff; of plant cultivators (horticulturalists); and the Conservancy office staff involved in business planning. For more details of the database structure see Empson & Sawyer (1995).

3. Where have populations of these plants formerly been known to occur?

We sought records of sites where target species were known to occur in the wild, or where they were formerly known to occur. We searched all the main herbaria for site specific records recording the site, date, collection and any notes about the species or site. All Wellington Botanical Society Bulletins and newsletters were checked for records of the plant species. Members of the botanical society were approached for more records of plant populations known to them

In a two year period we collected more than 270 native vascular plant lists for sites in the Wellington Conservancy (many from plant lists of Druce 1976, see also Sawyer & Laffan 1995). The species on each list were checked to see if any were of conservation concern. After collating this information it was then a relatively straight forward task to generate a map of the former distribution of species in the region (see Figure 1 for *Teucridium parvifolium*).

Evaluation of such maps helps to determine the current status of a species in an area and whether the species is well protected or not (i.e. how many of the sites occur in protected natural areas?).

4. What is the current distribution of plants of conservation concern?

You may wish to survey some of the populations at certain sites (in particular the historic sites to see if the plant is still there) and so determine the current status of the species more accurately. It is necessary to survey old sites rather than assume pre 1985 populations are all extinct. It is worthwhile visiting the sites of old records several times before you declare any local population extinct.

A survey of some of the sites where plants have been seen more recently is also valuable to provide baseline information about the status of the population against which you can detect future changes. We use a species record sheet for our surveys - most Conservancies have their own version of this recording sheet. A map can also be generated to show the distribution (and perhaps the abundance of individual plants) of a species at each site where it occurs (Figure 2).

Once all sites have been surveyed, current records can be added to past ones to generate a complete distribution map (Figure 1). The limitations of the map must also be recorded, i.e. is the mapped distribution real or are there large areas which have not been surveyed?

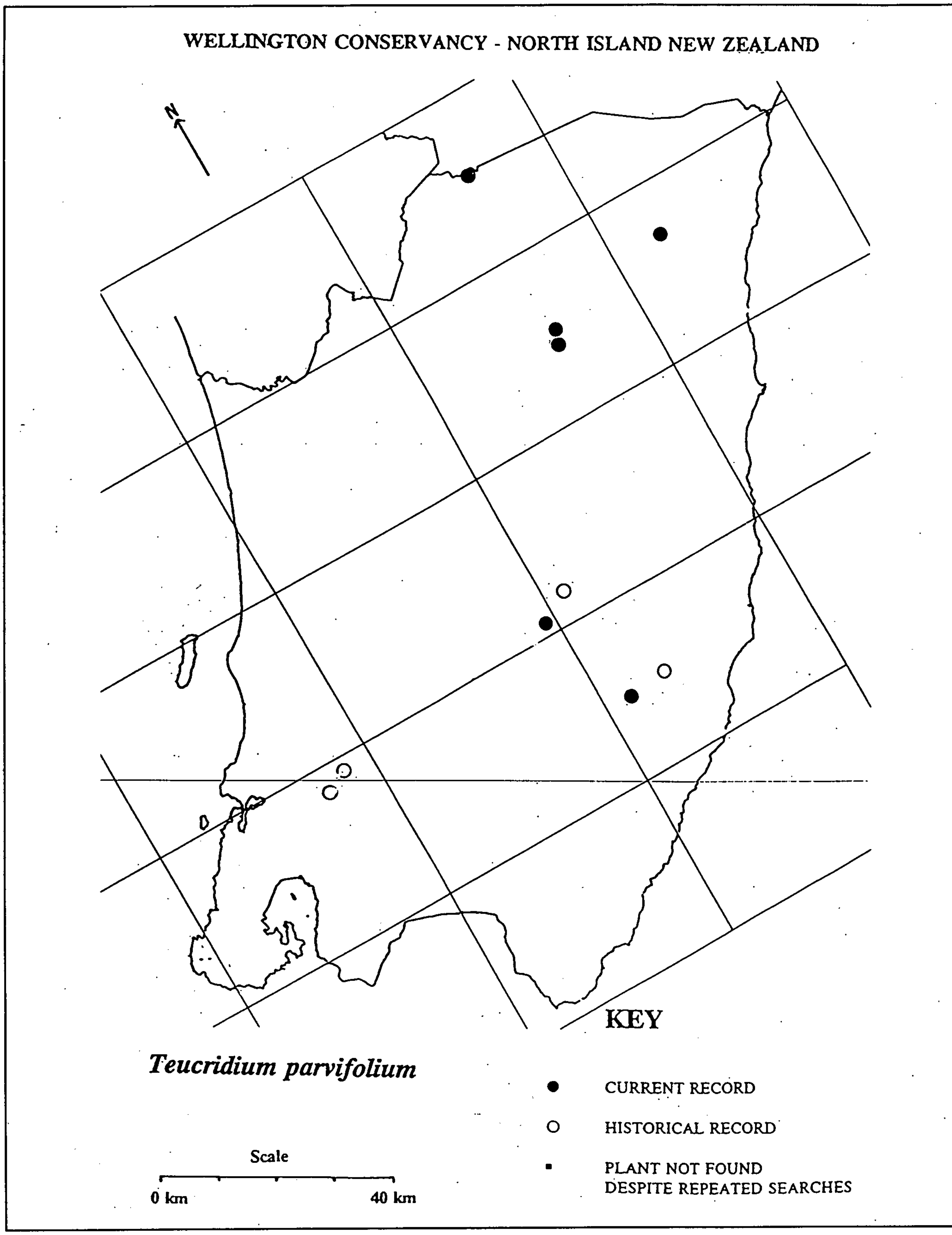

FIGURE 1. DISTRIBUTION MAP FOR *Teucridium parvifolium*.

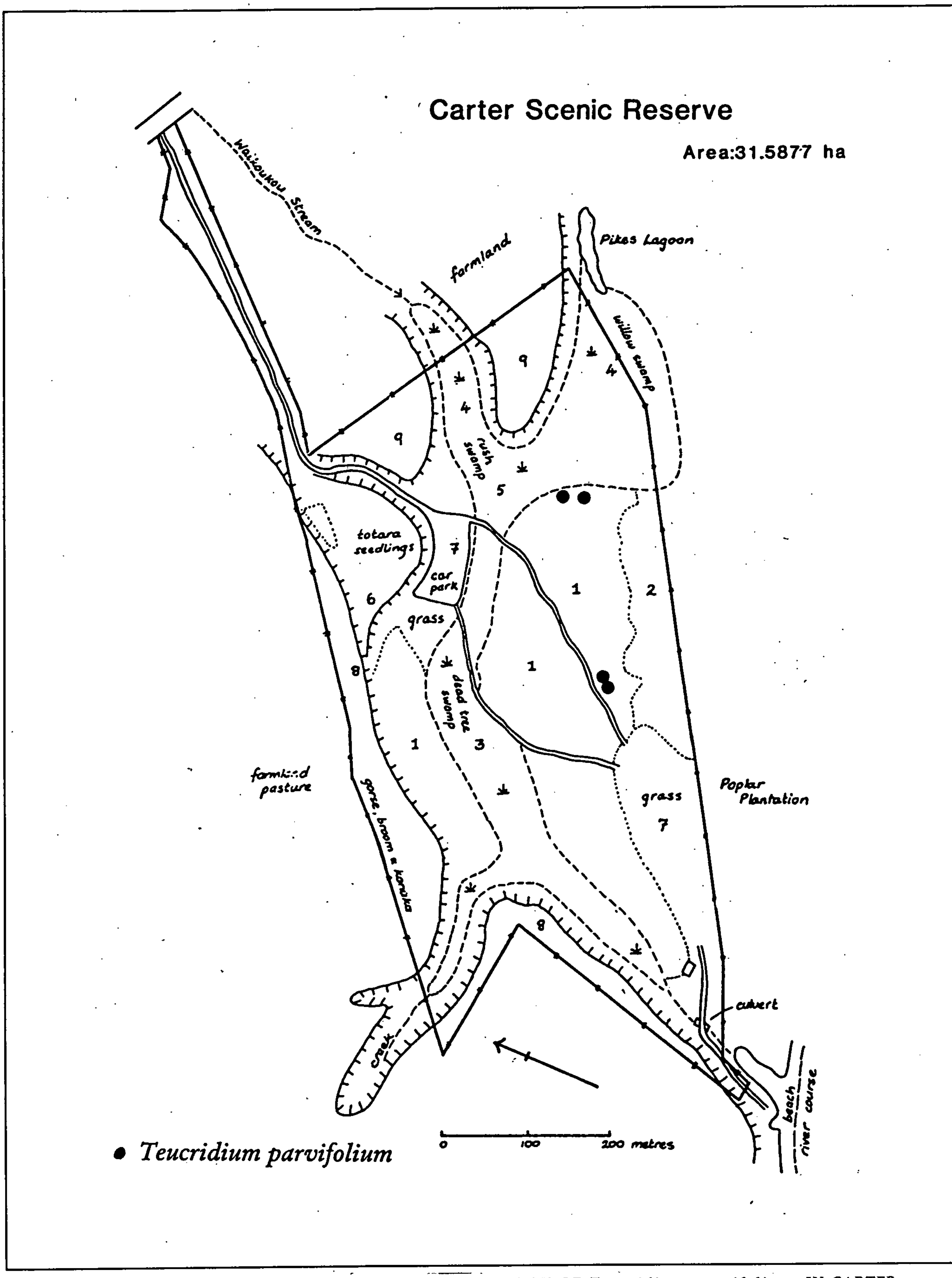

FIGURE 2. MAP SHOWING THE LOCATION OF *Teucridium parvifolium* IN CARTER SCENIC RESERVE, WAIRARAPA PLAINS ECOLOGICAL DISTRICT, WELLINGTON CONSERVANCY (MAP TAKEN FROM WASSILIEFF, *ET AL*,. 1986).

5. What management will we undertake for each of these populations?

At present we are doing little active management of threatened species, because there is little available information on their ecological requirements. Work carried out usually involves erecting fences to protect sites from cattle or sheep, or controlling invasive weeds that are competing with the plant concerned.

6. How will we know if management is effective?

Whether we are undertaking active management or not we are still keen to learn about how the plant is faring, i.e. we need to monitor. The objectives that we identified for monitoring plants in the Wellington Conservancy are:

- To detect change (usually for populations where we are not currently doing any active management).
- To determine the effect(s) of management

Some criteria that we have used are:

- Presence / absence
- Flowering and fruiting
- Number of individuals (and age structure of population)
- Number of individuals and their localised distribution
- Surface area covered by plant

Monitoring currently undertaken includes:

- *Atriplex buchananii* - abundance and mapping distribution
- *Olearia hectorii* - presence/absence of trees and fruiting times (fencing to protect trees)
- *Leptinella nana* - accurate distribution mapping to determine surface extent (using a relocatable transect)
- *Muehlenbeckia astonii* - Presence/absence and condition of plant (fencing to protect plants)
- *Lepidium oleraceum* - number count of individuals
- *Teucridium parvifolium* - permanent quadrats counting a number of plants and monitoring the fate of several individuals by tagging the plants
- *Anogramma leptophylla* - Number count of individuals along a transect

Further ideas for projects that may be useful

- Generate a list of agencies and individuals that may be able or interested in contributing time, energy or other resources to conserving plants in the region either in-situ or ex-situ i.e. form a regional plant conservation network. The network may be able to assist with work programmes e.g. recording new occurrences of plants, cultivating rare or threatened plants to generate material for species introductions, surveying old records, monitoring or checking existing plant populations.
- Create a local field guide to the plants of conservation concern in your region, to provide information about species that will be useful for field centre staff, botanists, horticulturists etc.
- Make an atlas of the distributions of plants of conservation concern in your region. This is useful for graphically illustrating how a species is distributed in the region and whether a plant occurs in protected areas.
- Create a photograph/illustration library (slides, prints and sketches). This can be a useful resource to develop over the course of time. Such photographs may also be useful as a baseline reference for future monitoring.
- Establish an ex-situ plant cultivation programme. Such plants can be used for insurance purposes or for future restoration projects.
- Cultivate plants of conservation concern outside field centres (for educational purposes) e.g. *Olearia hectorii, Muehlenbeckia astonii, Discaria toumatou, Coprosma acerosa* etc. at Masterton Field Centre.
- Prepare advocacy information to raise public awareness about the plant and inform land holders.

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Threatened plant monitoring in Wanganui Conservancy

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ABSTRACT

Key elements in the development of monitoring programs are identifying the question, and choosing the appropriate sampling technique to answer that question. Several case studies are presented here to show techniques used to answer a variety of questions encountered in monitoring threatened plant species.

INTRODUCTION

What is monitoring?

Monitoring is repeated surveys by standardised or directly comparable methods at identical or comparable places; the objectives being to detect change in condition over time that may or may not be the result of some management action.

Why might we want to monitor threatened plants?

- assess trends in individual species populations
- assess changes in community composition and structure (e.g. changes in abundance and distribution of species)
- assess impacts of introduced species (e.g. animal pests and weeds)
- assess effectiveness of management actions (e.g. after putting a fence up)

What are some of the difficulties?

- sustaining the programme
- sampling methods used are inconsistent among sites or years
- methods used do not address the questions being asked
- keeping track of data (especially with long term monitoring programmes)

What are the main points we should be concerned with?

- having clear objectives
- only monitoring where necessary
- using repeatable and simple methods
- keeping good records

- "Successful monitoring requires that the right questions are asked and that appropriate experimental designs are used."

CASE STUDIES

The following are some current threatened plant monitoring programmes being carried out in Wanganui Conservancy. They have been selected to show a range of monitoring questions, and techniques being used to answer those questions.

1. *Melicytus* "Egmont"

Facts

Survey of defined area where all *Melicytus* had been measured showed skewed size classes/ages with no seedlings and few juveniles.

Evidence of animal visitation in the form of bark biting/hedging of plants/faecal remains on tops of browsed bushes.

Questions for monitoring to answer

What animals are involved?

If we exclude animals does regeneration and health of plants improve?

Techniques used

Constructed two 5m x 5 m exclosures. These were made of galvanised wire mesh and warratah standards with wire tie-downs adding stability. One excluded goats, possums, and hares, while the other was open to possums.

Permanently tagged all *Melicytus* (numbered aluminium tag tied loosely around stem) within plots and measured height, crown spread (maximum distance from one side of crown to other side), number of stems, stem diameter, degree of browse (a subjective assessment of light, moderate, or heavy), occurrence of flowering, number and size of basal re-sprouts.

Set up control plot (unfenced) in nearby similar shrubland, and tagged and measured *Melicytus* as above.

Repeated measurements on yearly basis during spring.

2. *Dactylanthus taylorii* (bat flower)

Facts

Distribution and abundance of plants has declined.

Possums prevent flowering of *Dactylanthus* plants, preventing seed production.

Dactylanthus inflorescences (flower spikes) can be protected from possums by placing mesh cages over plants.

Questions for monitoring to answer

Does caging allow flowering to occur unhindered?

Does pollination and hence seed set occur under cages?

What is the maximum possum density allowing unprotected *Dactylanthus* to flower successfully?

Techniques used

Caged a proportion of *Dactylanthus* at each site (see 'Ecological Management' Number 3 June 1995).

Permanently tagged several uncaged *Dactylanthus* at each site (control).

Recorded flower and seed production, flower damage, possum density etc. on standardised monitoring form (available from *Dactylanthus* Recovery Group members).

Yearly re-measurement of same parameters.

3. *Ileostylus micranthus* (mistletoe)

Facts

Species is known from few sites within Conservancy.

At site where most abundant the host tree is hawthorn.

Some possum sign evident on mistletoes.

Questions for monitoring to answer

Is the mistletoe population stable, increasing or decreasing?

Are possums having an impact?

Is size of host tree related to abundance and size of mistletoes?

Techniques used

Intensive survey using Botanical Society. Survey conducted during winter when mistletoes most easily seen in deciduous hawthorn.

Tagging of all plants that could be reached and a count made of all others.

Tagging of all host trees and diameters measured.

Measurement of various parameters on recording form including size of mistletoe (maximum spread), and evidence of browse, flowering, fruiting etc.

Re-survey and re-measurement every two years.

4. Coastal herbfield containing threatened native species

Facts

Occupies narrow strip between cliff edge and farmland.

Some areas are accessible to stock, some are fenced from stock.

Pasture plants (grasses, clovers, flatweeds) found along inland edge of, and occasionally within, native herbfield.

At least one native species probably extinct at site within past 20 years.

Questions for monitoring to answer

Are the areas of herbfields stable?

Is the native species composition stable?

Are weeds and pasture grasses invading herbfields?

Is there a difference between areas where stock have access and where they don't?

Techniques used

Photographic transects established along the interface between intact herbfield and exotic pasture, three in grazed area and three in non-grazed area. Transects subjectively chosen where change expected and most easily measured.

Four plots (each 50 cm x 50 cm) established along four of the transects, two in grazed area and two in non-grazed area.

Recorded abundance of all species in plots (uncommon, occasional, common, abundant).

Diagram showing broad vegetation features of each plot sketched on graph paper, to show approximate location and extent within plot of weeds in relation to herbfield.

Re-measurement, initially at two-yearly intervals, now yearly.

5. *Ranunculus recens* (small buttercup)

Facts

Coastal hairless form known from only one small site in Conservancy.

Questions for monitoring to answer

Is population stable?

Is species composition at site changing?

Are weeds invading site?

Techniques used

Two 50 cm x 50 cm plots established (marked by corner pegs).

Counts of *Ranunculus* within plots, separated into adults and juveniles.

All other species within plots recorded.

Vertical photographs taken of plots. Cord is stretched around corner pegs to clearly delineate plot boundaries at time of photography.

Re-measurement at yearly intervals.

Seed of *Ranunculus* taken for propagation and possible re-introduction to nearby sites.

6. *Euphorbia glauca* (shore spurge)

Facts

Very localised in Conservancy.

Most sites have introduced pasture grasses and weeds.

Some occur in areas where stock have access.

Questions for monitoring to answer

Does the presence of stock affect abundance of *Euphorbia*?

Does fencing of *Euphorbia* result in overgrowth by rank grass and weeds?

Techniques used

Constructed 20m x 5m exclosure (wooden posts and 'Hurricane' netting) at key *Euphorbia* site and marked with warratah standard at each end, an adjacent 20 m long grazed 'control' site.

Measured 100 canopy intercepts taken at 20 cm intervals along a 20 m transect within the exclosure and the same within the 'control' area, to assess percentage cover of *Euphorbia*.

Established two $1m^2$ sub-plots in the exclosure (corner pegs mark plots) and two $1m^2$ sub-plots outside, and counted live and dead stems of *Euphorbia*.

Recorded a semi-quantitative vegetation description of sub-plots. Each species recorded in terms of their percentage contribution to cover within the plot.

Photographed transects (oblique) and sub-plots (vertical).

Re-measurements yearly (maybe 2 yearly here-after).

7. *Acaena rorida* (a bidibid)

Facts

Endemic to ecological district and very restricted within it.

Introduced grasses and weeds present in *Acaena* habitat.

Hieracium, now present, was absent 10 - 20 years ago.

Questions for monitoring to answer

Is population stable?

What is the impact of introduced grasses and weeds?

Techniques used

Eight permanent photo-points spanning the degrees of habitat intactness.

Each photo-point permanently marked by wooden centre peg with a numbered aluminium tag. A 50 cm x 50 cm quadrate is placed over the peg at time of photography to delineate plot boundaries.

Re-measured yearly.

Recognition and monitoring of pingao and comments on other plants of cultural importance to maori

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ABSTRACT

This paper summarises findings of a long term monitoring program on Pingao; a plant of important cultural value to Maori

INTRODUCTION

The significance of certain rare or localised plants to Maori is recognised through their inclusion (Category M) in the document that sets priorities for the conservation of New Zealand's threatened species (Molloy & Davis, 1994) (see appendix 1). However, it must be recognised that nearly all our native plants have been recorded as being used by Maori in one way or another: for food, fibre, medicine, housing, boating, arts, crafts, music and sport. Two prime sources of information on such uses are Manaaki Whenua - Landcare Research's database "Nga Tipu Whakaoronga" (contact: Sue Scheele, Manaaki Whenua - Landcare Research, Private Bag 1403, Havelock North) and Murdoch Riley's book "Maori herbal and healing". A further useful reference is Tom Paul's "Nga taonga o te ngahere" published by DoC in 1987. However, for local knowledge you should consult the kaumatua, artisans and practitioners in your area.

This paper focuses on pingao (*Desmoschoenus spiralis*, weaver's gold, Tane's eyebrows) which illustrates both Maori cultural values and the monitoring of ecosystem condition and trend. Selected other species are then dealt with briefly.

CASE STUDY: PINGAO

Pingao is a prized weaving plant for Maori because of its rich golden colour. It is much used in decorative and symbolic arts and crafts. It is a sand-dune specialist, and needs large mobile sand spaces for its existence (Figure 1).

A population of pingao at Ocean Beach, Hawke's Bay has been monitored for the past 10 years following an expression of concern from local weavers. Fixed plots, exclosures and photopoints were established, and have been monitored approximately annually.

PINGAO
(Golden sand sedge)
Desmoschoenus spiralis

THE PLANT
Running stems
Golden fibrous leaves
Sand-binding roots

HABITAT (unprotected)
Wild sandy coasts

THREATS
Coastal settlement
Weeds
Farm & feral animals
Fire
Off-road vehicles
Insensitive harvesting

TRADITIONAL USES
Fine woven containers
Decoration
Ceremonial articles
Genealogical panels

MODERN/POTENTIAL USES
Fibre arts/crafts
Ceremonial articles
Genealogical panels
Sand-dune rehabilitation
Coastal landscaping
Gardening

FIGURE 1. ECOLOGY AND USES OF PINGAO.

Summary of results to date

- pingao goes with the flow of sand; it needs fresh sand for rejuvenation and dies if undermined;
- pingao adults are at risk from cattle, horses, goats, off-road vehicles and coastal subdivision;
- pingao seedlings are browsed by rabbits sufficiently to prevent any recruitment; possums are less damaging;
- marram grass poses a major weed threat to pingao, squeezing it out rapidly;
- spinifex and pingao can coexist;
- it is quite feasible to propagate pingao for cultivation and restoration;

(Examples of a basic monitoring field sheet are shown in Figure 2)

COMMENTS ON OTHER SPECIES

Harakeke (*Phormium tenax*, lowland flax) - a multi-purpose plant, selected and cultivated and exchanged for different purposes: old plantations still exist but are disappearing fast, along with the knowledge about them. The booklet "Harakeke, the Rene Orchiston Collection" (Scheele & Walls 1994, Manaaki Whenua Press) is an introduction.

Kiekie (*Freycinetia baueriana* ssp. *banksii*) - our native screwpine, treasured for its delicious edible flowers and fruit (currently mostly eaten by possums and ship rats) and its leaves that are used for fine weaving.

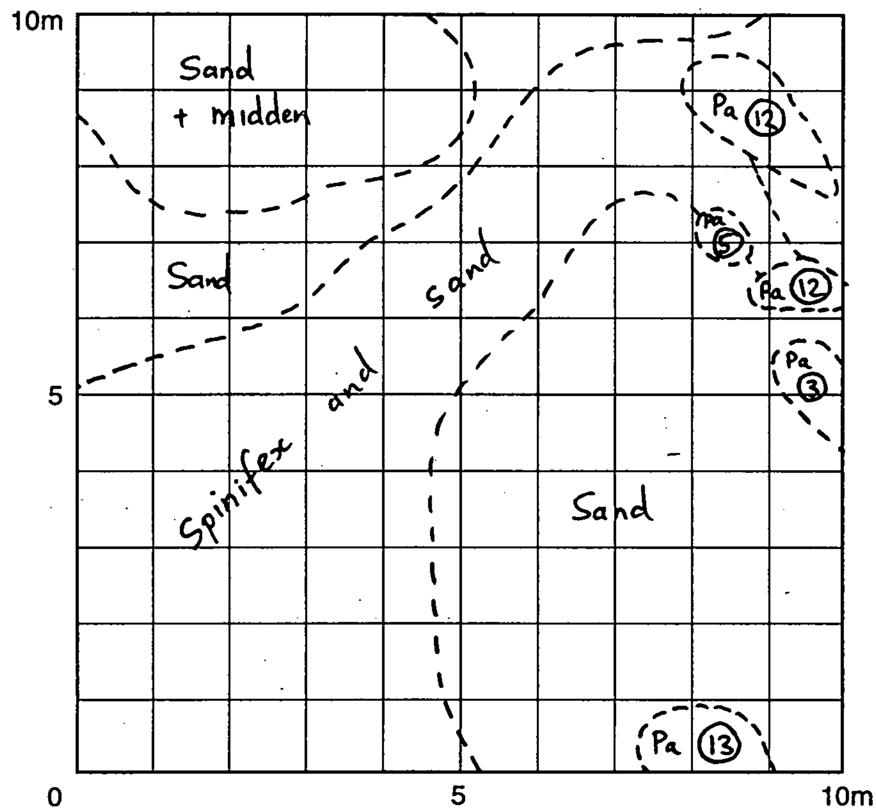
Ti (*Cordyline australis*, cabbage tree) - much used in the past for food (roots, shoots) and fibre (leaves), apparently planted around the country, now declining fast because of disease, stock and land practices such as exotic afforestation.

Karaka or kopi (*Corynocarpus laevigatus*) - once selected and cultivated for its fruits on a big scale, now declining.

Kuta (*Eleocharis sphacelata*) - once widespread in wetlands, used for fine mat weaving, now declining fast because of wetland degradation.

Taro (*Colocasia esculenta*) - brought from the Pacific hundreds of years ago and carefully cultivated in the north as a staple food, the only such plant to still remain in the wild (Northland, eastern Bay of Plenty, Kermadec Islands). Indicative of former settlements and gardens, now at risk in places from pigs, weeds and coastal subdivision.

Square No: Date:



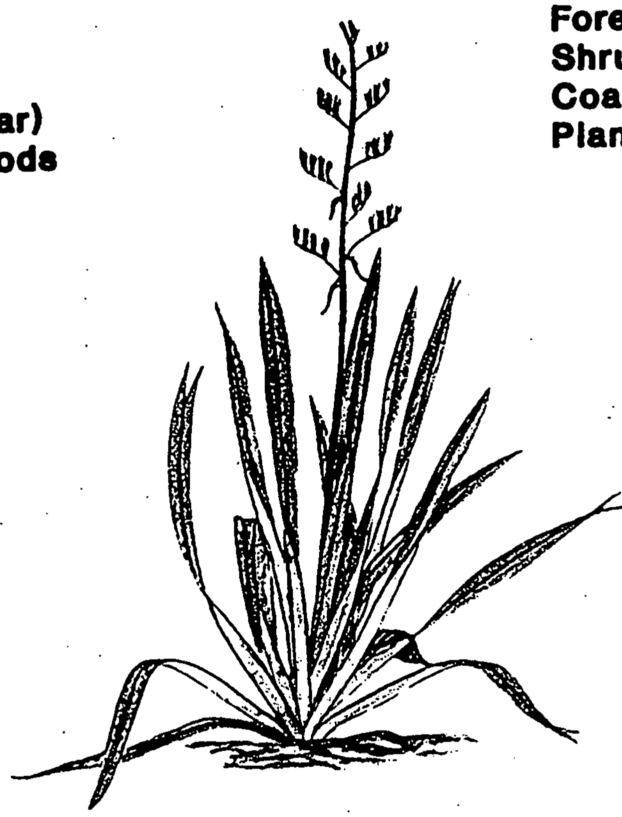
	% cover	No's	height	comments
(P)ingao – adult, healthy	3	45	25–50cm	
– " , dying	<1	5		
– " , dead	–	–		
– seedlings (established)	–	–		
– " (new)	–	–		
(S)pinifex	c.15			
(m)arram	–			
(C)arex pumila	–			
other veg.	✓	A few lotus like small plants and 1 evening primrose		
substrate	sand 80–85			

FIGURE 2. EXAMPLE OF A BASIC MONITORING FIELD SHEET.

HARAKEKE
(New Zealand flax)
Phormium tenax

HABITATS (semi-protected)
Swamps
Forest edges
Shrublands
Coasts
Plantings(cultivars)

THE PLANT
Leaves(fibre)
Flowers(nectar)
Seeds and pods
Roots
Stems
Gum



THREATS
Fire
Land clearance
Attrition

TRADITIONAL USES
Cordage
Clothing
Containers
Mats
Ceremonial items
Fuel
Flotation
Food
Medicines
Dyes

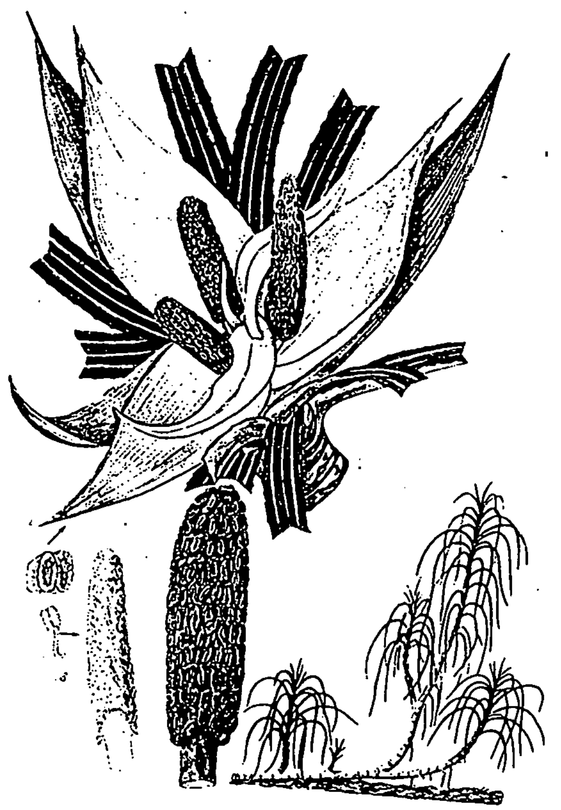
MODERN/POTENTIAL USES
Fibre arts/crafts
Cordage
Fabrics
Paper
Insulation
Medicines/pharmaceuticals
Fuel
Fodder
Landscaping/gardening
Land rehabilitation
Crash barriers

FIGURE 3. ECOLOGY AND USE OF HARAKEKE.

KIEKIE
Freycinetia baueriana ssp. *banksii*

THE PLANT
Fibrous leaves
Fleshy flower bracts
Fruits

HABITAT (semi-protected)
Lowland broadleaved forests



THREATS
Forest clearance
Feral animals
Insensitive harvesting

TRADITIONAL USES
Food (luxury)
Mats, garments
Containers
Decorative/ceremonial articles

MODERN/POTENTIAL USES
Fibre arts/crafts
Landscaping
Food (novelty)
Paper

FIGURE 4. ECOLOGY AND USES OF KIEKIE.

Appendix 1
(after Molloy and Davis, 1994, Category M, Page 57).

NAME	TAXONOMIC NAME	COMMENTS
aruhe, bracken	*Pterideuem esculentum* (named cultivars)	Found in all conservancies
aute	*Broussonetia Papyrifera*	Probably extinct in the wild. In cultivation
harakeke, lowland flax	*Phormium tenax* (many named cultivars)	Found in all conservancies
hue, bottlegourd	*Lagenaria siceraria*	Only in cultivation
karaka	*Corynocarpus laevigatus* (local cultivars)	Found in all conservancies except OT and SL
kiekie*	*Freycinetia baueriana* subsp *banksii*	Found in all conservancies except CA and OT
kumura	*Ipomoea batatas*	May be extinct in the wild. In cultivation
kutakuta	*Eleocharis sphacelata*	Found in all conservancies
para, king fern	*Marattia salicina*	Found in NL, AU, WK, WG, BP, EC
piharau, lamprey	*Geotria anustralis*	Found in all conservancies except TT
pingao	*Desmochoenus spiralis*	Found in all conservancies except TT
	Sporadanthus traversii	Found in WK, CA
taro	*Colocasia esculenta* (named cultivars)	Found in NL, EC
tawapou*	*Planchonella costata*	Found in NL, AU, WK, BP, EC
ti pore	*Cordyline fruticosa*	Found in NL
ti tawhiti	*Cordyline* ''kirkii', *C.* 'Thomas Kirk'	May be extinct in the wild. In cultivation
totara*	*Podocarpus totara*	Found in all conservancies
tuna, long-finned eel	*Anguilla dieffenbachii*	Found in all conservancies except TT
uwhi, yam	*Dioscorea alata*	Probably extinct in the wild. In cultivation
wharariki, coastal flax	*Phormium cookianaum* (several named cultivars)	Found in all conservancies

Monitoring of mistletoe in the Eglinton Valley, Fiordland

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ABSTRACT

A mistletoe monitoring program was established to assess the effectiveness of a possum control operation in the Eglinton Valley. Size and condition of 3 species of mistletoe were monitored at 3 treatment sites (inside control area) and 1 control site (outside control area) within the Valley. A higher proportion of mistletoe plants at the control site were damaged than at the treatment sites.

INTRODUCTION

The Eglinton Valley is one of the most significant South Island habitats for forest birds, containing a rich diversity and high populations of many species including the threatened yellowhead (*Mohoua ochrocephala*), kaka (*Nestor meridionalis meridionalis*), and kakariki or yellow-crowned parakeet (*Cyanoramphus auriceps auriceps*). In addition the Valley contains long-tailed bats (*Chalinolobus tuberculata*) and at least three species of threatened mistletoe (*Peraxilla tetrapetala, Peraxilla colensoi* and *Alepis flavida*) as well as intact forest communities.

Possums (*Trichosurus vulpecula*) are known to have direct impacts on individual plant species and entire plant communities. Possums may also impact indirectly on other components of the forest ecosystem, such as bird populations. To protect the significant features of Eglinton Valley from possum impact, a control operation was instigated covering approximately 6400 hectares (Eglinton Valley Possum Control Operation Plan 1994/1995 - see appendix 1). The objectives of the operation included reducing the possum population by 80% and maintaining control below 20% of the original population. Initial control was achieved by traditional possum trapping techniques and maintenance control will be achieved by using bait stations.

The main purpose of monitoring possum damage on vegetation in the Eglinton Valley is to judge the success of the possum control operation in improving vegetation condition.

VEGETATION MONITORING

Mistletoes are known to be highly palatable to possums and are scattered throughout the Eglinton Valley with a number of known locations of concentrated populations. This clumped distribution is quite typical for mistletoes in both Australia and New Zealand. Our vegetation monitoring concentrated on the three beach mistletoes; all three are ranked as nationally vulnerable, Category B (Molloy and Davis, 1994).

To date there has been no formal monitoring of threatened mistletoes in Southland, but there has been concern over their decline in the Eglinton Valley, presumably as a result of possum browse (G. Elliott, pers. comm.).

Objectives of mistletoe monitoring

The objectives were to; 1) record any recovery in the condition and growth of mistletoes which could be attributable to the removal of possums; 2) improve knowledge of mistletoe distribution and density in the Eglinton Valley; and 3) improve knowledge of mistletoe growth, flowering and fruiting characteristics and other aspects of mistletoe ecology.

Assumptions made were:

The majority of visible mistletoe damage is attributable to possum browse (it is noted that insect damage can look similar to possum browse, but the difference can be detected by an experienced observer).

The distribution of mistletoe species was variable and patchy within the Eglinton valley. The "control" area for the monitoring contains the mistletoe species *Alepis flavida* only, while the other three areas in which possums are being controlled contain *Peraxilla tetrapetala* and *Peraxilla colensoi* only. Powell and Norton (1994) suggested that *Alepis flavida* may be less vulnerable to browsing than *Peraxilla tetrapetala*, as *A. flavida* plants are located on the outer branches and form loose clumps with long branches. This may restrict the extent of possum browse on foliage of this species. As there is little available data on differences in susceptibility to possum browse of *A. flavida, P. tetrapetala,* and *P. colensoi*, this study. assumed all three mistletoe species were equally susceptible to possum browsing.

Methodology

Nationally, mistletoe monitoring has been initiated only recently and during the establishment of this project no standard methods were found.

As this monitoring is part of a larger possum control programme the methods were required to be relatively simple and easy to repeat. It will be possible to adapt and improve the monitoring method as better information becomes available.

Two methods of monitoring were established:

- size measurement and condition ranking assessment
- photographic monitoring.

Sites chosen were the known major locations of concentrated numbers of mistletoe plants (see appendix 2). At each site the most accessible and visible mistletoes were chosen to monitor and photograph. To relate those mistletoes to the total population a record of all mistletoes was also made.

For each mistletoe monitored at the four sites the host tree was permanently tagged (plus dazzle paint at three sites) and a location plan drawn. The following details were recorded: host tree species, mistletoe species, individual (discrete) mistletoe number. In order to locate mistletoes on the tree: height from ground, size (two dimensions), distance from trunk to mistletoes, aspect on tree, and distances and aspects to photopoints were measured and recorded. In addition a sketch was drawn of the position on the tree. A visibility ranking was established to give additional information on the accuracy of measurements and assessments (see appendix 3 - mistletoe monitoring field sheet).

Condition Ranking Assessment

All study mistletoes were assessed using this method. The criteria for ranking were as follows:

Condition ranking = % of mistletoe defoliated

0% (undamaged)

1-10% (light damage, some browsing detectable)

10-25% (moderate damage, browsing easily detectable)

25-50% (heavy damage)

50-75% (very heavy damage)

75-99% (severe damage)

100% (appears dead, i.e., branches but no leaves)

Mistletoe disappeared

A size measurement was also recorded, to be re-measured along with assessment (see appendix 2 for summary sheet).

Photographic Monitoring

For certain mistletoes, usually with a visual assessment of 1 or 2 (easily viewed and photographed), photopoints were established. Photopoints were not permanently marked but will be relocated using aspect and distance measurements. Photographs and slides were taken with a 50 mm lens, and time of day recorded and a marker scale used. Photographs using flash were found to be particularly effective.

Study sites

Four sites (Knobs Flat, Deer Flat, Dore Pass track and Totara Flat) were chosen. One site (Totara Flat) was located outside the possum control area and provides the "control" for the monitoring project. The three remaining sites were within the possum control operation area and contain *Peraxilla tetrapetala* and *Peraxilla colensoi* on silver beech (*Nothofagus menziesii*). . The "control" area contains *Alepis flavida* on mountain beech (*Nothofagus solandri var. cliffortioides*). Although there are concerns that the control site contains a different species of mistletoe, it is the only sizeable population of mistletoes in the Eglinton Valley, outside the possum control area.

From south to north the sites are as follows:

1. Totara Flat

Two areas have been identified at Totara Flat. The "island" is an isolated mountain beech stand (mainly forest edge) surrounded by grazed grassland situated between the Eglinton River and the Milford Road (SH92).

Totara Flat site 2 is forest edge dominated by mountain beech with scattered red beech (*Nothofagus fusca*) on the east side of Milford Road.

The mistletoes at Totara Flat are all *Alepis flavida* found on mountain beech.

After mistletoe growth has stabilised it may be possible to study *Alepis* specifically as the Totara Flat area contains two different sites, the forest edge and the "island". Possum control could be carried out on the forest edge while leaving the "island" or vice versa.

2. Deer Flat

This is an isolated stand of forest on a morainic knob adjacent to the Eglinton River. The forest is dominated by silver beech with some red and occasional mountain beech. The mistletoes monitored were *Peraxilla tetrapetala* and *Peraxilla colensoi* found on silver beech.

3. Knobs Flat (including NZDA Hut site)

This site is in two areas, the first in the vicinity of the NZDA hut in an open (discontinuous canopy) forest of silver beech. The second Knobs Flat site is forest edge adjacent to the Milford Road slightly south of the entrance to the NZDA hut site. The forest is dominated by silver beech with some red and occasional mountain beech. The mistletoes *Peraxilla tetrapetala* and *Peraxilla colensoi* are found on silver beech (*Nothofagus menziesii*).

4. Dore Pass track

This site comprises scattered silver beech trees on the banks of the Eglinton River immediately downstream of the original walkwire location. The mistletoes *Peraxilla tetrapetala* and *Peraxilla colensoi* grow on silver beech. The number of trees sampled and mistletoes monitored at each site are shown in Table 1.

TABLE 1. NUMBERS OF TREES AND MISTLETOES SAMPLED IN THE EGLINTON VALLEY.

	TREES TAGGED	MISTLETOES MONITORED	MISTLETOES PHOTOGRAPHED
Totara Flat	15	32	25
Deer Flat	18	34	24
Dore Pass track	7	13	10
Knobs Flat	17	25	20
Totals	57	104	79

Timing of re-measurement

Tree tagging, mistletoe identification and initial set up of monitoring were undertaken between December 1994 and March 1995 (mistletoes are easier to locate when flowering in December/January).

Optimal times for measuring growth/condition are in late winter (i.e., August-September) before the first flush of growth to show the winter minimum and, in mid summer (January-February) to show the summer growth maximum.

It is estimated that one day per site (perhaps less) would be required for re-survey (i.e., four days) and an additional two days for computer records and information analysis for each re-survey.

SUMMARY OF MONITORING DATA AT JUNE 1995

A much higher proportion of *Alepis flavida* plants were very heavily damaged (condition 5) at the control site (i.e., outside the possum control area). In contrast, *Peraxilla* species had a higher proportion of lightly damaged plants (condition 2).

Among the *Peraxilla* sites (all within the possum control area), patterns in plant condition varied considerably. At Deer Flat, plants were found in a wide range of condition categories, from undamaged to severely damaged (the heavily damaged plants being mainly *Peraxilla tetrapetala*). At Knobs Flat, a higher proportion of mistletoe plants were either lightly or moderately damaged, and at Dore Pass, mistletoe conditions varied from light to severe damage. There does not appear to be any correlation between size of mistletoe plants and extent of damage.

The use of photography to monitor change in mistletoe condition appears limited. The quality of many of the photographs taken (due to light conditions) was such that many may not be useful. Further development of photographic procedures for monitoring is required, particular the usefulness of flash photography.

Casual observation in March 1995 of mistletoes monitored in December 1994 identified the loss of one tree tag (deliberately removed), and some mistletoes completely defoliated which had leaves in December. Gretchen Rasch noted lots of broken mistletoe limbs in May. In June 1995, another mistletoe was found to be completely defoliated.

Note: It is important to determine if damage is caused by insects or possums and caging plants is one way to achieve this. However, in the long-term caging may affect pollination and markedly reduce the seed set.

The mistletoe monitoring team consisted of Gretchen Rasch, Brian Rance, Sue Bennett, John Whitehead, Chris Rance and Carol West.

ACKNOWLEDGMENTS

Thanks to Carol West, David Norton and David Kelly for their comments on the draft report.

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Location Map

Appendix 1

N

Possum Control Operation

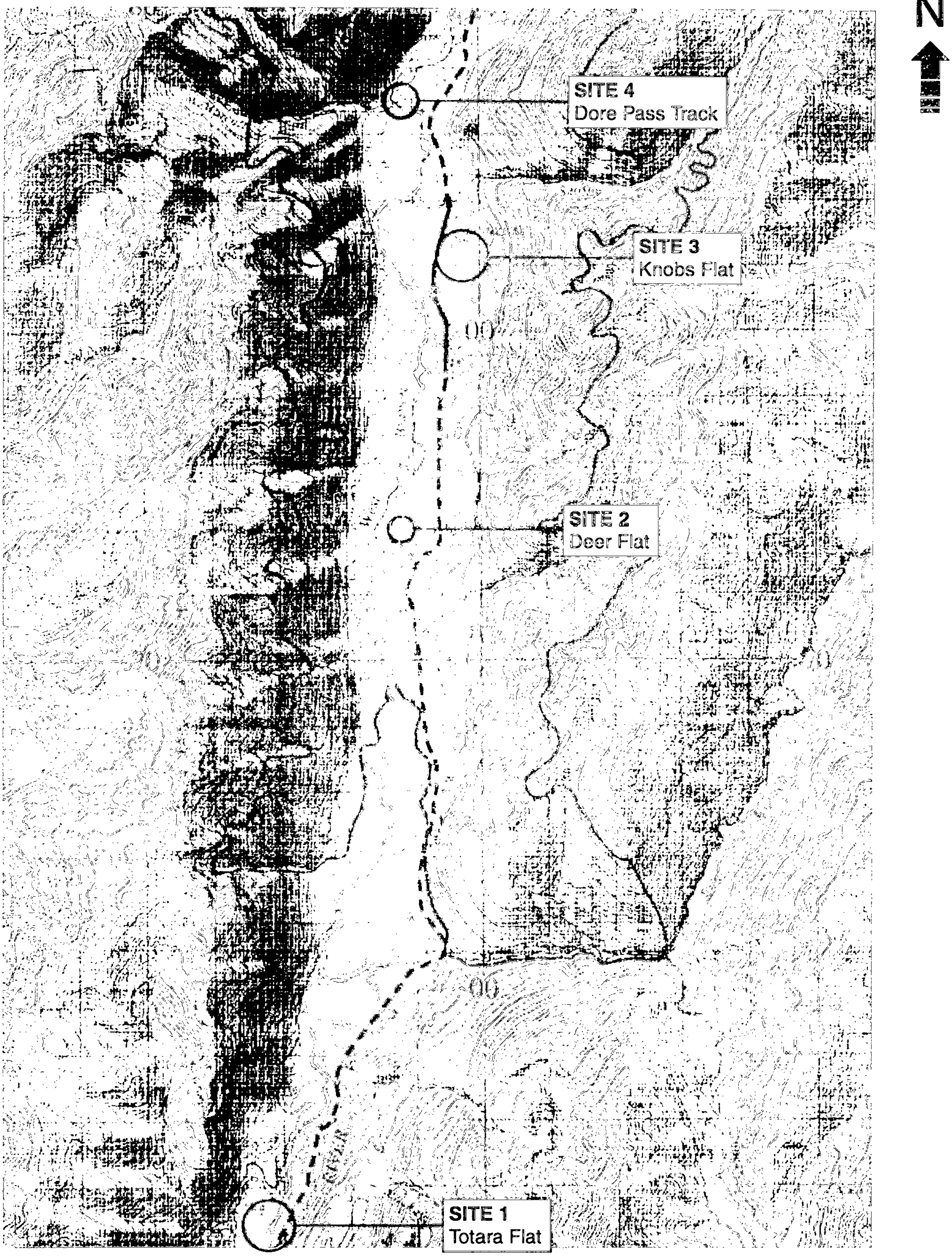
File: ANI 031

Scale: 1 : 300 000

Date: June 1995

Department of Conservation
Te Papa Atawhai

Appendix 2



Mistletoe Monitoring Sites

File: ANI 031

Scale: 1 : 54 000

Date: June 1995

Department of Conservation
Te Papa Atawhai

APPENDIX 3

MISTLETOE MONITORING FIELD SHEET	
DATE OF MONITORING	
SITE NAME	
HOST TREE TAG NUMBER	
HOST TREE SPECIES	
MISTLETOE SPECIES	
MISTLETOE NUMBER	
DISTANCE FROM PHOTOPOINT TO BASE OF TREE TRUNK (metres)	
DISTANCE OF MISTLETOE FROM TREE TRUNK (Location on tree)	
DISTANCE FROM PHOTOPOINT TO MISTLETOE (metres)	
HEIGHT OF MISTLETOE ABOVE THE GROUND (metres)	
VISIBILITY RANKING	
SIZE OF MISTLETOE (cm - height x width x depth)	
CONDITION RANKING	
ASPECT (magnetic)	
DESCRIPTION OF PHOTOPOINT (compass reading from tree tag to photopoint, for sketch of location see over page)	
ADDITIONAL NOTES	

Condition ranking (% defoliated)	Visibility ranking
1 = 0% (undamaged)	1 = Low on tree, easily viewed and photographed (ie less than 5m distance)
2 = 1-10% (light damage, some browsing detectable)	2 = Elevated, easily viewed and photographed (ie 5-10m distance)
3 = 10-25% (moderate damage, browsing easily detectable)	3 = Elevated, easily viewed but difficult to photograph (ie further away than 10m)
4 = 25-50% (heavy damage)	4 = Elevated, difficult to view and photograph
5 = 50-75% (very heavy damage)	
6 = 75-99% (severe damage)	
7 = 100% (appears dead)	
8 = mistletoe disappeared	

The use of threatened plants as indicators of ecosystem health and condition

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ABSTRACT

The use of threatened plants as indicator species in 5 separate studies is summarised.

INTRODUCTION

Threatened plants do not function by themselves. They are part of a system that nurtures them, and they contribute something particular to that system. Working out that relationship provides the key to using them as indicators of what is happening in the ecosystem.

CASE STUDIES

Mistletoes

Mistletoes, especially the colourful-flowered ones, provide perhaps the clearest example of a relationship that can be exploited in this way. It has just been discovered that the flowers of *Peraxilla tetrapetala*, *P. colensoi* and *Alepis flavida* need to be physically opened for pollination. They depend on tui and bellbirds to do this, and on these and other birds to disperse their fruit, offering nectar and fruit nutrients as rewards. So if you monitor flowering and fruit set of mistletoes you obtain information on tui and bellbirds. If you monitor condition and population structure of mistletoes, you know whether the bird/plant interactions in your forest are healthy or not, improving or deteriorating.

Mistletoes are highly vulnerable to browsing - by possums and deer especially - so they make very sensitive browse indicators.

Examples of survey and monitoring forms used for mistletoes in Hawke's Bay Conservancy are shown (Appendix 1). We now have a series of populations under surveillance subject to different management regimes.

Boundary Stream Mainland Island

The Boundary Stream Scenic Reserve is being developed as a mainland biodiversity sanctuary in Hawke's Bay. It has two threatened plants that we know of:

- yellow mistletoe (*Alepis flavida*)
- kakabeak (*Clianthus puniceus*)

The mistletoe is being monitored as a forest ecosystem indicator (linked to possum browse, host tree health, presence of tui and bellbird as pollinators). Kakabeak is an indicator of ungulate browsers - it used to be abundant, but is now confined to cliff sites inaccessible to goats, deer, sheep and cattle.

We have developed a fairly comprehensive survey, monitoring and research strategy for Boundary Stream, to focus on these and many other elements that indicate condition and trends of the ecosystem. A detailed description of plant survey and monitoring procedures are given in Appendix 2.

NW Ruahine Forest Park

In order to monitor the effects on the forest ecosystem in the Ruahine Corner-Lake Colenso area of possum control operations, we have set up monitoring systems for:

- red mistletoe (*Peraxilla tetrapetala*)
- *Pittosporum turneri*
- haumakaroa (*Pseudopanax simplex*)

All are highly vulnerable to possum and deer browse. We are primarily using annual photography and on-the-spot condition assessment to monitor changes in these species. The haumakaroa, is locally threatened, although not nationally. With prolonged browsing by deer and possums it is likely to disappear from these forests within a few decades. Haumakaroa is sufficiently abundant (as the mistletoe would have been 50 years ago), to provide a comprehensive and sensitive population for monitoring.

Chatham Islands

With the exception of Kopi, forest canopy tree species in the Chatham Islands are endemic and, many of which are considered threatened. In 1980, forest ecosystems throughout the Chathams appeared to be threatened and declining fast. The vegetation was mapped, and monitoring plots and photopoints established to find out what was happening. By re-surveying at intervals of several years, we have confirmed the rapid rates of decline and change in composition of forests as a consequence of browsing by domestic stock and feral animals. Additionally, these surveys have documented the equally rapid recovery of vegetation when such threats are removed (e.g. by fencing).

The standard New Zealand Forest Service grassland vegetation plot monitoring system is ideal for this type of monitoring. It is not difficult or over-demanding of resources, and yields data that can be readily analysed.

Lowland Reserves

We have a series of vegetation plots and photopoints in the lowland reserves of Hawke's Bay. Photopoints are a good basic way of assessing ecosystem trend and condition providing they are well chosen. They can be used for a variety of circumstances, including monitoring the habitat of threatened species. An example of a photopoint established by Napier Field Centre is shown in Appendix 3.

ACKNOWLEDGMENTS

I would particularly like to acknowledge ideas and perspectives picked up from Geoff Park, Geoff Kelly, Ian Atkinson and Bob Brockie in designing the forms.

APPENDIX 1

THREATENED PLANT RECORD FORM

Species:	Plant no:
Location: Grid ref:	Date: Recorder:
Site description/aids to relocation (attach sketch map, notes, etc.):	
Topography: Habitat: No. of plants: Age of plant(s): Size of plant(s) (height, width, depth): Condition: Host: Position on host: Host condition: Fruiting/flowering: Threats: Management needs: Monitoring set up? Photo taken? Specimen gathered? Plant(s) tagged? Protection work done?	
Comments:	

MISTLETOE MONITORING FORM

Location:	Date:
Grid ref:	Recorder:
Site description/transect details/monitoring setup:	

Mistletoe no.	Species	Host	Dimensions (WxHxD)	Condition	Browse (amount #, browser)	Phenology	Comments

Population status and management needs:

PLANT CONDITION ASSESSMENT FORM

Location:

Date:

Observer

Plant No.	Species	Condition[1]	Cause of damage	Phenology[2]	Comments

[1] Condition/extent of browsing	[2] Phenology
<1% browsed	Fl = flowering Fr = fruiting
1-30% browsed	Sh = shoots (buds, new leaves)
30-70% browsed	none
70-100% browsed	a little
100% defoliated; dead	moderate
	much

APPENDIX 2

BOUNDARY STREAM - MONITORING STRATEGY

[1 September 1996]

There are three basic categories of things to monitor:

1. Ecological indicators: things that tell us the condition, trend and response to conservation management of the forest (animals, plants, vegetation, water and climate);

2. Threats: things that threaten the forest, its processes and its biota (mainly exotic animals - feral animals and domestic stock);

3. People things: how people relate to the forest, its biota and the way it is managed (education, perception, interaction, involvement etc.).

Comparative sites

Obviously Boundary Stream Scenic Reserve is the focus for this monitoring. However, because the mainland island concept is special, it needs to be related to more "ordinary" kinds of areas and management. The nearest equivalent sites are Bellbird Bush (<1 km SW), Thomas's Bush (1.5 km S), Te Heru-o-Tureia Conservation Area (4 km NE, in East Coast Conservancy) and Cashes Bush (5 km WSW). Bellbird Bush and Thomas's Bush are close enough that much of the management effort in Boundary Stream will also impact on them. They could serve to show vegetation and invertebrate comparisons. For other aspects, other sites will be needed for comparison: Te Heru-o-Tureia Conservation Area is probably the best equivalent site, but it may be that Cashes Bush, Haliburton's (across the Mohaka River to the north), Ball's Clearing, Tangoio Scenic Reserve or Mohi Bush best serve that purpose.

More detail is laid out in the following tables. All the listed tasks are seen as essential "core" functions, primarily the responsibility of DoC. There is though plenty of scope for monitoring roles to be assumed by others, and for other monitoring activities to be added. Suggested setup times fall into three categories, depending on how pivotal the monitoring tasks are in relation to impending management actions and seasonal changes:

ASAP - important to set up and start as soon as possible, prior to possum/rodent knockdown;

Early 1996 - set up and start prior to mid 1996, prior to spring;

1996 - set up and start during 1996 (exact timing not critical)

1. ECOLOGICAL INDICATORS

VEGETATION		
Component [Key person/people]	Setup time; Monitoring frequency	Techniques [Resources]
Vegetation structure [Geoff Walls]	Early 96; 3-yearly	At least 5 (up to 10) 20 m x 20 m plots in different veg. types and situations; photopoints [2 people, 5 days/year]
Canopy condition [Geoff Walls/Alan Lee]	Early 96; 3-yearly	Airborne video; c.10 photopoints [1 person, 2 days/3 years]
Forest floor regeneration [Geoff Walls/Alan Lee]	Early 96; 2-yearly	c.20 1 m x 1 m seedling plots; c.20 photopoints [2 people, 2 days/2 years]
Phenology (especially important food plants*) [Geoff Walls]	Early 96; Monthly, seasonally	Observations of c.200 tagged plants (tie in with browse indicator plants); trays under 20 selected trees (tie in with litterfall/seedfall) [2 people, 1 day/month]
Litterfall/seedfall [Geoff Walls/Alan Lee]	Early 96; 3-monthly	Trays under 20 selected canopies (tie in with phenology) [1 person, 1 day/3 months]
Litter depth/quality [Geoff Walls]	Early 96; Annually	Measured and assessed at marked spots when monitoring veg. structure and seedling plots

*maire, hinau, horopito, tawa, kowhai, rewarewa, wineberry, fuchsia, podocarps, beeches, kamahi, kanuka, supplejack, etc.

PLANTS		
Component [Key person/people]	Setup time; Monitoring frequency	Techniques [Resources]
Threatened plants: - Yellow mistletoe - Kakabeak [Geoff Walls/Alan Lee]	Early 96; 3-monthly	Inspection [1 person, 1 day/3 months]
Browse indicator plants: - Yellow mistletoe - Lancewood - Fivefinger - Pate - Broadleaf - Raukawa - Supplejack - Broadleaf (epicormics) - Etc. [Geoff Walls/Alan Lee]	Early 96; Annually	Inspection and photos of c.100 tagged plants; [1 person, 1 day/year]
Other indicator plants: - Mountain holly - Toii - Neinei [Geoff Walls/Alan Lee]	1996; Annually	Inspection of c.20 tagged plants [1 person, 1 day/year]

BOUNDARY STREAM

SURVEY NEEDS AND OPPORTUNITIES

[1 September 1995]

Urgent: to be done as soon as possible (by end of 1995)

Vegetation patterns/types (map)	[Geoff Walls]
Kakabeak - presence	[John Adams/Alan Lee/Geoff Walls]
Kiwi - numbers, distribution	[John Adams/Ken Hunt]
Robin - numbers (approx.), distribution	[John Adams]
Bats - species present, roosts, main flight paths	[John Adams]
Adjacent landowner attitudes (consultation)	[Ken Hunt]
Local community attitudes (consultation)	[Ken Hunt/Claire McCormick]
Tangata whenua attitudes (consultation)	[Toro Waaka]
"Control" sites - suitability of nearby sites for comparison monitoring	[Ken Hunt/Keith Briden/Geoff Walls/John Adams/Terry Pellett]

Important: to be done within one year (by mid 1996)

Yellow mistletoe - status, distribution	[Geoff Walls]
Lizards - species present, habitats	[John Adams]
Freshwater fish - species present, habitats	[John Adams/Hans Rook]
Freshwater invertebrates - main indicator species, habitats	[John Adams]
Terrestrial invertebrates - main conspicuous indicator species, habitats	[Geoff Walls/John Adams]
Visitor numbers and perceptions	[Claire McCormick/Pat Sheridan/Team Leader]
Maori history	[Toro Waaka]
Pakeha history	[Pat Sheridan]

Necessary, but not so urgent

Other threatened plants - presence, distribution	[Geoff Walls]
Bird fauna - suite of species resident or transient	[John Adams/Geoff Walls]
Weeds - species present, distribution, degree of threat	[Keith Briden/Alan Lee]
Land snails - presence of *Powelliphanta* or *Wainuia*	[Alan Lee/Claire McCormick]

Other opportunities for survey

Flora (plant list) - additions to current list, noteworthy occurrences, relative abundances	[Geoff Walls]
Invertebrate fauna - suite of species present, habitats	[Geoff Walls/John Adams]
Visitor opportunities	[Pat Sheridan]
Advocacy effectiveness and opportunities	[Claire McCormick]

APPENDIX 3

PHOTO POINT RECORD SHEET

Location Boundary Stream – Rob's Hole	**Plot No** '1'	**Date Established** 27/11/96

Camera Ht 1.5m	**Focal Length** 50mm	**Format v/h** v + h	**Film** Kodak 200 asa
Shutter Speed 1/60	**Light**	**Apt**	**Am/Pm** midday

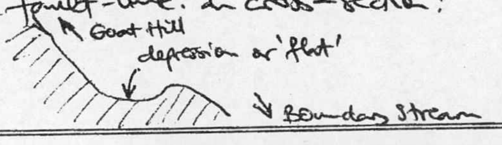
~~**Aspect**~~ Direction Due compass west (270°)	**Topography** Hillslope with small flat*	**Slope** 10°	**Alt**

Aspect = North

Canopy Scattered large kanuka, occ. cabbage tree + rewarewa, occ. smaller lemonwood + mahoe trees.	**Understory** Mod. sized Cyathea smithii, v. dense ground cover of Blechnum fluviatile & bush rice grass.

Comments Young kanuka establishing in gaps. Has been heavily browsed by goats, sheep, deer + possums til recently. Lots of browsed small bushes of putaputaweta ready to revive.

Location Map Directly below Goat Hill, on bait station line. (S. of Boundary Stm, N of Goat Hill)	**Notes** c. Midway between 2 kanuka plots (plot 13a & plot 13b)
* small straight-line depression that looks either like a slump feature or a fault-line. In cross-section:	Chosen because it is in a place where large kanuka are collapsing (old age, wind), + tree ferns + broadleaved trees are poised to regenerate if allowed.



An introduction to native freshwater fish surveys

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ABSTRACT

This paper provides a guideline to the steps involved in planning surveys, selecting the appropriate techniques for the survey, and procedures for undertaking field surveys for native fish.

INTRODUCTION: FISH - WHAT NATIVE FISH?

There are 47 species of freshwater fish, 27 native and 20 introduced, that are resident or spend a significant part of their life cycle in the freshwaters of New Zealand (McDowall 1990). While this figure is low compared to many other countries, it is typical of island faunas where species diversity gives way to uniqueness and specialisation. Of the 27 native species, 23 are endemic and we are still finding new species.

Native fish occur from sea level to elevations exceeding 1500m and few lakes, rivers or swamps are without fish of some kind. Both the character and composition of the fish fauna change as one moves from low elevations close to the sea to higher elevations and greater distance inland. Typically too, species diversity and composition change with habitat type, with greatest diversity occurring within streams in forested catchments with good access to the sea.

A number of the species have a marine phase in their life cycle (termed diadromous). Consequently, free access to and from the sea is vital for these species. Often the further inland you go the less species you encounter as increased water velocities, physical barriers like waterfalls and human-made structures like hydroelectric dams, weirs and culverts, prevent penetration upstream.

Ironically, the best known of the freshwater fish are those that have been introduced, for example:

- trout and salmon, which have a recreational and culinary value,
- koi carp and catfish, which most people correctly perceived to be pests with many populations originating from illegal releases,
- grass and silver carp, which land and resource managers see as tools for controlling plant pests and algae.

Few of our native species are as well known. The general public may recognise the ubiquitous "bully", a common name given to six species from the genus *Gobiomorphus*; the two species of eel, *Anguilla australis* and *A dieffenbachii*;

the five fish, *Galaxias maculatus, G. fasciatus, G. brevipinnus, G. argenteus, G. postvectis* that collectively make up the whitebait run; smelt *Retropinna retropinna* a well known bait used by sports fishers to catch trout; and perhaps the lamprey, *Geotria australis,* a traditional iwi food and somewhat of a curiosity.

But like many native and endemic species which evolved in a countryside clothed in tall forest with cool, clear and shaded waters, our fish have suffered a decline in their abundance and distribution. Several species are threatened, either regionally or nationally and currently ten (37%) fall into either an "A", "B" or "C" priority for conservation management (Molloy and Davis 1994).

Our ability to recover some of the ground, or in this case waters lost, is dependent on improving our knowledge of the status and distribution of fish and fish habitat and this requires field surveys.

RELEVANT STATUTORY RESPONSIBILITIES

Native fish, unlike most other native vertebrates, are not protected by law unless they are within the confines of a Reserve gazetted under the Reserves Act 1977 or land covered by the Conservation Act 1987, or their harvest is controlled by either Regulation - as in the amateur whitebait fishery or through provisions that control the commercial exploitation of native fish on Conservation land. Under the latter a license or concession will be required. There have been recent changes to Department policy regarding concessions, so ensure you are familiar with these.

DOC staff obtain statutory powers primarily from the following:

The Conservation Act 1987

Where, Part II, section 6, **"Functions of the Department"** states the Department shall: ***"preserve as far as practicable all indigenous freshwater fisheries and protect recreational freshwater fisheries and freshwater fish habitats"***

Freshwater fisheries and aquatic life has a very wide definition and includes any part of plant or animal that must at some time inhabit fresh water.

The Department is responsible for fish species and their habitats, but not directly for the management of water and water quality. This is the responsibility of the Regional Councils.

Ministry of Fisheries deals with the management of commercial freshwater fisheries, like eel, mullet and flounder, but whitebait are still regarded as a recreational fishery.

Relevant Sections of the Act are:

- Section 4, requires the department to give effect to the Treaty of Waitangi,
- Section 17 (l-m), provide for the preparation of management plans for freshwater fish,

- Section 26 (m) Freshwater Fisheries, controls the "Transfer or Release of live aquatic life" within NZ. The Minister of Conservation's (MoC) approval is required if aquatic life is to be release into a new location or onto any land or water managed by the Department,
- Section 39 " Other offences in respect of conservation areas". Sub-section (4), addresses pollution of waters, damage to any freshwater fishery, fish spawning grounds or food of freshwater fish in any river, stream, lake or other water.

Freshwater Fisheries Regulations 1983

These are now deemed to be Regulations pursuant to the Conservation Act 1987.

Part IV, sections 41-50, address the requirement for maintaining or providing for "fish passage",

Part VIII, sections 58-67 address the liberation of fish and eggs of fish. Note the relevant connections between 26 (m) of the Conservation Act,

Part X, section 60-71, protects native fish from people intentionally killing or destroying them, unless authorised by a permit or other regulation like the Whitebait Fishing Regulations 1994.

You should make yourself familiar with **all** Acts, their amendments and regulations effecting the conservation, management and exploitation of fish and fish habitats. These will include legislation like the Conservation Act 1986, Resource Management Act (RMA) 1990, Reserves Act 1977, Drainage Act 1908, and the Local Government Act 1956.

REASONS FOR SURVEY

Generally there are three primary reasons for undertaking a fish survey:

- to assess the environmental impact of a work, either initiated by DOC or through the RMA consent process,
- to respond to a request for fisheries information from an external organisation or within DOC,
- to determine management priorities for specific "fish" or a "fishery" within your Conservancy.
-

Then you wish to either determine the status and distribution of those fish within the Conservancy, or use information about the fishery to help justify or support a management proposal.

Most of the fisheries information held in Conservancies is a combination of old Ministry of Fisheries data dating from the 1960's to the 1980's, and data collected more recently by a core of energetic and interested DOC staff, as resources became available. However, much of the data collected was, and often still is, site specific, the results of "one or two spot" surveys of one accessible tributary or site within a much larger catchment. While this type of survey will record the presence of fish at the site at that time of the year and is useful in providing a general pattern of distribution, its application is limited. Of more importance are data that provide:

- some **estimation** of fish abundance,
- the **importance of the habitat** to a species within an ecological unit or region,
- some **confidence** that most, if not all species present, have been recorded.

Further, you must be mindful of the limitations of old data. Natural and human induced change within a catchment over time can significantly alter the abundance and diversity of fish, especially migratory species. Some of these changes would include:

- a change in land use
- change in water flows and velocities through abstractions
- introduction of exotic species
- the installation of culverts, weirs and fords downstream of the survey site
- even some "act of God", like a large land slip, may irreparably change the habitat.

Despite some of these problems our knowledge of native fish and the habitat individual species require or prefer is improving. We can make some sound predictions on "which species is likely to occur where", but there will always be the need to support fish conservation with reliable factual data. You should know how to collect, store and manage that data.

SURVEY OBJECTIVES

Objectives need to be clearly defined before any field work is undertaken and data collected. Be clear about **"why"** you are undertaking the survey and **"what"** information you require from the survey. Regardless of whether the proposed survey is "reactionary", in the case of responding to an external request or RMA consent, or "proactive", as identified in your CMS or business plan, the same procedures should be followed. If a survey fails or doesn't provide the required information, it is usually because the project manager has not planned the operation satisfactorily.

SURVEY PROCEDURES

Research the Site

locate the site on a map and obtain a topographical map reference

note topography, vegetation cover, land use and suitable access points from map

note first, second and third order tributary sites that are likely to be representative of the catchment and which can be targeted during the survey.

check for impediments to fish migration like waterfalls, rapids and dams downstream of the survey site

check ownership of adjoining land/catchment and note location of owner's house.

Check for Existing Data

A number of agencies may hold fisheries data. Checking for existing records is time well spent, particularly if those records can, in combination with your survey results, provide you with a past and present perspective. Possibilities include:

- NIWA data base
- Regional Council records
- Fish and Game Council records
- You local contacts and other DOC staff

Previous applications for resource consents in the same catchment. These will be held by your planning section.

Preliminary Inspection

While a reconnaissance of the site may be seen as an extravagance when both time and resources are scarce, it will allow you to determine:

- the most appropriate access/vehicle to use
- habitat characteristics including water quality and clarity, type of substrate and instream obstructions, and whether the site is flood prone
- type of species likely to be encountered
- the number of people required to undertake the survey
- how long the survey is likely to take

Determine the Method of Survey

From the information you have gleaned from existing sources and your preliminary site inspection, you should be in a position to select the appropriate survey methods.

There are a number of methods available to you and these are summarised in Table 1. Most surveys will use a combination of the following three methods:

(i) Electric fishing machines (EFM)

There is a perception that EFM's are the "in" technology and even inexperienced operators will achieve good results. This is not the case and though they are a good tool when used by experienced hands in the right location, they can also damage and kill fish if used in the wrong location or with inappropriate machine settings. Machines have one of two power supply options, a battery pack-set or a mobile generator. Generator-powered machines will become heavy if long stretches of stream are to be surveyed but they are preferable in waters greater than 0.4m in depth. Note: pack-sets require two certified operators and generator machines three certified operators.

(ii) Netting

There is a net for all occasions from cage/trap/fyke nets to panel/seine/gill nets, but no simple guide to help you select the right one. Selection will generally depend on site conditions, but baited and non-baited traps like G-minnows and fykes are good all-round sampling equipment.

(iii) Direct observations

This method is inexpensive and very effective yet under utilised. There is one essential requirement - patience. You need to anticipate the species you may find, evaluate the site, identify habitats like sections of riffle and pool, instream cover and overhanging banks that one or more species may occupy, then watch and wait with binoculars and Polaroids ready!

Surveying streams at night using a spot light and dip net is also a very productive method and a lot of fun. Many species are active at night and they can readily be observed, mesmerised by the light and caught, if necessary, in the dip net for positive identification.

If you wish to repeat the survey over time to compare results, be sure the survey method you have selected is repeatable and adequately described. Talk to your Conservancy Advisory Scientist or the fisheries staff of Land Protection Division in Head Office if you are unsure of the technical requirements of a robust survey or monitoring programme.

Organise Equipment and Staff

Equipment

Most conservancies will now have a selection of basic survey equipment like a dip net, G-minnow traps, a fyke net or two, and perhaps a confiscated gill net or whitebait net. If you don't have the equipment you need you will have to borrow it, and there are a number of sources available. The local Regional Council, Fish and Game Council, NIWA, MoF or the adjoining Conservancy may well assist if you provide the necessary encouragement. Be sure you check the items you need and test all equipment before going into the field.

Staff

Ensure you have the number of staff you require (no less than three) to complete the job, including people with experience and local knowledge. Use the opportunity to train other conservancy staff.

Timing

Make sure the equipment is available when you need it, that all staff involved have advanced warning of the survey dates and the surveys are timed to coincide with seasonal migrations, workable water levels and dry weather access.

Fish Identification

At least one person in the survey team must be familiar with the basic structure, body proportions (e.g. size of head in relation to body length), fin layout, shape of the caudal or tail fins of fish and the common features of the seven families of NZ fish species. They should know how to locate and count "fin spines" and "rays" and the position of "head pores". A knowledge of these features will enable you to identify most fish in the field using the available keys and field texts - e.g. McDowall (1990) (A text every DOC staff member should have and available from most book stores), McDowall (1980) (A very handy field ID booklet. See your librarian for a copy). Those species that cannot be identified should be well described, photographed and returned to the water, and the location precisely recorded.

Positive identification of juvenile fish like whitebait is extremely difficult even for the experts, so you may have no other alternative other than to take a specimen for identification later. For this you will require a preserving liquid, usually 5-10% formalin and sealed plastic container. For periods greater than a week, formalin should be substituted with 70% ethyl alcohol. Remember always to label your sample correctly.

Handling Fish

The identification of a fish usually requires its removal from the water by a dip net and placement in a bucket or bin. Most fish can be kept for short periods in these conditions with little or no ill effects. For longer periods, especially during warm summer conditions, you will need to cover the container, place in a shaded place, change the water frequently and/or consider using a portable aerator.

Avoid excessive handling. This damages the skin and natural mucus coating on scaleless species, like the *Galaxiids* and eels, but will also cause scale loss on those species with scales, like smelt, bullies and torrent fish. Damaging the skin surface can leave the fish susceptible to fungal infections like *Saprolegnia*, once released. Also avoid handling fish that are already diseased.

Some species are more sensitive than others. Smelt for example are intolerant of stress and handling and will often die if confined in a net or bucket or picked up.

If you need to handle a lot of fish, particularly eels, then consider using an anaesthetising agent like "benzocaine". This will enable you to handle a greater number of fish in a shorter time, avoiding frustration on your part and physical damage to those species that tend to "squirm" a lot.

Recording Survey Information

Most field surveys will record the presence of species, give an estimation of their abundance, assess the importance of the site and describe the habitat at the site fished. There will be occasions where quantitative surveys will be undertaken to determine the carrying capacity of a habitat, expressed in fish numbers per square metres of stream bed area. Regardless of the reason for undertaking the survey the result must be recorded.

The Department has adopted and contributes to the NIWA Freshwater database. This provides a systematic method of recording information on the occurrence and habitats of NZ freshwater fish. Since its establishment in 1977 much information has been added to this database by resource managers and researchers and this can now be accessed through the DOC electronic network (Richardson & Adcock, 1992).

Information is usually recorded on fisheries record cards available from NIWA. These cards allow recording of details of the location of the site, condition of the water, substrate, riparian margins and the fish species encountered. While there is no requirement for you to use these cards I would encourage you to do so. The cards do help to standardise the information submitted by contributing agencies and you can certainly add any additional information you believe appropriate.

Equipment Storage & Tidy Up

Storage of your gear and the return of any gear borrowed is important. Nets must be cleaned and dried before consigning to the storeroom, batteries removed from the portable electric fishing machines, scales and measuring boards cleaned and oiled if necessary and damaged equipment repaired/replaced. Don't leave specimens in sample jars or fish parts under the vehicle's seat. There's nothing quite like a week-old fish out of water in a temperature of 20°C!

Not all staff warm to the idea of participating in a fisheries survey, but in my experience those new to the game quickly become enthusiastic. When selecting your helpers keep an eye open for staff with strong backs and wide shoulders - *generators and lead weighted nets are heavy* - and long legs - *pools are often deep* - and remember, **there is no substitute for field experience when understanding and conserving native fish**.

ACKNOWLEDGMENTS

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TABLE 1. FISH SURVEY TECHNIQUES.

SAMPLE TECHNIQUE	ADVANTAGES	DISADVANTAGES
ELECTRIC FISHING		
Generator and Pack-set units	Instant result, little or no damage to fish. Effective in small waters. Portable. Established technique with credibility.	Not effective in larger or saline waters. Expensive and requires trained operators. Needs at least two operators. Over rated, misses many species, especially those under cover in debris. Potentially dangerous.
NETTING		
Fyke nets	Very effective in many different situations especially drains, canals, small lakes, streams, river margins, and estuaries. Portable, easy to use. Can be made in a range of sizes, shapes and mesh size can be varied to suit species targeted.	Size selective depending on mesh and entrance size. Needs to be set for a period, usually over night. Not effective at catching species reluctant to pass through a narrow entrance e.g. trout
Box traps & Hinaki	Effective in deep and shallow water. Excellent for eel and other bottom dwellers	Size selective. Usually need to bait because there are no "wings" as with fykes. Usually set overnight
"G" minnow & bait traps	Effective in many different places, especially shallow, confined vegetated margins and small open waters. Portable easy to use.	Size selective. Will not catch bigger fish. Usually set over night, bait optional.
Gill net	Very effective. Used in deeper waters, estuarine and fresh, will catch most fast swimmers. Multiple mesh sizes available. Cheap and easy to set.	Size selective. Fish often killed. Prone to weed, debris entanglement.
Beach seine	Instant result. Very effective in slow waters, pools. Easy to use.	Requires clear working zone. Limited by depth.
Stomp/dip netting	Effective in shallow swift waters. Instant result. Relatively little skill required.	Not as effective in slow deep waters.
Spotlighting	Instant results. No damage to fish. Not size selective. Effective for nocturnal species. Easy and cheap.	Observers need to be skilled at identification. Restricted to shallow, slowish, clear water habitats.
Drift/Crawl diving	Effective in a range of habitats and water depths. Instant results. Fish often very approachable.	Observers need some training in water competence and species observation. Relies on good visibility. Potential for double counting as fish move ahead.
Daytime Observations	Nil disturbance, no specialist equipment needed. Binoculars handy	Observers need to be skilled. Clear calm water essential. Needs patience. Will not see species favouring night low light conditions
LINE FISHING		
Using natural & artificial bait and barbless hooks	Effective in larger streams and pools in catching larger predatory fish. Will damage mouth parts.	Size selective, requires skill/experience to be effective.
POISONS		
Rotenone	Effective in small lakes, ponds and standing waters. Non selective. Excellent eradication tool	Kills all fish. May have impacts downstream. Mixing chemical through water column essential
EXPLOSIVES		
Numerous types available	Effective in small water bodies, like ponds. Useful eradication tool.	Destructive. Kills all fish. Training required. Potentially dangerous

Survey and monitoring techniques for insects

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ABSTRACT

A variety of basic surveying and monitoring techniques often used in the study of insect populations are outlined. Particular aspects to consider when designing and implementing a monitoring programme are discussed. General aspects of insect habitats, life history and the factors which have led to the threatened status of some species are also covered. Methods appropriate to threatened species are outlined together with notes on handling of collected insects.

INTRODUCTION

Within the animal kingdom insects make up the most diverse and numerous of all animal groups and occupy virtually every natural terrestrial habitat. They have adapted to feed on all parts of living plants (phytophagous), on living animals (carnivorous) as predators or parasites and to feeding on decaying material (saprophagous). During their life cycle all insects have a variety of life history stages including egg, larva or nymph, pupa and adult and frequently these different stages occupy different habitat types.

With such enormous diversity a range of different techniques are required to survey and monitor insect populations. Many of these techniques can also be used to monitor related groups of invertebrates such as spiders, woodlice, ground hoppers, millipedes and centipedes.

The aim of this paper is to introduce a range of surveying and monitoring techniques generally used by entomologists to collect insects. These techniques are applied to determine which insect species are present in an area, or find out more about a particular target species and better understand its relationship with its surroundings. Background information is also provided which highlights the differences between invertebrate studies and those on other, larger fauna groups, such as birds, which may be more familiar to the reader.

In addition to surveying and monitoring insects generally there is a focus on those techniques which are applicable to threatened species or restoration work.

Identification of insects is not covered as it is very specialised and too broad an area to present here. Before describing the techniques used to survey and monitor insects several aspects of the New Zealand fauna and insects in general are introduced.

When collecting from Department of Conservation (DoC) managed land or other reserves a permit, or possibly a concession, will be required under either the Reserves Act, Conservation Act and possibly the National Parks Act and the Wildlife Act. Enquires regarding the appropriate authority should be directed to the local DoC conservancy office

NEW ZEALAND INSECT FAUNA

Watt (1983) has estimated there are at least 20,000 different species of insects, spiders centipedes and millipedes in New Zealand, with about half of the fauna being beetles (Watt, 1982). Of the 20,000 only about half are actually described, i.e. have names (Watt, 1983). There is a long way to go before entomologists can say they are familiar with even the majority of our insect fauna.

Greater than 90% of New Zealand's beetle fauna is endemic to New Zealand (Watt, 1982). This figure is probably true for most insect groups, thus the only place these species can be conserved is in this country.

While some of our insects are large and spectacular, such as giant wetas or giant weevils, a large proportion of our fauna requires microscopic examination to identify. There are only a few groups, such as butterflies and moths (Dugdale, 1988), where the majority of the approximately 1800 species are large enough for identification in the field. Generally, insects have to be collected, stored and taken back to a base for identification, often with the aid of descriptive keys or reference specimens.

Some groups are well developed in New Zealand and make the country unique in the world. For example, giant wetas, although not unique to New Zealand, they have developed to fill the same role in our native forests as mice do in other countries. Our largest giant weta, the wetapunga on Little Barrier Island is one of the heaviest insects known world wide, with females recorded up to 70g (Meads, 1990). All wetas are omnivorous feeding mostly on live plants, but may also scavenge dead plant and animal matter. Some weta species can be active predators of smaller invertebrates, but with their much lower metabolic rate, are not known to be as significant predators as mice and rats.

INSECT HABITATS

a) Different Habitats

Insects have adapted to virtually every different habitat type. Most plants are utilised by many different insect species, often at different times of the year and by different stages in the life history of the insect.

As well as feeding on living plant foliage (e.g. caterpillars, stick insects, some beetles) other habitats include; 1) dead or dying plant matter especially rotten wood (e.g. termites, many beetle grubs, cranefly larvae); 2) leaf litter(e.g. collembola, silverfish, cockroaches, some beetles); 3) underground habitats where insects feed on plant roots (e.g. cicada nymphs, some beetle grubs); 4) underwater in streams and brackish water (e.g. nymphs of caddisflies, dragonflies, mayflies, stoneflies); 5) as parasites on all other fauna species (e.g.

fleas, lice); and 6) as predators of other insects (e.g. some beetles, dragonflies, robber flies).

b) Generalist species

Some insect species have a very wide host range, e.g. some caterpillar species can feed on the leaves of many different plant species, and others, like wetas, feed on live leaves as well as scavenge dead material.

c) Specific niche insects

Other insects are very specific and may only feed on a single host plant (e.g. some giant weevils only found on speargrass plants) or be capable of parasitizing a single host animal species (e.g. bird lice restricted to a single bird species). When the host is adversely affected in some way, e.g. through browsing by possums or stock, then all the insect species which depend on it may also be adversely affected.

DIFFERENT LIFE HISTORY FORMS

Egg - Larva/nymph - Pupa - Adult

There are two basic types of insect life cycle:

a) Insects with a nymph juvenile stage

The juvenile stage looks very similar to, but smaller than, the adult. (e.g. wetas, grasshoppers, shield bugs).

b) Insects with a larval juvenile stage

The juvenile stage looks very different to the adult. (e.g. caterpillars which become moths, maggots - become flies, grubs - become beetles).

Many insects have annual life cycles, (i.e. all life history stages from egg to adult are completed within one year). Thus adults will only be present for one period of the year, and usually at the same time each year. This is where many insects vary from lizards, birds and other vertebrates.

Some insect species may be active as adults for only a matter of weeks. Many of these species will occupy the resting stage, or pupa, through the winter, or have a long slow juvenile stage development during the colder months. Even with species which have long life cycles, such as the seven years that nymphs of some cicada species spend feeding on roots underground before emerging, the adults will always be present (and singing) at the same time of year.

Either way it is important to understand that insects are often seasonal. Consequently there is usually a limited time in which to survey or monitor for adults. The exceptions being species which have long lived adult stages, (i.e. tree wetas and some larger beetle species like giant weevils).

Focusing on the adult stage is important because, for the vast majority of insects, the species can only be identified from their adult stage. It is also important to realize that for many species the adult stage often occurs in a completely different place or habitat than the juvenile stages.

WHY SOME INSECTS ARE THREATENED

The two major causes of loss in New Zealand native fauna are habitat destruction and predation from introduced mammals. Insects are no different to vertebrates in this regard, having suffered from both causes extensively.

a) Habitat destruction

While virtually no insect habitat has escaped degradation in some way those which have suffered the most are lowland forest and freshwater wetland habitats.

Pastoral farming has claimed vast areas and little is known about the numbers of insect species which may have already been lost from these areas. We suspect, for example that there were a number of giant weta species throughout the lowland forest of the North Island, similar to those species at Mahoenui and on Little Barrier Island.

Invertebrate habitats can be affected in many ways other than complete removal. When stock, particularly cattle are left to graze in forest areas they severely modify the lower forest tiers, reducing plant diversity and decimating invertebrates in the litter layer. Grazed forest remnants that appear healthy from above can often be virtual deserts for invertebrates.

Edge effects through wind getting under the forest canopy may also adversely affect insect habitats, particularly through moisture loss. This has important implications for placement of traps for monitoring, keep them well away from forest margins unless specifically measuring this ecotone.

Most introduced browsers, such as cattle, goats, possums and deer, can be regarded as competitors to New Zealand native browsing invertebrates. These exotic species all have their preferences which in turn reduce the available habitat and food for certain invertebrates.

b) Predation

As with other fauna groups, insects have suffered losses through introduced mammals including mice, three rat species (including kiore), three mustelid species and cats. While many have regarded mice and kiore as vegetarian they are in fact predators of a wide variety of invertebrates (Moller, 1977).

A number of introduced insect predators, including wasps and ants are also suspected of having an effect on our native invertebrates, although the degree of this effect has yet to be clearly determined. Exotic wasps will take a wide range of soft bodied invertebrates, particularly caterpillars and spiders. There are also a number of exotic bird species which take large numbers of native insects. The total effect of these is largely unknown.

WHY SURVEY AND MONITOR INSECTS

a) Threatened species

Survey should reveal the area of distribution and give an indication of population density. It may also reveal useful information about the general biology of the species.

Monitoring aims to reveal any changes in these factors over time. It may also be appropriate to monitor the food plants of threatened species, especially if the insect is restricted to only one or two host species.

b) Indicator species

There are many insects which are known to be hunted by predators and the absence of these can indicate the presence of such predators. For example several large species of flightless ground-dwelling beetles, called darkling beetles, are present on many rat-free northern offshore islands. On islands where rats have invaded these beetles have been either completely eliminated or reduced to very low numbers. Monitoring the numbers of such species can give an indication of the presence/absence of rats as well as reveal something of the history of rat presence.

There are a number of insect groups which are good indicators of the quality of freshwater streams and the presence of pollutants. New Zealand has a well developed fauna of caddis-flies and different species of these, and other freshwater insects, have variable tolerances to different pollutants.

The use of indicator species of invertebrates in forest habitats remains to be developed in New Zealand. There is great potential for the use of insects in this area, particularly in monitoring the effects of restoration management to habitats, for example after removing predators and/or browsers from areas.

DESIGNING A MONITORING PROGRAMME

Monitoring programmes can be relatively simple, where a species is monitored over time to determine natural changes in abundance. In more complex programmes the monitoring is designed to show what changes in abundance have occurred as a result of changed management of an area. Ecosystem restoration programmes currently being run by DoC frequently involve the latter and require the measurement of populations not only in the treated area but also in a non-treated or 'control' area. This design aims to show that changes in insect numbers are due to changes in management (e.g. increased abundance of an insect species following rodent control), rather than due to some other unforeseen factor.

When designing a monitoring programme it is crucial to reduce variability in parameters other than those being measured. Traps used for monitoring must be identical and set up so that samples will be taken from the same habitat type, vegetation type, at the same altitude, slope, aspect, soil moisture gradient position and at the same time of year. When using monitoring techniques other than traps (e.g. collecting samples of leaf litter) samples should be of a consistent size, volume, weight or from the same surface area of ground.

Consistency in sampling applies to the treatment site, the control site as well as between the two. From an insect perspective, even if all the parameters look the same to us there will still be variability in the microhabitat area where each insect has its territory. Therefore, there must be replication of traps or samples to account for this and provide statistical confidence in the results of the monitoring programme.

The number of replicates required will depend on the degree of this variability as well as other parameters such as weather, the lunar cycle or host plant quality. These parameters can dramatically influence insect behavior and thus the likelihood of capture in a trap or sample. For example, during summer many adult insects use rainfall as a trigger for emergence or general activity. Some species are not as active during the later stages of the lunar cycle near full moon, and many foliage feeders favour fresh young shoots to feed on and thus may not be evenly distributed on the host plant. Precise determination of the ideal number of replicates can require complex calculations such as those found in Southwood (1978) but some general guidelines are given below for several of the more commonly used monitoring techniques.

Because weather is one of the most significant variables in studying insects in the field it is important to have a source of reliable weather information as close to the treatment and control sites as possible. At the very least both maximum and minimum temperatures as well as rainfall measurements should be recorded. Such information may prove critical in explaining between year variation in insect population levels which are not explainable through treatment effects.

If monitoring is being used to measure the effects of management then contemporaneous controls (i.e. measured at the same time as the treated sites) should be included in the design. Sometimes there may be occasions where control sites will differ in some respect from the treatment sites. The effects of these differences can be overcome by obtaining baseline information by beginning the monitoring programme at least two or three years before the treatment is applied. The aim is to build a robust amount of baseline data on the insect populations so that any changes following the treatment can be measured against this baseline for an indication of the effects of the treatment.

SURVEY AND MONITORING TECHNIQUES

Many of the techniques described below employ very cheap equipment and are easy to operate. It is important to understand that while many insects can be collected relatively easily and quickly this is not the case during identification of the catch. Identification is usually very time consuming and thus potentially expensive, particularly if it involves sorting and mounting, which is often the case.

When embarking on a monitoring programme, particularly if it involves long term trapping make sure that the cost of sorting and identification of trap material has been taken into account beforehand. There are very few entomologists available for such work and they are virtually an endangered species in themselves.

It is essential to carefully plan any project involving survey or monitoring to ensure the techniques chosen provide the information required. An experienced entomologist should be involved in the planning stages.

a) Collection by hand through searching.

Key attributes which assist in hand collection of insects include knowledge of the habitat requirements and signs likely to be left by the target species. Patience is also a useful attribute. Day or night searching will reveal entirely different species. Habitats which can be searched include:

Foliage or flowers

For many species it is easier to look for the damage they cause on their host plant, thus if you know what plant species to look at and the type of damage you can quickly find the target species.

On or under bark, in rotten wood

This involves hand searching but is often destructive to the habitat and so should be used with some restraint. Careful thought should be given to the amount of such searching.

Under logs or rocks

During the day many nocturnal species will hide under logs or rocks and can be easily located. However, this technique can also be destructive to the habitat and care should be taken to always replace the log or rock in exactly the same position as found.

In forest litter

Forest litter has the highest density and diversity of invertebrate species compared to any other habitat type. Litter can be examined in the field or, more usually, collected into cloth bags and removed for extraction back at a laboratory base. The litter is then placed on coarse netting in a funnel. As the litter dries out from above the insects migrate down through the litter, exit through the netting and fall out the base of the funnel.

A low wattage light bulb suspended above the litter provides a heat source to speed the drying process. Most litter and soil invertebrates are nocturnal and prefer dark, relatively humid surroundings and will naturally move deeper as the top litter surface dries out. The funnel apparatus is called a "Berlese Funnel" or "Tulgren Funnel"

Invertebrates can be collected dead or live by varying the contents of the container under the funnel. If the specimens need to be collected live (dry), layers of moss or leaves provide layers for the different species to hide from each other until checked each day. If the specimens can be collected dead (wet), a preservative (such as 75% alcohol) can be placed in the container instead. For further details see "trapping techniques" below.

Litter may be collected at random, by taking handfuls from various places to make up a set volume per sample, or from a set number of quadrats. However, the use of quadrats has the potential bias of not sampling the difficult to get to places where a quadrat won't fit. For example, between rocks and against dead branches or logs etc., where there may be a build-up of litter holding a greater diversity of species.

Vigorous shaking through a course sieve allows a greater density of insects by volume compared to removing all litter with the sample.

b) Beating and netting.

These techniques use equipment which will temporarily capture insects and allow the operator to sort the catch in the field so those insects not required can be released immediately.

Techniques include:

Beating

If the damage on foliage or flowers is obscure or the species is too small to easily locate then a useful technique is to place a tray or cloth under the foliage/flowers and **give the branch a sharp tap** to dislodge the insects present. This should not be used as an excuse to vent your frustrations on the foliage as shredded leaves are no use to anyone. Over vigorous beating can also damage the insects, making identification more difficult.

Sweep netting

This involves the use of a net to sweep through or against the tips of foliage to catch insects, particularly winged species that may temporarily be at rest. Again care is required not to needlessly destroy the plants as well as any insects unfortunate enough to be present at the time.

Netting flying insects

This is self explanatory and, as with the other techniques, it can apply both day and night depending on the activity periods of the target species.

Netting freshwater insects

Here a net is held downstream from an area where stones are dislodged or the stream-bed is stirred up. The insects present will drift down into the net.

c) Trapping techniques.

Several of the trapping techniques described below can be used either 'wet' or 'dry', i.e. insects can be caught in a preservative solution (wet) or alive in the container (dry).

For wet trapping a variety of preservatives can be used, depending on how often the trap is checked, 75% alcohol, 30% ethylene glycol (antifreeze), gault's salt solution (mix of three "salts") or even a saturated solution of common salt (approximately 25% salt, 75% water). Alcohol tends to evaporate quickly so is suitable only if short periods elapse between trap clearance, usually less than a week. If flooding is a particular problem an extra tablespoon of common salt can be added to each trap to enhance preservation.

For dry trapping it is essential to put material in the container to increase the surface area for the insects to rest on and reduce the insect to insect contact.

Any predators caught aren't just going to sit around and admire the view so it is advantageous to make it difficult for them to devour the entire catch at a single sitting! Material such as leaf litter, moss, screwed or ripped-up crinkled paper can be used. Traps should be checked daily when dry trapping.

Pitfall trap, wet or dry

Pitfall traps operate on the principle that insects moving over the ground surface will fall into the trap, either accidentally or deliberately. Usually pitfall traps are used to collect an unbiased sample of those invertebrates that would normally be expected to be present in that area of ground during the trapping time interval. Figure 1(a,b) shows two designs of pitfall traps and a third design is described in Moeed and Meads (1985).

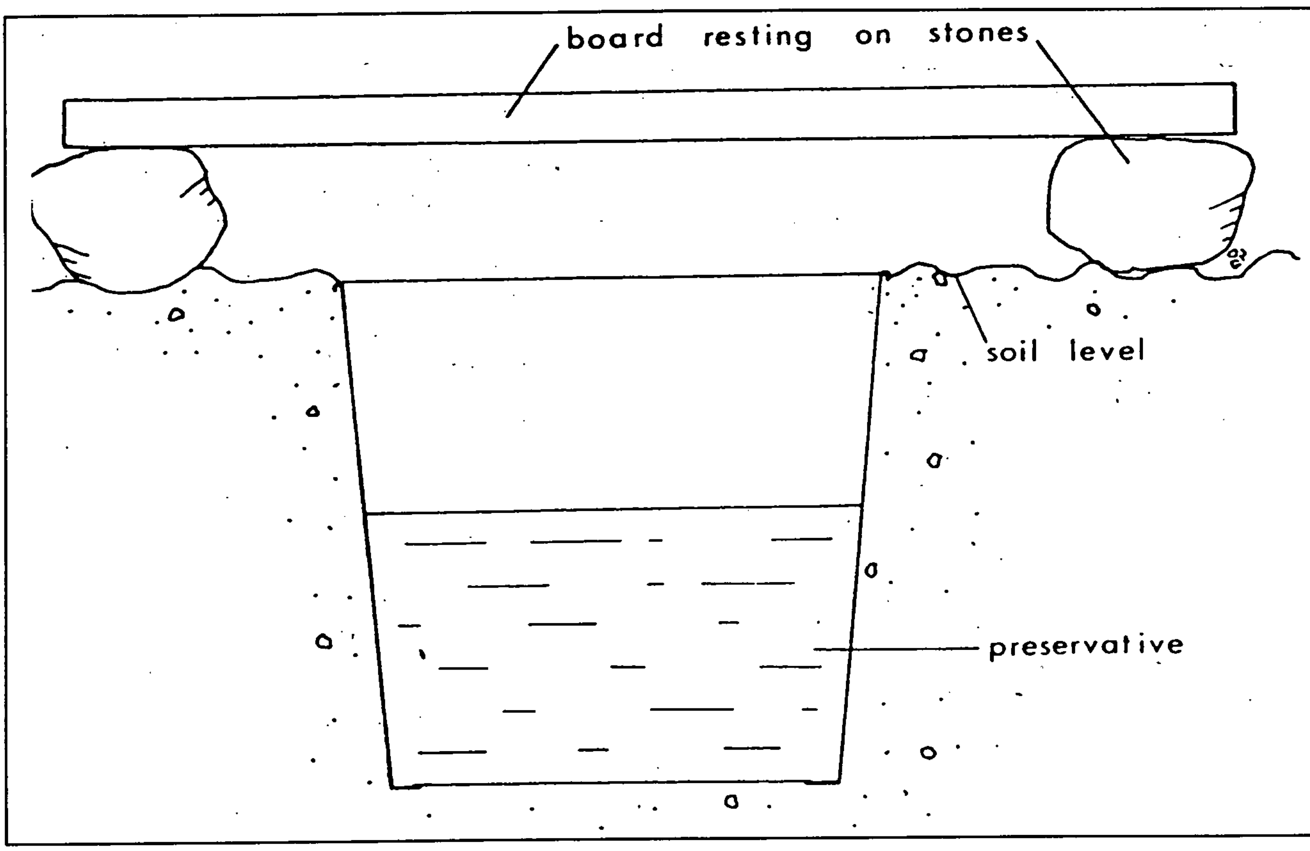

FIGURE 1A. ILLUSTRATION OF PITFALL TRAP (SINGLE CONTAINER).

To operate effectively the lip of the trap container must be flush with the ground level (see Figures 1a and 1b) so insects the size of ants can gain easy access without having to engage in mountain-climbing. The trap will be less effective the higher the lip is above ground. Conversely the lower the lip is below ground level the more litter and debris will fall in and significantly add to the time taken to sort and identify the catch. The lip level should be checked carefully each time the trap is cleared and remain constant throughout the study period.

Generally pitfalls are wet traps (see above) so they can be set up and run for consistent periods, e.g. weeks or even months. Covers can be used to protect the preservative from being diluted by direct rainfall, although dilution can occur through runoff. Covers should be at least 15 - 20mm above the trap lip to allow insects easy access to the trap itself. In areas where traps may be disturbed by other wildlife the covers may need to be held down by a rock, branch, wire, nails (as in Figure 1b) or some other form of attachment. Possums and other exotic mammals are often inquisitive and can be very destructive. If the traps are checked more frequently tent shaped pieces of 25mm wire mesh can be used instead of solid covers to exclude leaves and other debris.

In order to avoid the preservative overflowing the container, with consequent loss of surface floating invertebrates, the container should have several holes drilled at least 30mm, preferably 50mm, down from the lip.

For monitoring work pitfall traps can be set in transects or as groups at each site. In both layouts replication is crucial to improve the accuracy of results. The degree of replication required will vary from site to site but a general rule of thumb would be a minimum of 10 traps at each site. Transects through forest habitat could require 20 traps set up in pairs to account for between trap variability (the greater the variability the greater the number of traps required).

When checking pitfall traps every effort should be made to reduce the impact on the ground around the trap. Similarly when initially digging in the trap avoid unnecessary disturbance and ensure that surplus earth is discarded away from the trap. Some invertebrates may either be attracted to or avoid areas of disturbance, thus biasing the catch during the initial period after set-up.

Pitfall traps generally catch ground based species, which are often flightless. The more active species, most of which are nocturnal, have a greater probability of being caught e.g. worms, spiders, harvestman, woodlice, ground hoppers, cockroaches, wetas, ants, beetles millipedes and centipedes.

Malaise trap, wet or dry

Malaise traps operate on the principle of catching the insects which fly through a set airspace (Figure 2). They are usually slightly smaller than, but the same shape as, a classic two-person tent that has had its sides cut away. Made of fine curtain mesh material the top is white while the rest is black, including a screen which is located in the centre from the top down to ground level. Insects fly into this centre screen then walk up to the top and on up to the apex. Here they exit the net into a bottle suspended on the outside of the trap. Hutcheson (1991) and Cresswell (1995) have described designs of the catch bottle and its method of attachment to the net. Traps should be positioned to intercept likely flight-paths through the habitat to be sampled. Trap corners can be secured to pegs, stakes or to branches of neighbouring trees.

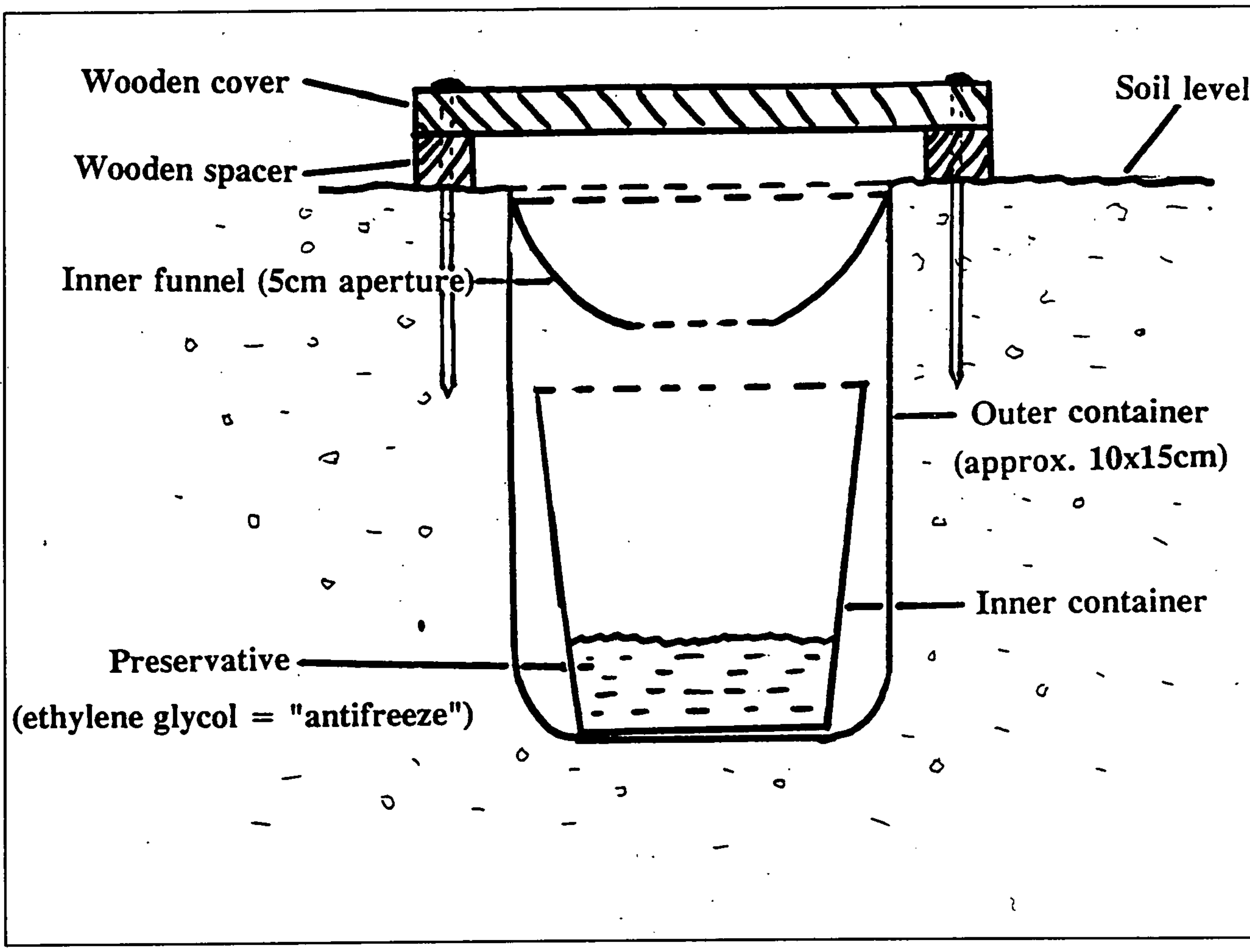

FIGURE 1B. ILLUSTRATION OF PITFALL TRAP (DOUBLE CONTAINER WITH FUNNEL) WITH COVER FIXED TO PREVENT DISTURBANCE BY LARGER ANIMALS.

Although designed to catch flying insects some ground insects can crawl up the netting and be caught. Most flying insects will be associated with the neighbouring habitat but some species may be capable of flying from other habitat types remote to the study site. Therefore some caution may be required in interpreting the relationship between the species caught and the trap site habitat. Three or four malaise traps may be required at both treatment and control sites (i.e. four plus four), to account for within site variability (John Hutcheson, pers. comm.).

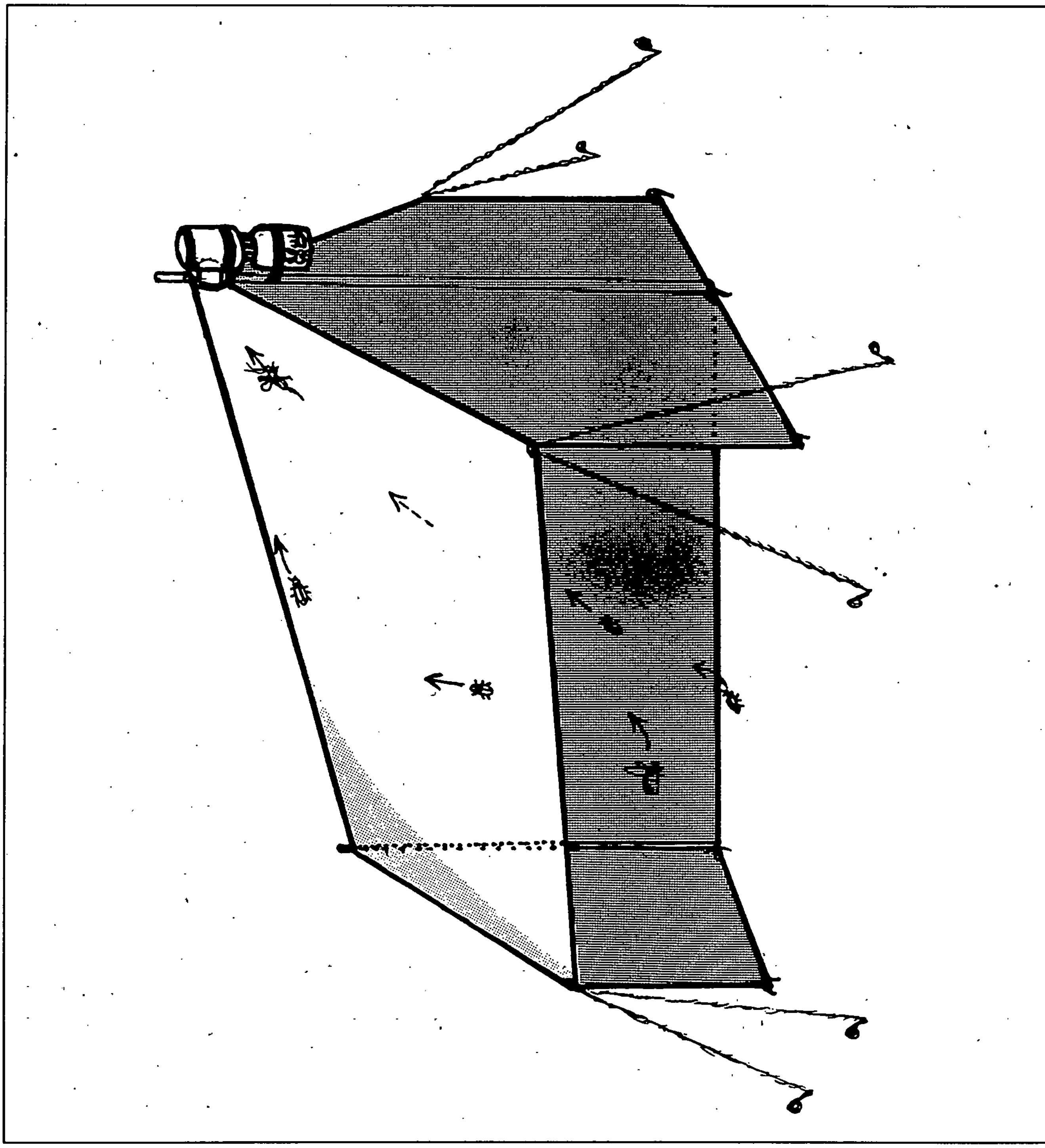

FIGURE 2. ILLUSTRATION OF A MALAISE TRAP.

Pan trap, wet only

Pan traps are trays of liquid placed on the ground to collect insects falling from trees above, attracted to the water surface through light reflection, including moonlight, and those species jumping over the ground surface. They can be any size of container but a commonly used containers in New Zealand are plastic "Chinese take-away" food trays measuring approximately 210 x 150 x 30mm. Traps should have at least 20mm depth of fluid and water can be used if cleared daily. A drop or two of dish-washing detergent should be added to reduce surface tension so the insects will sink quickly.

Pan traps are frequently coloured bright yellow which is very attractive to day flying insects, particularly species of flies, bees and wasps. These species tend to be influenced by local weather conditions, being more active in warm, sunny, calm weather thus a greater catch is likely under these conditions compared to cool, overcast and windy weather. Yellow pan traps can also catch more insects when sited on the edges between different habitats, for example on forest margins or natural clearings. Rather than just resting on the ground surface pan traps can also be set into the ground, rather like pitfall traps. Thus they may catch ground species such as those listed above under pitfall traps.

Pan traps usually have a high surface to volume ratio and are frequently exposed to the sun. Accordingly, they tend to have high evaporation rates and the fluid needs regular topping up. Consequently they are less suitable than pitfall and malaise traps for continuous long term monitoring studies. However, pan traps are quick to set up and good for short term surveys.

Light trap, dry only

Light traps attract nocturnal flying insects, mainly moths and caddis flies with the odd beetle, to a light source which they fly around until hitting the bulb or glass panels and dropping into the trap (Figure 3). Even small insects tend to end up below the bulb and fall into the mouth of the trap. Egg cartons or screwed up paper inside the trap provides a variety of surfaces for the caught insects to rest on until the trap is checked in the morning.

Bulbs can either be mercury vapour (160 watt) or "black light" tubes which both have a greater amount of ultra violet light than incandescent bulbs. Although the latter bulbs can be used (150 watt or greater), an ultra violet light is more attractive to nocturnal insects and is likely to lure a greater variety of species. A glass cover must be used to protect the bulb to prevent it exploding during periods of rain.

Weather conditions can significantly influence the number of insects attracted to light. More activity around a light occurs on warm, cloudy, humid, calm nights with little or no moon than on cold, clear or windy nights with a bright moon.

An alternative to a trap is simply to place the bulb in a holder on a large white sheet spread over the ground. In forest areas the sheet reflects the light up to the under side of the forest canopy which in turn reflects it further. This technique allows the operator to select only those specimens required and leave the rest.

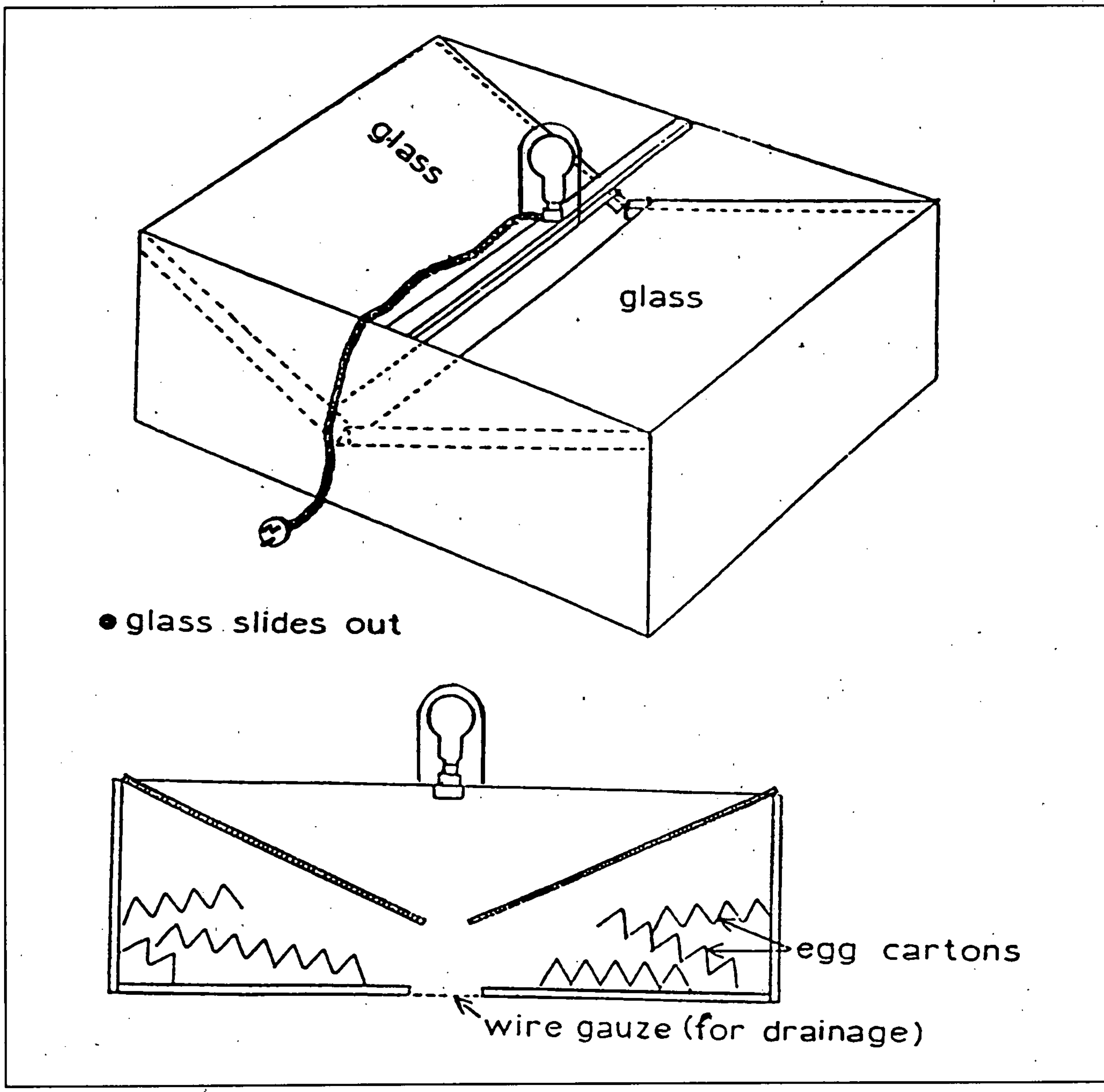

FIGURE 3. ILLUSTRATION OF LIGHT TRAP (DRY).

Trunk trap, wet or dry

Moeed and Meads (1983) used trunk traps to catch invertebrates crawling both up and down tree trunks. Such traps are specialised and could be useful during general surveying or when monitoring particular species when the host is known.

Emergence trap, dry only

Emergence traps are another specialised type of trap specifically designed to collect insects which have just emerged as adults from under-ground or litter based pupation sites (Figure 4). The trap is placed over level ground with the edges embedded so insects cannot escape. The trap requires regular checking every day or two.

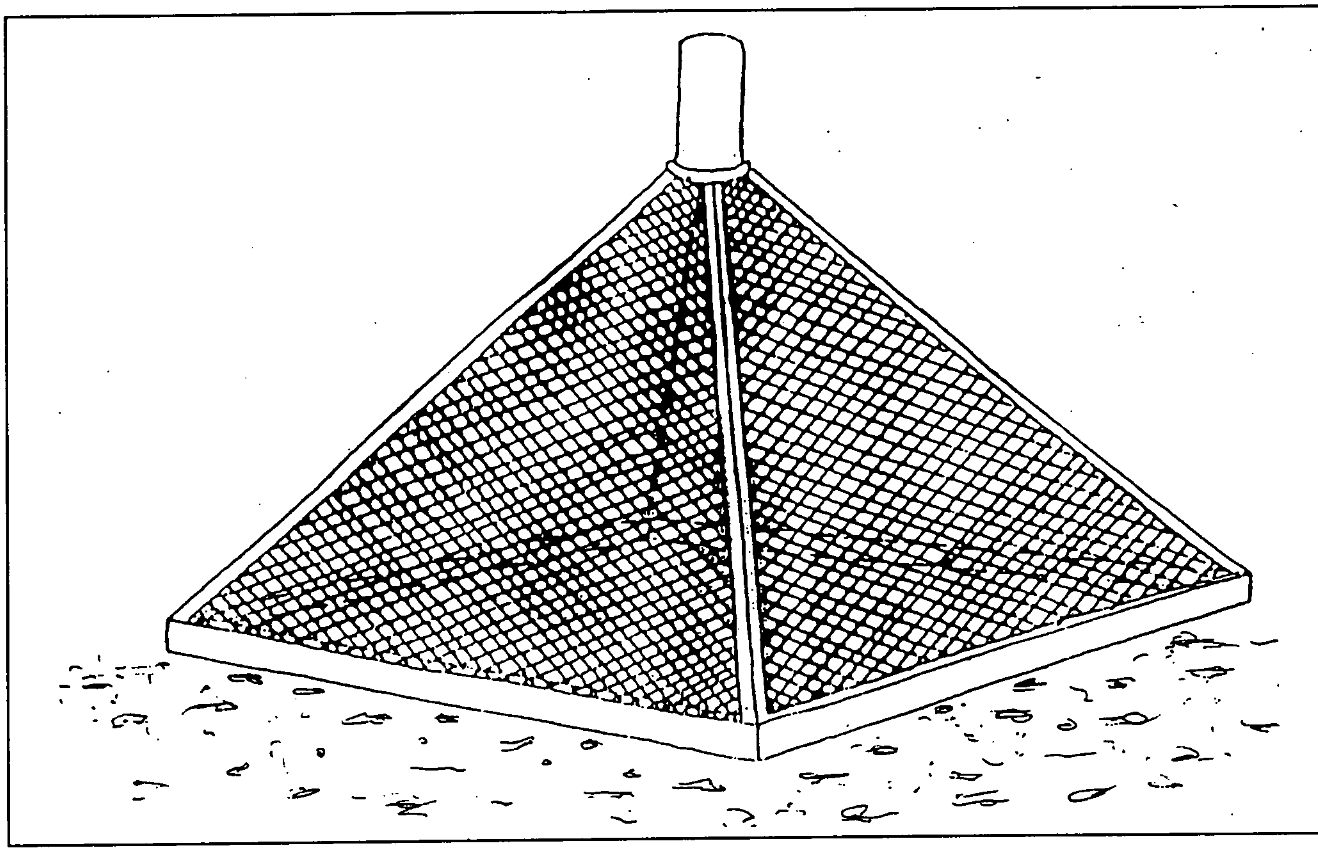

FIGURE 4. EMERGENCE TRAP.

Baiting

Pitfall, pan and other forms of traps can be baited with either sweet solution, fruit, meat or rotting material, depending on what species is targeted. The bait is suspended within the trap but not in the preservative fluid as both would deteriorate quickly and lose effectiveness. Baits can also be simply placed at intervals on the ground or suspended in trees and checked regularly during the day or night.

Radio telemetry

A research technique which is useful in filling gaps in knowledge of the behaviour and life history of larger species is radio telemetry. Radio transmitters have been developed for attachment to many species of animal which can be followed using radio tracking equipment. On insects however, this method has only been used on larger species (e.g. giant weta, including the Middle Island tusked weta, Stephens Island giant weta and wetapunga on Little Barrier Island - George Gibbs and Mary McIntyre pers. comm.) due to weight constraints. Although not a population monitoring technique it can provide information which allows more efficient targeting of techniques, such as those described above, to determine population levels. With increased miniaturization of this technology it should eventually be applicable to other, smaller species.

Disadvantages include high cost, short battery life, currently about three weeks, and that the transmitter will be shed along with the skin during the next moult if the insect is not an adult. Transmitters have a range of about 50 metres.

WHICH TECHNIQUES FOR THREATENED SPECIES

When working on threatened species great care is required in selecting a sampling method which is appropriate for the particular species concerned. The choice will depend on factors such as the type of habitat in which it is found, the degree or category of threat and the likelihood of predators being in the area, particularly where traps may be left unattended. Some techniques may have to be adapted or formulated specifically for certain species, for example setting out large numbers of predator proof artificial roost sites which can be easily checked.

Appropriate techniques include:

Hand searching

This is the most commonly used technique at present as most threatened species are large enough to locate and identify in the field. Several of our threatened species are restricted in their host range. For example the giant flax weevil feeds only on flax and adults also leave a characteristic feeding pattern which is different to other flax feeders. Thus it can be relatively easy to determine the presence of this weevil species.

However, hand searching as a monitoring technique has the major disadvantage of variability between searchers. Thus, results may vary greatly using the catch-per-unit-effort method and it can be very difficult to standardize across this variability during analysis.

Beating and netting

These techniques can be used but, as with hand searching, can be difficult to undertake in a uniform way between different operators. Set numbers, usually high, of random sweeps with a net or branch taps above a beating tray can be used to assess population levels.

Pitfall traps - dry only

Pitfall traps are a very good technique for both survey and monitoring of species that spend a lot of time on the ground. When using dry pitfalls they need to be checked regularly, usually once a day, preferably at the same time of day to standardize results. As stated above it is important to put some damp litter or moss *etc.* in the bottom to give cover to the insects trapped.

Pitfall traps are cheap, relatively easy to set up and check but care is needed in interpreting results in relation to population size or abundance of the target species. Like many trapping techniques pitfalls depend on activity levels which can be influenced by many variables.

RECORDING INFORMATION

As with any specimen that is collected there is a minimum amount of information which needs to be recorded. Unless the following information is recorded, any insects collected are of little use for further scientific study.

Essential data includes:

- where - locality, as precise as possible
- when - the date found
- who - the name of the collector
- on what - what plant species, or substrate such as rotten wood or other habitat type
- how collected - method used to collect the insect, e.g. what sort of trapping technique if one was used, trap period.

If you suspect that the insect is a threatened species then it should be kept alive while you make enquiries to have it identified. Consider taking a close-up photograph then releasing at a marked release site.

KEEPING LIVE INSECTS

If a threatened species is being held temporarily for measurement it may be kept in a cloth bag until release. Such bags facilitate easy handling but care is required to ensure the bag and its contents are not crushed.

Some basic rules for temporarily housing any live insects include:

- -never completely seal the container, perforate the lid to allow air movement for ventilation
- -never let sunlight get onto the container, always keep it in the shade
- -ensure the container is of sufficient size
- -provide something for the insect to rest on or under, depending on where it was found
- -its generally a good idea not to let the atmosphere dry out in the container so, provided there is ventilation, add a few drops of moisture.

WHERE TO DEPOSIT SPECIMENS

All dead specimens should be retained for further study and should generally be preserved in 75% alcohol in sealed containers. Always put the collection label inside the container with the specimen(s). Collection labels should be written in dark pencil or indelible black ink, never in ball-point as this fades in alcohol. Walker and Crosby (1988) give detailed description of methods for mounting, labeling and preservation of insects.

The New Zealand Arthropod Collection housed at Landcare Research in Auckland is the largest collection of New Zealand insects. For many studies, including those which involve a wide sampling area, this collection may be the most appropriate place to deposit insect specimens. The Museum of New Zealand in Wellington and regional museums may also be appropriate. Collecting permits may specify where specimens are to be deposited to allow future reference and study.

ACKNOWLEDGMENTS

The Threatened Species Unit of DoC has run a series of training workshops for staff and this paper is a synthesis of the insect training provided. I wish to thank Dr George Gibbs, Victoria University of Wellington, for assistance during one of these workshops. I also thank those DoC participants who have provided feedback which has stimulated me to add and improve the content of my talks and consequently this paper.

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Aspects of the ecological management of New Zealand frogs: conservation status, location, identification, examination and survey techniques

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ABSTRACT

The ancient endemic *Leiopelma* frogs are of high biological and conservation importance, while two of the *Litoria* frogs introduced to New Zealand may be at risk in their native Australia. Techniques for identifying, locating, examining and sampling frogs are described, and the impact of field work on *Leiopelma* discussed. Ecological management requires a range of field approaches from national mapping surveys, to local surveys and some intensive population studies. All four *Leiopelma* species have been bred in captivity, providing new knowledge on reproduction and on captive propagation techniques. Translocation of native frogs should follow accepted protocols and should be based on knowledge of the species' demography and habitat requirements. Most appropriate techniques for long-term monitoring should be decided upon in the near future.

INTRODUCTION

The endemic New Zealand *Leiopelma* frogs (family Leiopelmatidae) are amongst the world's most primitive anurans. Due to their antiquity and scientific interest, they rank with the tuataras as biological icon species and were the focus of the recent native frog Recovery Plan (Newman 1996).

At a time of increasing world-wide concern for declining amphibian populations (Vial & Saylor 1993), it is important that trends in New Zealand's amphibian populations are adequately monitored for early identification of potential problems. Since human settlement, all extant species of *Leiopelma* have declined, and three other species are now extinct (Bell 1985b,1994; Worthy 1987; Newman 1996). The three formally described extant *Leiopelma* species are; Archey's frog *L. archeyi*; Hamilton's frog *L. hamiltoni*; and Hochstetter's frog *L. hochstetteri*. The three extinct species are the Aurora frog *L. auroraensis,* Markham's frog *L. markhami* and the Waitomo frog *L.*

waitomoensis (Worthy 1987; Bell 1994; Newman 1996). The Maud Island frog, formerly considered to be *L. hamiltoni*, is now recognised as a separate cryptic species, increasing the total of extant *Leiopelma* species to four (Bell et. al., in prep.). A feature of recent research on *Leiopelma* in New Zealand has been its close integration with conservation management and this should be encouraged given the rarity of surviving populations.

In addition to *Leiopelma*, at least nine alien species of anuran - in three genera - have occurred in New Zealand (Thomson 1922; Bell 1982a, b, unpubl.): *Rana temporaria/esculenta*, *Bufo vulgaris* (=*B. bufo*), *B. calamita*, *B. marinus*, *Litoria adelaidensis*, *L. aurea*, *L. caerulea*, *L. ewingii*, *L. gracilenta* and *L. raniformis*. Three of them - the Australian Green & Golden Bell Frog *Litoria aurea*, the Whistling Frog *L. ewingii* and the Warty Green Frog *L. raniformis* - have successfully established (Bell 1982a, b; Gill & Whitaker 1996). These introduced frogs also require monitoring, as some pose a threat to the endemic *Leiopelma* species, or are threatened in their country of origin (Groombridge 1993; Bell 1994; Thurley & Bell 1994; Goldingay 1996).

CONSERVATION STATUS OF FROGS

Leiopelma species

Under current IUCN criteria (IUCN 1994) all extant *Leiopelma* are threatened. In increasing order of concern, *L. hochstetteri* is classed as *Lower Risk (Least Concern)*, *L. archeyi* as *Lower Risk (Near Threatened)* and *L. hamiltoni* as *Vulnerable* (Bell 1994). Once the Maud Island species is described, its status will also be *Vulnerable* but the Stephens Island *L. hamiltoni* then becomes *Endangered* (Bell 1994). Department of Conservation species rankings for these taxa are: *L. hochstetteri*, *L. archeyi* and Maud Island frog '*B*', *L hamiltoni* '*A*' - the highest priority species for conservation action (Molloy & Davis 1994).

Litoria species

In their native Australia both *Litoria aurea* and *L. raniformis* have declined (Robinson 1993; Goldingay 1996; Mahony 1996; White & Pyke 1996) and are listed in the *1994 Red List of Threatened Animals* (Groombridge 1993). Their status in New Zealand requires monitoring, although available evidence suggests they remain widely distributed (Bell 1994).

LOCATION OF FROGS

National distribution

The former and current distributions of *Leiopelma* have most recently been summarised by Bell (1994) and Newman (1996). The distribution of *Litoria* (as well as *Leiopelma*) in New Zealand was summarised by Bell (1982a,b) and Pickard & Towns (1988). Accurate records of any frog seen and identified in New Zealand are important as they help contribute to the Department of Conservation's *New Zealand amphibian/reptile distribution scheme* and so to our national biodiversity inventory.

Faunal surveys over the last two decades have resulted in dramatic range extensions of both *L. archeyi* and *L. hochstetteri* in the North Island - for instance the discovery of both species in Whareorino forest in the northern King Country - the *L. archeyi* being 150 km from other known populations in Coromandel (Bell 1993,1994; Bell & Thurley 1994; Bell, Daugherty & Hitchmough 1995; Thurley 1996). Further searches for new populations of *Leiopelma* in New Zealand are required, including areas well beyond current known ranges .

Habitats

The introduced *Litoria* species are typically associated with freshwater breeding sites - ponds, ditches and swamps - from which loud choruses can be heard during the breeding season. When not breeding, however, these species may occur more widely (Bell 1982a,b). *L. aurea* has recently been found with *Leiopelma* at 800 m in Whareorino forest (Bell 1993; Thurley & Bell 1994; Thurley 1996).

Associating frogs with water, many observers have thought that forest streams are the prime sites to search for native frogs. This is appropriate for *L. hochstetteri*, which occurs alongside forest creeks, in seepages, or in damp catchments above forest creek systems. However, the other three *Leiopelma* species are essentially terrestrial, occurring under forest and scrub, or on open ridges and mountain tops. *Leiopelma* species are essentially nocturnal, remaining under cover by day, except *L. archeyi* which is partially diurnal (Bell 1978a, 1982a,b, 1985b).

Searching for *Leiopelma*

Day searches

By day native frogs are most likely to be seen under the cover of retreat sites - rocks, logs, roots, ferns and other vegetation. However, during or after rain some *L. archeyi* may emerge by day and may be seen on the ground, or perched on nikau palm fronds or other vegetation. In some areas, sustained searches of hundreds of sites may be necessary to reveal a single frog even though they are known to be present. The varied and camouflaged patterning of native frogs, coupled with their relatively small size (up to 5 cm snout-vent length (SVL)) makes them difficult to see, especially in dark crevices under the forest canopy or along shaded creeks. A small hand torch is useful in such situations.

Night searches

Searches at night should preferably be done using a head-lamp, as described by Whitaker (1994) for night lizard searches. The reflecting tapetum of the eye of *Leiopelma* species results in a distinct pinkish eye-shine in the lamp beam. The 'headlight' eyes of the larger Stephens and Maud Island frogs are particularly noticeable. Eye-shine is most effective at middle distance, whereas frogs at close range are best located by direct observation in a torch beam. Weather conditions markedly affect the emergence of native frogs, particularly the terrestrial species which emerge most on mild, humid nights, especially when rain follows a long dry spell (Bell 1978a; Cree 1985,1989; Newman, Crook & Imboden 1978).

Best time of year to search

Native frogs can be searched for at all times of the year, although few are likely to be seen during night searches when it is dry and/or cold. Day searches can reveal frogs throughout the year. Creek beds are likely to attract more *L. hochstetteri* when adjacent areas are very dry, while fewer may be along the creeks during heavy rain and flooding. The late summer/early autumn period may be the most appropriate time for annual sampling, since breeding (in terrestrial species) should be mostly over by then, and the climatic conditions may not be too extreme. The *Native Frog Recovery Plan* proposed January-February as the best period in which to monitor *L. archeyi* and *L. hochstetteri* (Newman 1996).

IDENTIFICATION OF FROGS

It is important to ensure that frogs are accurately identified. Adequate keys for all the New Zealand frogs are available (see Bell 1982a; Gill 1986; Gill & Whitaker 1996). Information can also be found in the DOC Fact Sheet *New Zealand Native Frogs* (Department of Conservation 1995). It should be noted that these keys only relate to species known to have established in New Zealand. New species may be introduced to New Zealand at any time (e.g. the recent occurrence of the Cane Toad, *Bufo marinus* on the Wellington waterfront; a species of major concern in Australia -Thomson, Long & Horton 1987).

Leiopelma species

If the external eardrum (tympanum) is absent, the pupil more or less rounded, the thighs drab, and there are no loud breeding calls, then the frog is a native *Leiopelma*. The more robust *L. hochstetteri* has distinct webbing on the hind toes. The other extant *Leiopelma* do not have such webbing but do have a pronounced longitudinal parotoid ridge behind the eye. *L. hamiltoni* from Stephens Island is anatomically very similar to the Maud Island species, although it tends to be lighter coloured (Bell 1978a; Bell et. al., in prep.). Both these species are generally brown in colour, unlike the smaller *L. archeyi* which may be brown, green, or a mix of green and brown, pink or orange (Stephenson & Stephenson 1957; Stephenson 1961; Bell 1978a; Thurley & Bell 1994).

Litoria species

The three introduced *Litoria* species all have horizontal pupils and external eardrums, although in *L. ewingii*, the eardrum tends to be obscured by a dark brown longitudinal patch. -*L. ewingii*, the smallest of the three species (up to 47 mm SVL), is a brown frog with orange thighs and a repetitive cricket-like call. *L. aurea* and *L. raniformis* are heavier and larger (up to ca 90 mm SVL), green and gold in colour with blue thighs and loud croaking calls, which differ between the two species. *L. aurea* can usually be distinguished from *L. raniformis* by its lack of a mid dorsal stripe and more or less continuous pale dorso-lateral line (Courtice and Grigg 1975; Bell 1982a,b; Gill and Whitaker 1996).

EXAMINATION OF FROGS

Measurements

Measurements of frogs can provide information on age, sex, condition, growth rate and inter-population differences. While up to 19 individual body measurements have been used in some New Zealand studies, their collection can be very tedious and time-consuming. Normally only one or two measurements are necessary in general population work.

The standard measurement has been the snout-vent length (SVL), although in various studies the tibio-tarsus length, weight, and body girth or fatness (on a scale from 1=lean to 5=fat) are also recorded (e.g. Bell 1994). Weight or fatness values may result from a range of factors including level of food reserves, water retention and gravidity (females). Linear measurements are taken with vernier jaw calipers, preferably dial or digital models which can be read directly. Portable digital electronic balances and Pesola spring balances (0-10 g, 0-30 g) can be used for weighing native frogs, providing there is protection from rain and wind respectively.

Where the intention is to simply obtain an index of numbers, direct handling or measurement of frogs may be unnecessary or even undesirable. In such cases a visual identification of species, colour and approximate size can be made if required. A visual estimate of a frog's size can be made using a reference card on which frog outlines of different sizes are drawn. Such an approach was adopted in a recent assessment of frog numbers before and after a 1080 operation in Coromandel (Perfect and. Bell, in prep.).

Colour pattern

Recording frog colour and patterns allows comparisons of different areas and, if sufficiently detailed, may allow individual recognition. In population studies at Coromandel, Whareorino, Maud Island and Stephens Island three colour parameters were recorded: predominant colour, colour pattern and colour intensity (Stephenson & Stephenson 1957; Bell 1978a,1994; Thurley & Bell 1994; Bell 1995a; Bell et. al., in prep.).

Individual identification

If individual identification is a necessary facet of a population study, it is important that the method is applied consistently so that all individuals in the population can be reliably identified and statistical estimates of population size not compromised. Methods of mark-recapture population estimation are widely reviewed in the literature - see for instance Heyer *et al.* (1994) and Halliday (1996).

By taking photographs of individual *L. hamiltoni* on Stephens Island, Newman (1977,1990) was able to identify members of the study population from their individual colour patterns. More uniform colour patterns prevented such an approach in other areas. Maud Island and Coromandel individuals were identified by toe-clipping (Newman 1990, Bell 1994). An alternative approach, using the venation patterns in the eyes, is currently being investigated on Maud Island. Other methods include freeze-branding (Daugherty 1976) and possibly tissue-embedded transponders.

IMPACT OF STUDIES ON FROGS

All native frogs are protected under the Wildlife Act 1953 and can not be disturbed, handled or collected without the authority of the Department of Conservation. The extent to which native frogs are disturbed in a survey depends on its relationship to defined management and research objectives. A basic rule should be to restrict disturbance of frogs and their habitats to a minimum.

Trampling and crushing risk

When surveying native frogs (by day or night), care needs to be taken to minimise the risk of accidental trampling of animals, or the risk of crushing them beneath retreat sites (in litter or vegetation, or under logs or rocks). As the frogs are very cryptically coloured they are hard to see, even to the trained eye, and use of a hand-torch during day searches is recommended. Often their presence under a rock is only revealed by their movement, so every care is needed before replacing rocks or logs lifted in frog surveys.

Habitat deterioration

The very act of searching can modify their habitats, for instance the fern sites occupied by some *L. archeyi* in Whareorino forest (Thurley & Bell 1994) and rocks or rock piles occupied in this and other areas. In terrestrial sites, the rock pile habitats may have remained essentially undisturbed for decades, or even centuries. Lifting and rearranging them can considerably alter the frogs' micro-habitat, e.g. through drying out formerly moist cracks and crevices. It is important to lift rocks carefully and replace them in their former positions. Rocks not replaced properly often reveal whitish under-surfaces, which can readily attract other people to the site (this problem also occurs when feral pigs forage at such sites). Return the frog only after the retreat site is replaced to its original state.

Breeding site disturbance

Deep excavations of rock piles should be avoided as there is little chance of their being properly reconstructed. Eggs and young are prone to desiccation and potential predation if left exposed. If frogs are found on or near egg clusters or hatchlings, then providing there is no risk to the frog/s or progeny, cover should be immediately and carefully returned over the site, to avoid desertion of the brood (this has been done on study plots without damage or desertion by the adult frog).

Stress from handling

Handling of native frogs should be kept to a minimum and heat stress should be avoided (e.g. they should not be held within a clasped hand for more than 30-60 secs). If the frogs are not to be immediately processed, they can be placed in numbered plastic bags closed with twist-ties, each bag's number corresponding to a numbered plastic garden tag placed at the site of capture. Such bags should be kept in a cool site, and any held during the day should be placed in the dark or shade, away from the direct sun and covered with protective material if necessary.

Dead specimens

Following Whitaker's (1994) advice for lizards, if dead frogs are found, the site details should be recorded and specimens preserved for future research use e.g. sent to the Museum of New Zealand, PO Box 467, Wellington. The relevant site information to be recorded is: species (if known), date, collector, locality, grid reference, habitat, elevation and possible cause of death. Material can be frozen for temporary storage and then preserved in alcohol or formalin (preferably 70% ethanol), with the body cavity carefully opened ventrally for better preservative penetration. Note even decomposed or desiccated specimens can be of value as skeletons.

SURVEY METHODS FOR FROGS

To assist management of New Zealand frogs, a range of survey methods have been employed to provide basic population information on the different species. The various methods by which their distribution and numbers have been measured are discussed below. Note that the methods are not necessarily mutually exclusive and that they cover a broad spectrum from national distribution surveys, through local area surveys to intensive, more localised, population studies. Several survey methods are given here. Other survey methods can be found in Bibby *et al.* (1992 - for birds, but with some application to anurans), Heyer *et al.* (1994), and by Sutherland (1996a - which has useful reviews of basic ecological census techniques, particularly the articles by Greenwood and Halliday). When recording field data, use notebooks or, preferably, pre-prepared waterproof field-record forms that prompt you for the required data. Do not rely on your memory.

Twenty commonest censusing "sins"

Before initiating a survey, it is salient to remind yourself of Sutherland's (1996b) twenty commonest censusing "sins":

1. Not sampling randomly;
2. Collecting far more samples than can be possibly analysed;
3. Changing the methodology in monitoring;
4. Counting the same individual in two locations and counting it as two individuals;

5. Not knowing your species;
6. Not having controls in management experiments;
7. Not storing information where it can be retrieved in the future;
8. Not giving precise information as to where sampling occurred;
9. Counting in one or a few large areas rather than a large number of small ones;
10. Not being honest about the methods used;
11. Believing the results;
12. Believing that the density of trapped individuals is the same as the absolute density;
13. Not thinking about how you will analyse your data before collecting it;
14. Assuming you know where you are;
15. Assuming sampling efficiency is similar in different habitats;
16. Thinking that someone else will identify all your samples for you;
17. Not knowing why you are censusing;
18. Deviating from transect routes;
19. Not having a large enough area for numbers to be meaningful;
20. Assuming others will collect data in exactly the same manner and with the same enthusiasm.

National distribution surveys

National grid-mapping scheme

Turbott (1942) and Stephenson & Stephenson (1957) provide early information on *Leiopelma* distribution. Systematic surveys of both native and introduced frogs were initiated in the 1970's through the former Ecology Division of DSIR, and are now maintained by the Department of Conservation (e.g. Pickard & Towns 1988). The continued receipt of records of amphibians from all over New Zealand is important for determining their national distribution and assessing any changes that have taken place over time. Maps of sub-fossil *Leiopelma* records can be found in Worthy (1987); Bull and Whitaker (1975); Bell (1982b); Bell *et al.* (1985); Newman (1996); and Bell et. al.(in prep).

Local surveys

The methods described below are those used for local surveys of frog populations in New Zealand. They are arranged in increasing order of complexity, more time generally being required to establish and carry out the later methods.

Local area searches

Meandering local area day searches for frogs can be made within areas of frog distribution, and are economic in that no prior surveying is needed. They involve wandering around the selected search area without the use of measured transects or grids. The problem with this method is the difficulty of accurate replication by the same or a different observer.

Such searches can incorporate systematic recording to provide simple indices of numbers, thereby allowing comparison between areas and species. For instance, at the same sites at Tokatea, Coromandel, in 1973 and 1995, I collected data on the number of frogs found (1) per unit search effort (no. frogs/100 sites searched) and (2) per unit search time (no. frogs/hour) (Table 1). Such searches can also be used to collect simple data on habitat selection, such as the type of retreat site, or the wetness of the substrate there (Bell 1978a; Bell *et al.* 1985).

TABLE 1. COMPARISON OF SEARCH INDICES, TOKATEA RIDGE, COROMANDEL 1973 AND 1995.

	1ST SURVEY SEPT 1973	2ND SURVEY NOV. 1995
	No. sites searched	
Stones	1339	1367
Logs	49	5
Total	1448	1372
Search time (hours)	9.67	6.28
	No. of frogs located	
L. archeyi	12	23
L. hochstetteri	45	26
Total	57	49
	Site based search indices	
% sites with *L. archeyi*	.83	1.68
% sites with *L. hochstetteri*	3.11	1.9
% sites with frogs	3.94	3.57
	Time based search indices	
Mean *L. archeyi* /hour	1.24	3.66
Mean *L. hochstetteri* / hour	4.65	4.14
Mean frogs/hour	5.89	7.8

Note that where frogs are examined and measured, the time taken to process these frogs also needs to be recorded, so that the actual search time can be accurately determined and not over-estimated.

In the Motu catchment in 1981 and 1983, McLennan (1985) carried out day surveys of creek beds for *L. hochstetteri*, with a record being taken of the time spent searching, the stones and logs turned and the number of frogs found, as well as their distance from the water. Limited searches were also done at night, but few frogs were found; low or zero counts from night searches of *L. hochstetteri* were also recorded by Slaven (1992) and Bell (unpubl.).

Point sampling

McLennan (1985) estimated the [minimal] absolute density of *L. hochstetteri* in two small streams in the Motu catchment by positioning 31 quadrats (0.25 m^2)

at random points along their banks. All stones and loose debris within each quadrat were turned and the number of frogs found was recorded. The density of frogs in piles of stones at the foot of slips was also determined by measuring the area of each pile before searching began.

In a survey of *L. hochstetteri* in the eastern Bay of Plenty Shaw (1993) used a 10 minute search at a point every 50 m along a watercourse. With this approach only parts of the habitat are disturbed, and progress along the watercourse can be more rapid than continual searching.

Variable-length transect counts

Rather than a meandering local area search, frogs can be located in a more focused way by searching along line transects, whose length varies with site conditions.

In surveys of *L. hochstetteri* at 12 localities around New Zealand, Green & Tessier (1990) carried out general day searches under rocks besides streams, recording two measures of abundance: 1) frogs / 100 m of stream; and 2) frogs/hour. As the number of collectors varied (1-3), an adjusted measure of frogs/person-hour was also calculated.

Another approach is to record both the length of each transect and its habitat features using a standard recording form (as in surveys of *L. archeyi* and *L. hochstetteri* in Whareorino forest in 1991 and 1993 - Thurley & Bell 1994; Thurley 1996).

For the 1994 survey of *L. hochstetteri* near the Opotoki Field Centre, the emphasis was placed on the presence or absence of frogs. In this survey, all likely looking sites were searched, giving an almost continuous transect along some watercourses. All watercourses up to 1.5 m in width were searched (Shaw 1994).

Standard-length transect counts

A more formal base-line for assessing frog abundance is the standard length line transect, a method already used for studies of various *Leiopelma* species in New Zealand (Stephenson & Stephenson 1957; Perfect & Bell 1995) and proposed by the Native Frog Recovery Group for possible long-term monitoring of populations (Newman 1996). The linear distribution of *L. hochstetteri* along creek systems makes transect counts obviously suitable for this species, but it has been used for *L. archeyi* as well.

Moehau survey

The first recorded quantitative survey of *Leiopelma* was a linear transect survey for *L. archeyi* on Mount Moehau, Coromandel, in January 1956 (Stephenson & Stephenson 1957). They used a 20 yard (18.29 m) rope to mark each transect, with four observers searching two 1 x 20 yard quadrats either side of the rope. All moveable logs and stumps were lifted, and all vegetation carefully examined. Findings for each side of the rope were recorded separately in terms of body lengths, numbers and groupings of frogs, and colour patterns. They note that the time taken to examine an area of 20 square yards (16.72 m^2) was considerable, and that search time needs to be considered in any survey of this type. In total they surveyed sixteen 1 x 20 yard transects - four paired quadrats in a north-south direction, four in an east-west direction. Over the total sample area of 320 square yards (267.56 m^2), they found 40 frogs clearly dispersed as groups, finding overall 2.5 frogs/quadrat (20 square yards), 2.86 per group, and 0.875 colonies per quadrat. The estimated frog density amounts to 0.15 per m^2, or 1 frog per 6.69 m^2.

Hunua survey

To assess the impact of a 1080 operation on *L. hochstetteri* in 1994, McNaughton & Greene (1994) surveyed three streams in the Mangatawhiri catchment of the Hunua Ranges using a 200m transect along each stream bed. Each transect was then marked off at 25 m intervals, and stream features sketched. Locations of frogs were plotted onto these sketches during each count, and the same rocks lifted every count. The sites were counted at weekly intervals for three weeks before the 1080 drop and at weekly intervals for four weeks after the drop, plus one more count 18 weeks after the drop. Counts were made going upstream to avoid any frogs swimming downstream and being counted twice. Based on frogs found, the estimated densities of frogs in three streams were 6, 12 and 22 frogs per 100 m of stream.

Tapu survey

In a recent study of the impact of 1080 on *L. archeyi* and *L. hochstetteri* behind Tapu, Coromandel, transects were used as the main method of assessing frog numbers (Perfect & Bell 1995). Frog survey sites were chosen within (operation sites) and outside (control sites) the 1080 treatment area. Several 2 x 50 m marked transects were sited within and outside the 1080 area and searches for each species done at intervals of one month or more. Nine transects along five streams were established for *L. hochstetteri*, and six transects in two areas of ridge-top forest for *L. archeyi*. Some transects comprised multiple 50 m units, extending over 100 m or more, although the basic unit for comparison remained the 50 m transect. Searches for each species occurred on a single day to minimise climatically-induced variation. The age, condition and colour of each specimen were assessed visually. Search effort was recorded per unit time and per retreat sites searched (rocks, logs and vegetation). Indices of frog numbers were provided by (i) the number found per unit search time, (ii) the number found per unit sites searched and (iii) the number per 50 m transect (Perfect & Bell 1995; Perfect in prep.). Frog numbers before and after 1080 treatment were compared using statistical analyses. Initial results are given in Figure 1.

Extensive grid surveys

A grid search approach involving a series of sample points across a surveyed sampling grid can reveal more detailed information on relative numbers of frogs across a given area of habitat. An extensive grid covers a wide area of habitat, hectares rather than square metres in extent.

Maud Island survey

An extensive grid survey was used in 1993 to measure the distribution pattern of the Maud Island frog across 17 ha of its main forest habitat. A series of 17 parallel sampling lines 20 m apart were surveyed, each line comprising a search path 1 m wide with a 2 m^2 recording plot every 20 m. This allowed mapping of frogs (Figure 2) and habitat features on a 20 x 20 m grid (Bell & Bell 1994; Bell 1995a).

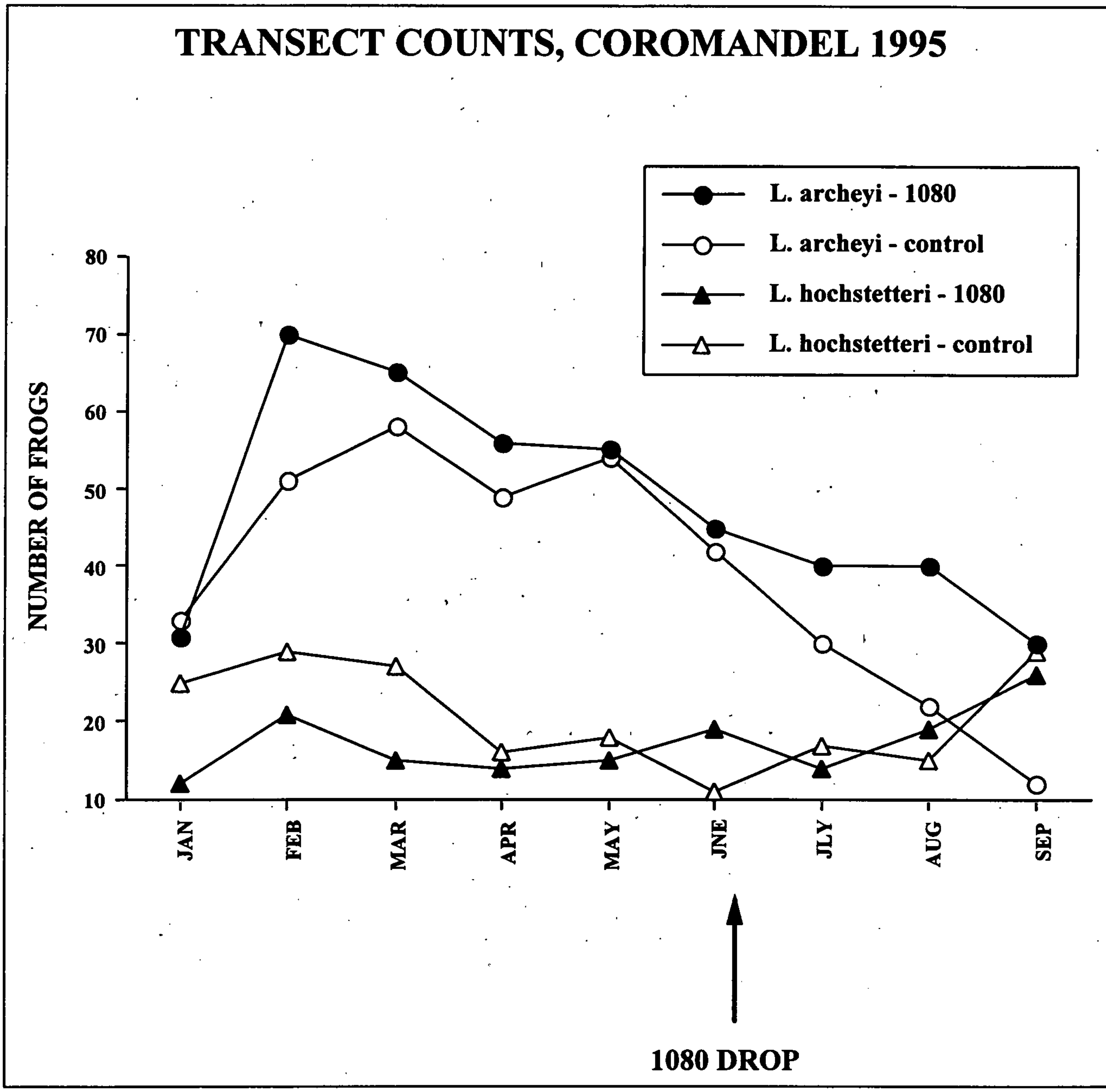

FIGURE 1. SUMMARY OF MONTHLY FIELD SURVEYS ALONG TRANSECT LINES IN COROMANDEL (AFTER PERFECT & BELL 1995).

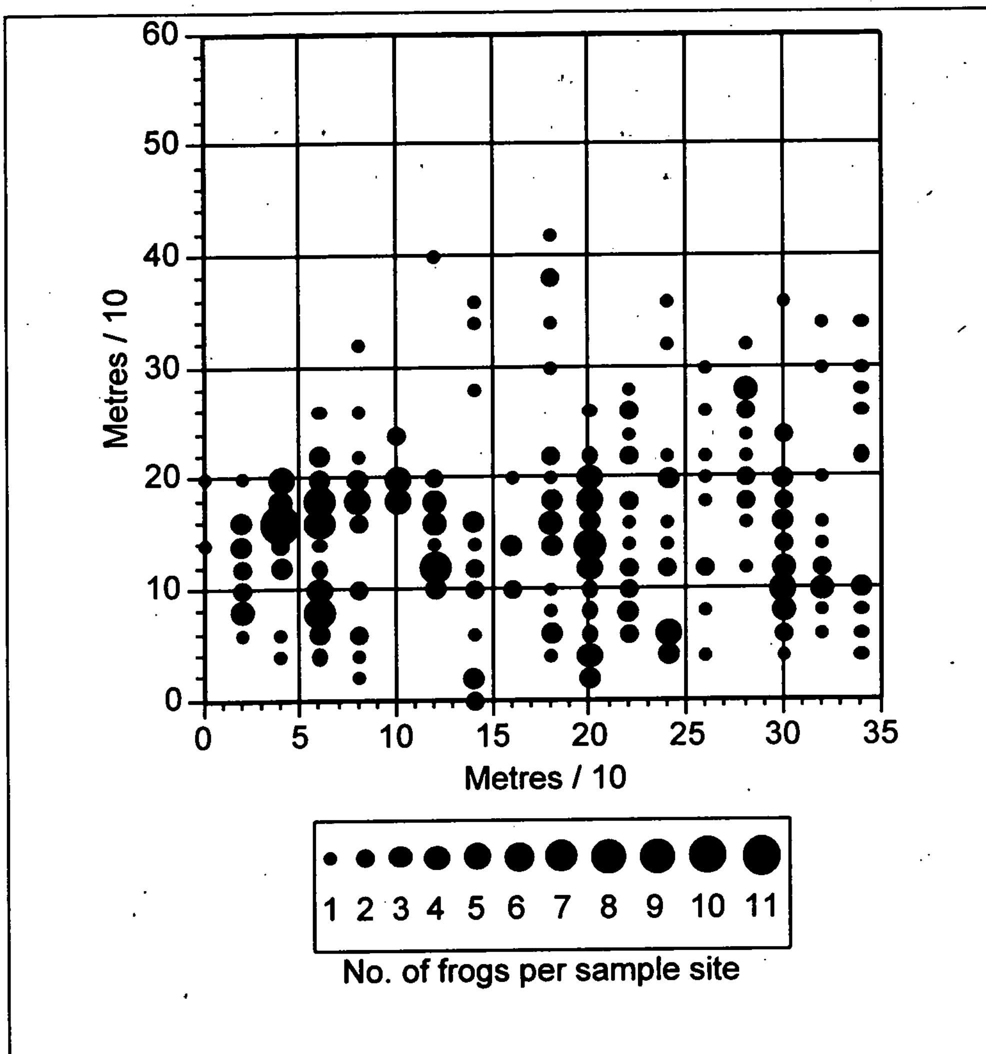

FIGURE 2. DISTRIBUTION OF THE MAUD ISLAND FROG WITHIN ITS MAIN FOREST HABITAT (AFTER BELL & BELL 1994, BUT COMBINING DATA FOR TWO SAMPLING VISITS).

Intensive population studies

Intensive population studies involve more time and effort and are generally focused on a much smaller study area. They provide basic demographic data on the study populations, typically involving a mark-recapture approach, coupled with documentation of frog sizes, colours and movements within the study area. Such intensive studies provide information on individual life-histories, population size, growth rates, longevity and survivorship, individual ranges and movements. They are generally carried out over many years, especially since individual *Leiopelma* may live for 25 or more years (Bell 1994, unpubl.). Intensive studies carried out in New Zealand comprise studies of *L. hamiltoni* on Stephens Island (Newman 1990; Brown 1994; Thomson 1996), the Maud Island frog (Newman 1990; Bell 1994), *L. archeyi* (Bell 1994); and *L. hochstetteri* (Slaven 1992).

Transect-based population studies

Maud & Stephens Island board-walks

To minimise the effects of disturbing and trampling on Stephens and Maud Island study sites, raised wooden plank walkways were constructed across rocks and more open ground (Newman 1990, Bell 1994; Brown 1994; Thomson 1996). On Maud Island Newman used strip transect searches totaling 40 m^2 on each of two 100 m^2 study plots. On Stephens Island a transect walkway was used to access part of the "frog-bank" habitat (Newman 1990, Fig. 3; Brown 1994, Fig. 2). The walkways were numbered to provide frog observation reference points, while horizontal wooden battens and chicken wire were used to reduce risks of the operator slipping on steeper walkways on Maud Island.

Gold Cross *L. hochstetteri* study

A mark-recapture study of *L. hochstetteri* was carried out along adjacent streams 75 - 194 m in length near Gold Cross, South Coromandel over 1989-1991 (Slaven 1992) and these sites have recently been re-surveyed (A.H. Whitaker, pers. comm.).

Grid-based population studies

Grid-based population studies have been used to study the Maud Island frog (night searches) and *L. archeyi* in Coromandel (day searches). These studies provide long-term, comparative demographic information (Table 2), as well as data on movements and condition (Bell 1994, Bell 1994,unpubl.).

Maud Island night search grids

On Maud Island, two 12 x 12 m study grids were searched on 4-6 successive nights at roughly bi-annual intervals since 1983. Over 24 visits (1983-1993) 966 frogs were captured on one grid and 1890 on the other, comprising 188 and 510 individual frogs respectively (Bell 1994).

Tapu day-search grid

In Coromandel, a 10 x 10 m ridge-top study plot was established at Tapu, and frogs were located using day searches under rocks, logs and other ground cover (each search taking a day to complete). Over 12 visits (1982-1993) 766 frogs were captured, comprising 525 individual *L. archeyi* and 4 *L. hochstetteri* (Bell 1994).

Pit-fall trapping and other techniques

Pit-fall trapping has not been extensively employed for frog research, despite its potential value as a technique that can minimise observer search bias and the risk of crushing frogs under stones or logs. Small frogs have been taken in pitfall traps set for invertebrates on Maud Island (D.G. Newman, E.A. Bell, pers. comm.).

The use of pit-fall trapping should be explored further for *Leiopelma*, as it removes potential observer bias, providing frog safety is assured. The technique has most potential for surveys of terrestrial species of *Leiopelma*, although the ability of the frogs to successfully escape from unset traps would have to be carefully evaluated. The method could prove more of a problem in the creek-side habitat of *L. hochstetteri,* due to risks of sudden flooding and a high water-table in the substrate in which the traps are placed.

TABLE 2. DEMOGRAPHIC COMPARISONS OF FROGS ON MAUD ISLAND AND COROMANDEL SAMPLING GRIDS 1983-1995 (PRELIMINARY DATA AFTER BELL AND PLEDGER, IN PREP.).

	MAUD ISLAND FROG		ARCHEYS FROG
	GRID1	GRID2	TAPU GRID
No. sampling visits	26	26	13
Mean sample size	39	78	69
Total no. individuals caught	199	539	578
Mean probability of capture	0.41	0.32	0.17
Mean population	100	257	450
Mean survival rate (Jolley-Seber model)	0.98	0.95	0.75

POPULATION MANIPULATION

The previous methods of study have involved only enough disturbance necessary to obtain required data on the study populations. In some areas of conservation management it is necessary to manipulate populations in a more intrusive way, at least initially.

Population translocation

Kapiti Island

The first recorded translocation of native frogs was 15 individuals taken to Kapiti Island from Coromandel in December 1924 (13) and March 1925 (2). The liberations, in the Kahikatea catchment behind Rangatira Point were evidently unsuccessful as no frogs have been recorded there despite searches since 1975 (Bell 1985b). Although reported by A.S. Wilkinson at the time to be *L. hochstetteri*, the frogs were possibly *L. archeyi* (Bell 1985b), a species not described until much later (Turbott 1942).

Maud Island

On Maud Island an experimental frog translocation to Boat Bay was carried out over 1984-85 to expand the range of the species on Maud Island and to simulate an island-to-island transfer. 100 frogs were translocated and all were released at the same site in a rocky scree under regenerating forest (Bell 1994). The first release of 43 was in May 1984. After confirming good survival of this first group of frogs, the final 57 were liberated in May 1985. A representative cross-section of age/size classes was transferred to Boat Bay, though the sample was biased in favour of frogs in the 34-40 mm snout-vent length range. Frogs over 40 mm are more likely to be females (Bell 1978a). Not all frogs in the 34-40 mm range will be adult males; some will be smaller adult females. After release, most of the frogs relocated were in the boulder area within 10 m of the liberation site, though one individual moved approx. 25 m to an alternative boulder area.

Individual frogs generally settled into discrete home ranges, and ten locally recruited young frogs have been found there (Bell 1994).

Island-to-island translocation of the Maud Island frog is planned for the near future to an appropriate predator-free site in the Marlborough Sounds, following surveys of potential destination islands (Bell 1995b; Newman 1996). Towns *et al.* (1990) advise on appropriate protocols for such island transfers.

Stephens Island

The latest frog transfer was on Stephens Island in May 1992 when 12 adult frogs were moved from the frog "bank" to rocks in an artificially created frog "pit" under native forest 40 m away (Brown 1994). A yearling was seen at the site in October 1996 (D.G. Newman, pers. comm.).

An island-to-island transfer for *L. hamiltoni* would need many more than the 12 moved to the frog "pit", so is premature at present since numbers remain very low (Newman 1990; Brown 1994; Thomson 1996).

Captive maintenance

All four extant species of *Leiopelma* have been bred in captivity, including *L. archeyi* from both Coromandel and Whareorino (Bell 1977, 1978a, b, 1982a,b, 1985a, b, 1993; Thurley & Bell 1994). A captive population of *L. hochstetteri* has also been maintained in North America, although no breeding has occurred (Sharbel & Green, 1992). Maud Island frogs were previously held at the Mount Bruce National Wildlife Centre.

In successful captive breeding programmes near Wellington, emphasis has been placed on the study of reproduction and development, and on breeding the rarer *L. hamiltoni* and Maud Island frogs. Young of these species have been reared up to 2 years of age, with one *L. hamiltoni* being reared to adulthood (Bell 1985b, unpubl.; Newman 1996). All terrestrial species breed well in suitable captive conditions, and it was in such colonies that the pattern of male parental care and dorsal brooding was discovered (Bell 1985a). Our limited knowledge of reproduction in *L. hamiltoni* and the Maud Island frog is based primarily on studies of captive frogs. Regular breeding of *L. hochstetteri* has been more problematical, evidently due to difficulties in replicating its natural breeding habitat in captive enclosures (Bell 1985b).

Sufficient knowledge has now been gained to allow more conservation-oriented captive breeding programmes to be initiated. Breeding programs should now be considered for the more endangered *L. hamiltoni*. For other species, captive breeding could be considered if natural populations are placed at greater risk - e.g. through colonisation of Maud Island by rats, or through marked decline of relict mainland populations, such as Whareorino *L. archeyi* (Bell 1994; Thurley & Bell 1994).

THE NEED FOR STANDARDISED METHODOLOGY

This review of methods used to study frogs in New Zealand exposes the wide range of approaches that have been adopted to date (Table 3).

Long-term monitoring of *Leiopelma* species should be more formally established in New Zealand. Monitoring of introduced *Litoria* species is also needed as some pose a threat to our endemic *Leiopelma* species, or are threatened in their country of origin (Bell 1994; Thurley & Bell 1994).

Recognising the need for standardisation of such long-term monitoring techniques, in November 1994 the Native Frog Recovery Group determined to make recommendations for standard methods of monitoring which were presented in the *Native Frog (Leiopelma spp.) Recovery Plan* (Newman 1996), in which it is noted (Appendix 2) that "Techniques most appropriate to specific circumstances should be decided upon by the recovery group in consultation with the DoC Conservancies concerned".

TABLE 3. SUMMARY OF METHODS USED TO STUDY *LEIOPELMA* POPULATIONS IN NEW ZEALAND. SEARCHES CARRIED OUT AT NIGHT ARE SHOWN IN BOLD.

TYPE OF SURVEY	TARGET SPECIES	LOCATION	REFERENCES
NATIONAL SURVEYS			
Distribution mapping (1988)	All frog species	New Zealand	Bell (1982a), Pickard & Towns (1988)
	Sub-fossil *Leiopelma*	New Zealand	Worthy (1987)
	Extant *Leiopelma*	New Zealand	Bell (1994)
LOCAL SURVEYS			
Local area searches	*L. archeyi / L. hochstetteri*	Coromandel	Bell (1978a)
	L. hamiltoni	**Stephens Island**	**Bell (1978a)**
	Maud Island frog	Maud Island	Bell (1978a)
	Maud Island frog	**Maud Island**	**Bell (1978a)**
	L. hochstetteri	Motu, East Cape	McLennan (1985)
	L. archeyi / L. hochstetteri	Whareorino	Bell (1993)
Point sampling	*L. hochstetteri*	Motu, East Cape	McLennan (1985)
	L. hochstetteri	Bay of Plenty	Shaw (1993)
Variable-length transect	*L. hochstetteri*	N. New Zealand	Green & Tessier (1990)
	L. archeyi / L. hochstetteri	Whareorino	Thurley & Bell (1994), Thurley (1996)
	L. hochstetteri	Opotiki	Shaw (1993)
Standard-length transect	*L. archeyi*	Mount Moehau	Stephenson & Stephenson (1957)
	L. hochstetteri	Hunua Ranges	McNaughton & Green (1994)
	L. archeyi / L. hochstetteri	Tapu, Coromandel	Perfect & Bell (1995)
Extensive grid survey	**Maud Island frog**	**Maud Island**	**Bell & Bell (1994), Bell (1995a)**
POPULATION STUDIES			
Transect-based	***L. hamiltoni***	**Stephens Island**	**Newman (1990), Brown (1994)**
	Maud Island frog	**Maud Island**	**Newman (1990)**
	L. hochstetteri	S. Coromandel	Slaven (1992)
Grid-based	**Maud Island frog**	**Maud Island**	**Bell (1994)**
	L. archeyi / L. hochstetteri	Tapu, Coromandel	Bell (1994)
POPULATION MANIPULATION			
Translocations	*L. hochstetteri (? L. archeyi)*	Kapiti Island (1924-1925)	Bell (1985b) after A.S. Wilkinson
	Maud Island frog	Maud Island (1984-1985)	Bell (1994)
	L. hamiltoni	Stephens Island 1992	Brown (1992)
Captive maintenance	*L. archeyi*	Coromandel	Bell (1977, 1978a,b, 1982a,b, 1985a)
	L. archeyi	Whareorino	Bell (1994), Thurley & Bell(1994)
	L. hochstetteri	Coromandel	Bell (1985a,b)
	L. hochstetteri	Coromandel	Sharbel & Green (1992)
	Maud Island frog	Maud Island	Bell (1982a,b 1985a,b), DOC, (Mount Bruce unpub.)
	L. hamiltoni	Stephens Island 1992	Bell (1982a,b 1985a,b)

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