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GUIDELINES TO THE DEVELOPMENT AND MONITORING OF ECOLOGICAL RESTORATION PROGRAMMES

by

I.A.E. Atkinson

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by
I.A.E. Atkinson
Ecological Research Associates of N.Z. (Inc.), PO Box 48-147,
Silverstream, Upper Hutt, New Zealand

ABSTRACT

Ecological restoration is defined in relation to other management actions, and a distinction made between "restoration" and "protection". An assessment of the Department of Conservation's current restoration programmes considers their extent, goals and objectives, methods, monitoring, problems, and successes.

Examples of goals and objectives for monitoring programmes are suggested. Priorities for restoration programmes include geographic and community/ecosystem priorities, and those associated with restoration goals. Developing an effective programme involves a critical path for planning, relating to other activities within the Conservancy, data collection and programme design, and restoration plans covering a minimum of five years.

Success of a programme can often not be judged until the final phase of the programme, but progress and success can be measured by the achieving of some specific objectives that can be quantified. Criteria should be decided at the time the programme is initiated. Systematic monitoring is necessary, but the process should be kept simple so monitoring is not disrupted by changes in staff.

1. INTRODUCTION

Restoring biological communities to an earlier condition is usually labour-intensive and costly. Thus it is imperative that goals are defined, suitable criteria for measuring success are applied, and all procedures are robust, both practically and scientifically. Failure to monitor steps and rates of progress in a restoration programme may result in loss of significant information that could avoid further mistakes or enable successful programmes to be repeated.

This report provides some guidelines for maximising the biological effectiveness, and therefore the cost effectiveness, of terrestrial restoration programmes undertaken by the Department of Conservation. It is concerned mainly with principles. Helpful information on operational details relating to provenance of plant material, seed collection, nursery propagation and planting can be found in the publications of Godley (1972), Benecke *et al.* (1975), Forest Research Institute (1980a,b), Evans (1983) and Timmins & Wassilieff (1984). Procedures for species recovery and many other aspects of ecological restoration are discussed in *Ecological Restoration of New Zealand Islands* (Towns *et al.* 1990).

2. OBJECTIVES

- To develop criteria for measuring the success of restoration projects.
- To develop procedures that allow more than one restoration technique to be tested.
- To develop scientifically robust procedures for monitoring and documenting the "success" of restoration experiments.
- To develop national guidelines for defining appropriate restoration goals and procedures applicable to a wide variety of New Zealand environments.

3. METHODS

Features of successful restoration programmes were reviewed, both those overseas and those in New Zealand. Successful programmes were identified by the extent to which originally defined goals for restoring the structure and composition of particular biotic communities had been achieved. Outstanding overseas examples are that of Guanacaste National Park in Costa Rica (Janzen 1986) and Nonsuch Island in Bermuda (Wingate 1985). One of the more successful New Zealand examples is that of Cuvier Island, Hauraki Gulf (Veitch 1989). From this review it was possible to identify features that had contributed significantly to success as well as develop criteria for its measurement.

A questionnaire was sent to all Conservancy Advisory Scientists requesting details of current restoration programmes in which the Department of Conservation has at least some involvement (Appendix 1). Questions were asked relating to monitoring procedures, problems encountered, and successes achieved. The practicalities of using experimentation in restoration programmes were examined in the light of results from this questionnaire.

4. DEFINITIONS

4.1 Ecological restoration

Restoration in the context of nature conservation includes a range of management activities, some of them ill-defined. For the purpose of this study, *ecological restoration* is defined as management that aims to restore particular biotic communities to a condition more like that of a selected time period in the past. It is concerned with both animals and plants as parts of self-maintaining communities and is therefore system-orientated rather than species-oriented. However, attention to the ecological requirements of individual species, both the dominant plants and animals, and other less common species, is essential for success with restoration. Furthermore, improving the chances of survival for some threatened species often requires re-establishment of suitable habitats. Here, the goals of community and species management coincide.

It should be noted that reference to "a selected time period" in the above definition acknowledges that any past system we seek to imitate will always have been in a state of changing structure and composition. The aim is not to establish communities of narrowly defined composition as static glimpses of the past. It is to re-activate the major successional processes likely to have operated during the selected time periods and within the physical conditions (site factors and climate) specified for each restoration programme. The definition of ecological restoration given by Atkinson (1988:1) may not give sufficient emphasis to the dynamic nature of the systems we are attempting to restore.

4.2 Distinction between restoration and protection

How does restoration differ from protection? Control of mammalian browsers and predators, or of problem weeds, is often necessary to prevent degradation of ecological systems we value. This is an example of protection with the expected outcome that natural restorative processes, such as plant and animal succession, will be sufficient to halt or reverse the degradation. However many systems are so altered, particularly by loss of species or changed physical conditions, that no amount of control work will restore these species or conditions. If sufficient value is attached to restoring a particular system to something more like its former condition, then *active intervention to reinstate the lost species or lost physical conditions (e.g.* a former water-table regime) will be needed. It is this additional kind of intervention that distinguishes ecological restoration from protection. When the distinction is made, it focuses attention on the goals of the programme and enables funding for restoring something of the past to be separated from that required to maintain the *status quo.*

Both protection and restoration can be labour-intensive but some kinds of protection can be applied to large areas. With ecological restoration there are needs for continuing intervention over a considerable period of time and for regular monitoring of progress. Much of this work must be conducted in a site-specific manner. These needs place substantial constraints on the size and kind of place than can be used for restoration.

Restoration without human intervention is widespread. It results from normal regeneration and successional processes in which, with the passing of time, species of both native and alien plants and animals replace each other at a site. Restoration programmes should always aim to complement whatever natural regeneration of plants and animals is taking place rather than attempt to substitute for it.

4.3 Rehabilitation

The original ("Latin") meanings of *rehabilitation* and restoration are identical. However the emphasis in rehabilitation work has been to replace lost vegetation, often with something generally similar, but with no particular aim of re-instating a system from a former time period. Where eradication of a pest species is possible, such as on an island or fenced-off mainland peninsula, natural regeneration of plants may be sufficient to rehabilitate the area without further intervention.

4.4 Revegetation

Because ecological restoration sometimes requires planting, there can be confusion between revegetation and restoration. *Revegetation* involves re-establishing a plant cover of some kind: indigenous, exotic, or mixed. It may be done for a variety of purposes, such as erosion control, stabilising batters along roadsides or canals, re-establishing plants on mining sites, or beautifying an unattractive area. There may be no particular need to restore the plant cover to a former state.

In one respect, ecological restoration is a specialised kind of revegetation; in another, it goes beyond revegetation because of the interest in animals. Soil restoration emphasises soils; land restoration emphasises physiography, vegetation and soils; ecological restoration includes animals as well as physiography, vegetation, and soils.

4.5 Recovery

Recovery has also been used in an ecological context. The term has in recent years become particularly associated with species recovery plans. A recovery programme for a threatened species is something that can stand on its own, but it may often involve restoration of a biotic community as habitat essential for the species.

4.6 Enhancement

The term *enhancement is* often used loosely, but in an ecological context it refers to an increase in the quality or quantity of some characteristic of a site or area. Whether this results in an improvement on the previous condition can be a subjective judgement.

4.7 Ecological engineering

It is possible to establish new combinations of plants and animals, both native and exotic, as biotic communities for conservation purposes; for example, as habitat for a threatened species. The extent to which some pine forests have been used by kiwi highlights the potential of this kind of management which I have elsewhere called *ecological engineering* (Atkinson 1990:85).

- ***Distinguish between management action that is primarily protective (maintaining the status quo) and that which is primarily restorative (adding to the existing system.***
- ***Distinguish ecological restoration (restoring former biota and physical conditions) from other restorative action (rehabilitation, species recovery, ecological engineering, etc.).***

5. DEPARTMENT OF CONSERVATION RESTORATION PROGRAMMES

Included here is information relating both to DoC's restoration programmes and those in which the Department has at least some involvement. The information is derived largely from that supplied to the writer by conservancies (Appendix 1). Further information is derived from Conservancy Business Plans and from the writer's knowledge of particular programmes. The results are summarised in Appendix 2.

A large amount of protection work throughout the DoC estate involves control or eradication of problem weeds and pest animals. I have not included information on these projects in Appendix 2 unless they are associated with further restorative action such as planting, i.e., are compatible with the definition of ecological restoration given in Section 4. This exclusion is not to be taken as a discounting of the immense value of this kind of protective action when properly executed. It is done to focus attention on ecological restoration itself, a specialised management action that involves small areas compared with the areal extent of protective action against weeds and pests.

6. ASSESSMENT OF DEPARTMENT OF CONSERVATION'S RESTORATION PROGRAMMES IN PROGRESS

All conservancies responded to the short questionnaire concerning restoration programmes (Appendix 1). A number of programmes suggested as restoration programmes were excluded because they appeared to have rehabilitation as the primary aim. Goal statements were not requested and the fact that goals and objectives were often not included in the returns should not be taken to mean that none existed. In some cases goals could be inferred from other information supplied. Other criteria used in making this brief assessment were evidence of systematic monitoring, acknowledgement of difficulties, evidence of successes, and the extent to which an experimental approach had been used.

6.1 Extent of restoration activity

A total of 45 restoration programmes are listed in Appendix 2, giving an average of 3.2 programmes/conservancy. Restoration work on islands usually includes a range of community types (not separated in Appendix 2). Treating island restorations as a single class, these programmes (33%) and restorations of mainland forests (22%) are the largest components of restoration activity in the country. However, many other kinds of restoration are in progress: dunes (16%), wetlands (11 %), riverbeds and river margins (2%), estuaries and estuary margins (2%), lakes and lake margins (5%), scrub and shrubland (5%), subalpine communities (2%), and cliffs (2%).

6.2 Goals and objectives

Restoration goals were seldom clearly identified, and this was widely acknowledged and regretted by respondents to the questionnaire. Islands exemplify this problem. I have not suggested goals for any particular island restoration in Appendix 2 as this may pre-empt the discussion between interested parties needed to reach a satisfactory decision on these goals. It should be made clear that categorising an island as a "restoration island" in the functional scheme suggested by Atkinson & Towns (in Atkinson 1990) is not a statement of a restoration goal. If this scheme is followed, the questions that must be asked are: "In which direction is the restoration aimed? Is it towards the refuge or minimum impact categories, or towards open sanctuary or multiple use categories?" A parallel but more varied range of uses applies to mainland restorations.

All restoration programmes described are associated with at least some specific objectives. Most frequently, these give the broad category of system to be restored, some target species required, and species of alien plant or animal to be controlled or eradicated. An historic time period for the restored community is usually not mentioned unless it is replacement of something still present on adjacent land, as at a mining site. Control of water tables are regularly listed as crucial objectives for restoring wetlands. Downstream effects are mentioned in only one programme.

6.3 Methods for restoration

The dominant method is planting. One respondent expressed the view that emphasis on planting was at the expense of other restoration techniques. Little research appears to have been done on how processes of normal regeneration of native plants can be accelerated or reinforced so that the planting effort can be reduced. Where, however, communities are being restored *de* novo to a landscape that has lost its native cover and seed sources, there is no substitute for a vigorous planting programme.

Some respondents expressed a need for more information about restoration methods, particularly those for non-forest communities, including wetlands, and soil conditions that affect the restorative process. Although not mentioned in the replies, the role of grazing animals and alien weeds during restoration of modified tussocklands is a complex issue for which we still lack reliable guidelines. There is a need for a central information centre within DoC where experience with various methods can be stored and retrieved easily (cf. 13.1).

6.4 Monitoring

In most conservancies there are no formal procedures for monitoring restoration programmes. A great deal of informal monitoring as well as some systematic monitoring (particularly of threatened species dependent on restoration programmes) is taking place. Without studying the details of individual monitoring programmes, no comment can be made on the quality of monitoring in relation to its purpose. It is apparent from the questionnaire returns that in most programmes only one or two parameters are being monitored.

6.5 Problems

Alien plants and animals, as well as climatic extremes, have caused problems, not all of which were readily predictable. With dunes, for example, exclusion of stock is not necessarily sufficient to allow effective restoration; exclusion of hares or rabbits is often necessary as well. Problems with inexperienced volunteers have sometimes arisen but are more easily cured than those associated with alien organisms. An occasional problem has been lack of effective communication between parties with interests or involvements in particular programmes.

As could be expected, the most widespread problem was seen as lack of secure funding for restoration work, including funding for maintaining programmes already well advanced. This comment was often made as a generalisation rather than related to particular programmes. It was sometimes associated with a perception that restoration is under-rated by the Department. Whether this is actually so is not known to the writer but, whatever the funding, restoration work is regularly identified under two key output classes in Conservancy Business Plans.

6.6 Successes

The data in Appendix 2 suggest that successes with planting efforts far outweigh failures. Some efficient plant nurseries have played a significant part in these successes. Some threatened species are recovering their numbers as a direct result of habitat restoration programmes. Public support for particular programmes is strong.

The lack of practical criteria for measuring successes in a quantitative manner is almost certainly obscuring both the extent of progress and some of the real successes achieved. Section 10 lists criteria available to improve this situation.

6.7 Trials and experiments

Only three programmes appear to have used either trials or replicated experiments to test alternative restoration procedures. These were the replacement of *Pinus contorta* stands at Erua, the habitat restoration on Mangere Island, and the limited trial on Mana Island (Timmins *et al. 1988).* The Erua trials involve a test of different combinations of release weeding and planting densities, the Mangere Island work is testing different combinations of weeding and fertiliser, and the Mana Island trial is testing suitability of several plant species for less favourable sites. Trials and experiments are discussed in Section 12, but it is apparent that opportunities to test more than one technique for restoring particular systems are generally not taken.

7. GOALS AND OBJECTIVES FOR RESTORATION PROGRAMMES

7.1 Goals

Goals for restoration should state the primary long-term aim of the programme. They determine the kind of areas selected, or are determined by the kind of area available. They influence the kinds and magnitudes of resources allocated. They are the raison d'etre for the whole programme, and failure to identify them clearly will place the enterprise in jeopardy.

Some widely recognised restoration goals are suitable as national guidelines:

- Reconstructing biotic communities that have been lost from the landscape.
- Repairing damaged communities where protective measures have proved inadequate.
- Providing essential habitat for threatened or potentially threatened species.
- Conserving genetic variation of native plants and animals, particularly of common species.
- Providing educational opportunity/scientific study, i.e., restoration activity used as an educational tool or as a source of new information.
- Providing recreational/aesthetic benefits that may extend in certain circumstances to nature tourism.

Most restoration programmes are likely to be driven by several goals.

7.2 Relationship between goals and choice of site

Some goals place narrow limits on the kind of area, i.e., sites, that can be selected: at one extreme, for example, sand dune or swamp communities cannot be reconstructed on inland ridges; the habitat requirements of a threatened plant or animal species may also be tightly constrained by some major factor, such as freedom from alien herbivores or predators. Almost any restoration programme is likely to have educational, scientific, or recreational benefits; it is only a matter of deciding whether any of these three categories of goals should receive the greatest emphasis.

Site characteristics such as altitude, distance from the coast, exposure, slope, aspect, soil depth, fertility and drainage, interact with the available plants and animals to determine the way in which the restored community develops. The available plants and animals can be strongly influenced by intervention whereas the physical factors listed can only be manipulated in a limited way. Thus at an early stage in any restoration programme, it is necessary to identify, and if possible map, the range of sites available. Proper site characterisation is too often neglected in restoration work.

A first approximation of the sites present in an area selected for restoration can be reached by delimiting the landforms present. A useful approach is combining ground observation with study of aerial photographs and a landform classification of the type developed by Atkinson (1992), see Appendix 3.

7.3 Objectives

Major goals have to be re-cast as specific objectives before they can be implemented. These objectives can be generated by answering the following questions:

- What kind of biotic community is to be reconstructed or repaired?
- What time period is the community to represent? Replacement of the present state (after destruction), post-1950, 1850-1900, 1600-1800?
- What major component species of plants and animals will need to be established to achieve the restoration?
- What other species of plants or animals will need to be established so that the goals of the programme, as well as the above objectives can be met? (Note that a complete species list is not essential).
- What alien species of plants or animals will need to be controlled or eradicated to achieve the restoration; or what alien species will be acceptable in the restored community without disruption of its functioning? For example, restoration of a community to the condition it might have been in during a post-European, pre-ungulate/possum period, would be a system that still contained pigs, cats, and Norway rats.
- What native species of plants or animals will require control to achieve the restoration?
- What physical or chemical conditions will need to be created or modified to achieve the restoration? Factors of slope angle, slope length, water table, drainage, and availability of nutrients may require modification.
- What effects, either downstream or on immediately adjacent land, are likely to develop as a result of the restoration programme?

- ***Identify the major goals of the restoration programme and relate these to the kinds of site available.***
- ***List the specific objectives that must be implemented if major goals are to be achieved.***

8. PRIORITIES FOR RESTORATION

Priorities can be approached from at least three standpoints: geographic, community/ ecosystem, and particular restoration goals.

8.1 Geographic priorities

Lowland areas of New Zealand (<300 m a.s.l.) have suffered greatest losses of native communities. Areas of almost complete clearance for agriculture are centred on the Waikato basin, western Taranaki, the Manawatu lowlands, Wairarapa-Hawke's Bay, eastern Marlborough, Canterbury, Central Otago, and parts of Southland. Within these broad areas there are a few places with soils of low agricultural value, particularly stony soils, where restoration of lost native communities would be possible. Leaving aside the educational value of such ventures, a major benefit of restoration programmes in the lowlands would be the opportunities they would create for protecting lowland genetic variants of many common plant and animal species.

8.2 Community/ecosystem priorities

Numerous statements have been published listing priorities for protecting remnants of native communities. In some conservancies specific priorities have been identified by the Protected Natural Area Programme. Priorities for protection invariably draw attention to a more limited number of places where protection by fencing, and alien mammal or problem weed control should be supplemented by planting, and sometimes re-establishment of lost or dwindling species, i.e., where restoration should become the major goal.

The kinds of community or ecosystem most often identified for protection are estuaries, dunes and other kinds of coastal community, lakes, wetlands, braided rivers, lowland forest, and grazed tussocklands. Examination of the kinds of restoration programme currently active in the DoC estate (Section 6.1) reflects these priorities reasonably well, given that nearly 80% of the country was originally covered by forest. However, one kind of community that appears to be under-represented is lowland tussockland, possibly a reflection of the difficulties inherent in restoring these systems.

8.3 Priorities associated with restoration goals

Both priorities and restoration goals have in the end to be acknowledged as matters of value judgement. They cannot be resolved by scientific or economic analysis even if these approaches have a role to play. However, if a yardstick of safeguarding available options is used as a guide, one of the goals listed in Section 7 can be seen as of crucial importance: that of providing essential habitat for threatened or potentially threatened species. Failure of a programme to reconstruct a lost biotic community or repair a damaged one still leaves options for making further attempts. Failure to save a species from extinction is a permanent reduction of options: loss of the species itself, and restriction of the quality of future restorative work as a consequence. Although some will argue that losing a few high-profile species is less important than losing distinctive kinds of community, this is not a valid comparison. Providing essential habitat for a high-profile species invariably provides habitats for numerous other species and is itself restoring a distinctive kind of community. A similar argument applies to the goal of conserving genetic variation of native plants and animals, particularly of commoner species.

Most restoration programmes are driven by several goals. If the national need to retain as much as possible of genetic variation at the species and subspecies levels is recognised, other priorities can be more strongly influenced by both local needs and opportunities that become available.

- ***List the particular needs for ecological restoration in your conservancy.***

- ***Decide on the priority order in which these needs are best met***

9. DEVELOPING AN EFFECTIVE RESTORATION PROGRAMME

9.1 A critical path for actioning a restoration programme

The various steps identified as necessary for an effective restoration programme are summarised in Figure 1, together with some additional steps that have not been discussed. The most crucial of these steps are likely to be the definition of goals and objectives, the feasibility study (which must be realistic in appraising the resources required over the time period of the programme), the relationship of the proposal to other activities within the Conservancy, the expected benefits or possible adverse effects, and a decision to proceed or not. Following a positive decision, application can be made for any planning consents needed, and data collection and preparation of a management plan can begin. It may sometimes be more efficient to combine small restoration programmes with similar goals into a single management plan. In this way they can benefit from the economies of a larger programme.

9.2 Relationship of proposal to other activities within the Conservancy

All conservancies run programmes of protection including fencing, control of problem weeds, browsing mammals, and introduced predators. It is important to decide how best to link any restoration proposal with these programmes so that most efficient use is made of human and physical resources. It is equally important to examine the proposal in relation to the Conservancy's education and advocacy programme so that maximum advantage can be taken of the restoration work. The increasing number of species recovery plans for which conservancies are taking responsibility raises the question of whether the needs of several of these plans can best be met by a much smaller number of restoration programmes. Given the tension that sometimes arises between species-orientated and community/ecosystem-oriented approaches to conservation, species recovery plans can become bridges that harmonise these apparently disparate approaches.

Although administrative boundaries for examining these relationships are those of the Conservancy, in a biological sense the boundaries of an Ecological District or Region may be more effective in bringing together commonalities for similar management. An example is the Conservation Action Plan for the Mercury Islands Ecological District (Thomson et al. 1992).

9.3 Data collection and programme design

A number of matters should be included under this heading, and some of them require field work if the information is to be reliable.

- Identification of sources of required plants (as seeds, seedlings, cuttings) and animals of appropriate genetic provenance.

- Selection of nursery and captive-rearing facilities if needed.

- Site survey and mapping to identify the range of physical conditions present within the proposal area, and decisions on the nature of any physical or chemical modification required.

- Collection of relevant data on the extent to which normal regeneration can achieve the required restoration with or without minor intervention.

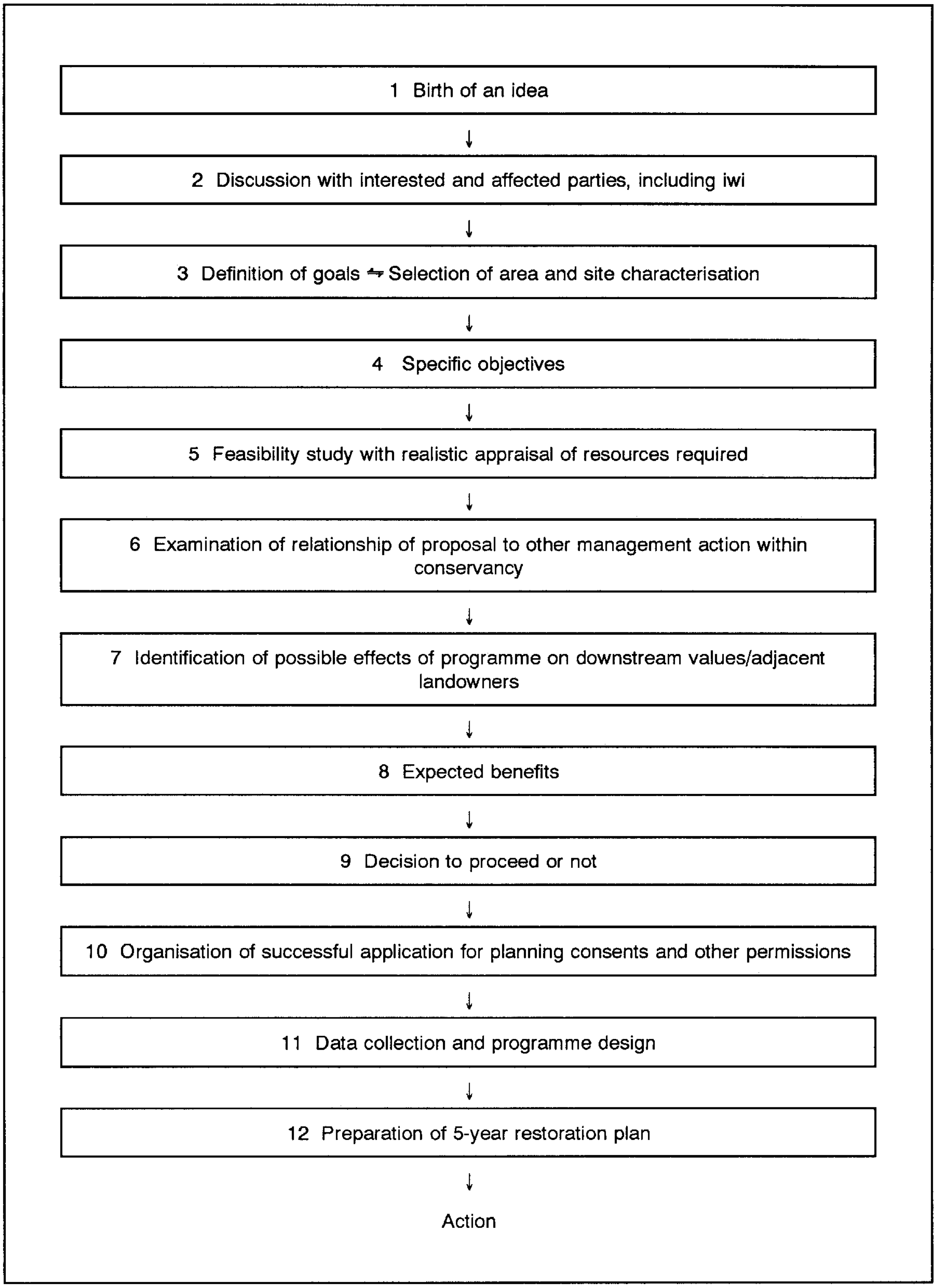

Figure 1 Essential steps in developing an effective programme of ecological restoration.

- Collection of relevant historical information about the community to be restored.
- Design of the monitoring programme and selection of the criteria to be used in measuring progress (see Sections 10, 11).
- Decision on the need for trials or experiments. Design of any trials or experiments that are needed (see Section 12).

Resources will be wasted if intervention such as planting is not planned to complement or reinforce already existing regeneration. It may sometimes be found that eradication of a problem weed or control of a problem animal is sufficient for non-interventionary processes to complete the changes originally considered to require a restoration programme.

A second point to emphasise is the necessity for effective monitoring (Section 11). Without it, mistakes will be repeated and opportunities for repeating successes will be lost.

9.4 Restoration plans

These should cover a period of at least 5 years and detail staff responsibilities, budgets, the order of steps required including the order of introduction/re-establishment of target species, and reporting times and procedures. Plans should be written with sufficient latitude to allow for modification when unexpected new information comes to light. As far as possible they should incorporate responses to any biological risks or other effects that the programme may bring about on other land. Plans should also include details of the procedures to be used for monitoring progress and success of the programme (see Sections 10 and 11).

- ***Restoration programmes should not be pursued in isolation from other kinds of management.***
- ***Restoration programmes must be planned well in advance of their implementation and a plan should cover a period of at least 5 years.***

10. MEASURING PROGRESS AND SUCCESS OF RESTORATION PROGRAMMES

Most restoration goals are long-term so that whether or not success has been achieved can often not be judged until the final phase of the programme. For this reason goals are frequently unsuitable for measuring progress. However, progress with achieving some specific objectives can be quantified. Examples are:

10.1 Major component species

How many major component plant and animal species need to be established? How many have been introduced to the restoration site? How many are now represented as self-maintaining populations, i.e., with recruitment from juveniles sufficient to maintain adult numbers? Of these self-maintaining populations, how many are within 10% of their likely proportions in the former community that is being imitated?

10.2 Other target species

How many additional species of plants and animals need to be established? These may include threatened or potentially threatened species, local genetic variants of common species, or key species that will not be major components of the restored community in a numerical sense. How many of these additional species have been introduced? How many are now represented as self-maintaining populations?

10.3 Control of alien plants and animals

How many alien species need to be controlled? How many have been controlled? For how many of the controlled species are the control methods sustainable?

10.4 Eradication of alien plants and animals

How many alien species need to be eradicated? How many have been eradicated? For how many of the eradicated species are there strategies for protecting against re-invasion? How many of these individual strategies are sustainable?

10.5 Control of native plants and animals

How many native species need to be controlled? How many have been controlled? For how many of the controlled species are the control methods sustainable?

10.6 Physical and chemical conditions

How many separate kinds of change or modification to physical or chemical conditions are required to achieve restoration? How many of these steps have been taken? For each step, what percentage of the required amount of change has been achieved?

10.7 Effects on other landowners or on other parts of the catchment

What potential or actual non-target effects on other species (native or alien) or on physical and chemical conditions outside the restoration area have been identified? For how many of the negative effects recognised have steps been taken to nullify or ameliorate them? For how many will the action taken be acceptable and sustainable long term?

10.8 Educational, scientific, and recreational benefits

How many distinct kinds of educational, scientific, and recreational benefits are expected to be generated by the restoration programme? How many of these are taking place? Of these, how many will need to be modified (kind of use or number of users) if they are

Table 1 Hypothetical example of progress assessment for a forest restoration.

Criteria for progress based on specific objectives	Baseline objectives for each criterion (time zero = 1990)	Extent of progress					
		1992	1994	1996	2000	2010	etc.
No. of major component plants to be introduced/re-established	4	2	4	4	4	4	
Major component plants now self-maintaining	4	–	–	–	–	1	
No. of major component animals to be introduced/reestablished	3	–	–	–	2	3	
Major component animals now self-maintaining	3	–	–	–	1	1	
Major component plants within 10% of required proportions	Species A 30%	5%	15%	23%	28%	35%	
	Species B 25	5	5	0	6	14	
	Species C 20	4	7	10	15	17	
	Species D 15	2	0	1	2	5	
	Bare ground/other spp. 10	84	73	66	49	29	
Other target species of plants/animals to be introduced or re-established	5	–	–	2	3	4	
Other target species now self-maintaining	Species E	–	–	–	–	1	
	Species F	–	–	–	–	–	
	Species G	–	–	–	–	–	
	Species H	–	–	–	–	1	
	Species I	–	–	–	–	–	
No. of alien plants to be controlled	3	3	3	3	3	3	
No. of alien plants for which control method is sustainable	3	3	3	2	2	2	
No. of alien plants to be eradicated	1	–	–	–	1	1	
No. of eradicated plants with sustainable strategies against reinvasion	1	–	–	–	1	1	

Criteria for progress based on specific objectives	Baseline objectives for each criterion (time zero = 1990)	Extent of progress					
		1992	1994	1996	2000	2010	etc.
No. of alien animals to be controlled	4	2	4	4	4	3	
No. of alien animals for which control method is sustainable	4	2	2	2	2	2	
No. of alien animals to be eradicated	1	–	1	1	1	1	
No. of eradicated animals with sustainable strategies against reinvasion	1	–	1	1	1	1	
No. of physiographic or other physical changes/modifications required	2: constructn of raised ground.	–	100%	100%	100%	100%	
	: fencing	100%	100%	70%	100%	100%	
No. of chemical changes/modifications required	0	–					
No. of non-target effects anticipated	2	2	2	2	2	2	
No. of non-target effects for which there are adequate responses	1	–	–	–	1	1	
No. of distinct educational, scientific & recreational uses:	5	2	2	3	3	4	
How many of these uses require modification?	–	–	–	1	1	1	
How many of these uses have been modified?	–	–	–	–	1	1	

to be sustainable without detriment to the restored community? How many have now been modified in this way?

Not all the criteria suggested will be equally applicable to all programmes. Programmes that include management of a large number of introduced species and conditions to achieve their goals will not be comparable to smaller programmes where the objectives are more modest. However, the purpose of measuring progress/success is not to compare one programme with another (although this will be done), but to measure the progress/success of an individual programme against the original objectives set for it. An example of the way this evaluation might work is given as an objective x time matrix in Table 1. Field managers will be able to devise their own schemes appropriate for the restoration problems they encounter. The important principle is that procedures for evaluating all restoration programmes are developed and activated.

- ***Progress and success of a restoration programme are best measured against achievement of specific objectives.***

- ***The personnel, criteria and procedures for measuring progress and success should be decided at the time the programme is initiated.***

11. SYSTEMATIC MONITORING

An effective procedure for evaluating progress and success of a restoration programme will not be possible without systematic monitoring. Unless appropriate objectives are quantified there is no reliable baseline against which to measure progress. The baseline for monitoring must be derived from objectives such as major component and other target species to be established, alien species to be controlled or eradicated, and physical/chemical conditions to be modified or replaced. These in turn can be related to either a selected time period or to current conditions, e.g., if open-cast mining will destroy a stand of forest that will then be replaced, the baseline data can be derived from the stand before it is destroyed. Failing this, a baseline can be derived from studying the conditions in the surrounding undisturbed forest.

The objective-based questions suggested in Section 10 allow a direct comparison between the number of actions taken and the number of actions identified as necessary for achieving the restoration. This is a simple robust procedure, although answers to some of the questions listed will require estimates (and sometimes mapping) of the numbers of adult plants or animals in a population, together with sampling of the age-class distribution as an indication of the extent of recruitment to the adult population. These questions are often relatively easy to answer for plants, but much more difficult for animals. It is not appropriate to launch full-scale population studies of animals to answer such questions, except for threatened species where the information is likely to be required as part of a recovery plan. Counts of adults may be the only practical way of judging whether the species is maintaining itself from year to year. **Important as monitoring is, if the procedure becomes too complex and, therefore, too demanding of time, it will not be done.**

Photopoints should be established at vantage points, both outside and inside the restoration site, and photographs (black and white, and colour) taken from time to time. The qualitative information gained is limited mainly to changes in plant cover, but it can prove an invaluable back-up for other monitoring and a powerful educational and public relations tool.

Monitoring control and eradication, changes in physical/chemical conditions, non-target effects, as well as educational, scientific, and recreational use, are as important as monitoring populations of native species. Failure or slow progress with one part of a programme may be counter-balanced by success with another. No programme should be judged by one or two parameters alone. Systematic and comprehensive monitoring will give a more accurate picture of the extent to which objectives, and ultimately goals, are being met.

Is it advisable to standardise monitoring procedures for restoration programmes throughout the country? It is necessary to standardise and properly record the monitoring procedure used in any particular programme. This allows different staff over a period of time to continue the monitoring in a repeatable manner. Restoration of different kinds of biotic community will require differences of approach. An attempt to standardise monitoring procedures nationwide would probably be premature. Very few restoration programmes have yet run for more than a few years and the monitoring done so far has usually been incomplete. We need to test procedures and compare experience much more than we have done in order to develop the most robust procedures possible.

- ***Systematic monitoring is necessary for measuring progress of a restoration programme but the procedure must be kept simple to ensure that it is done.***

- ***Written instructions for monitoring should be prepared for each restoration programme so that monitoring is not disrupted by changes of staff.***

12. RESTORATION PROGRAMMES AS MANAGEMENT/RESEARCH EXPERIMENTS

The question has been asked: "Can restoration programmes be used as management/ research experiments?"

Any restoration programme, if properly documented, is a source of scientific information. If compared with an unrestored but otherwise similar area as a "control" it takes on some features of an experiment. Comparisons between biotic communities on similar sites, with and without intervention, can yield useful insights as can comparisons between restored and nearby unrestored islands.

The limitation of such comparisons is that invariably there are factors additional to human intervention whose effects cannot be separated from those of intervention. To achieve this separation a proper experiment is required. This will necessitate the asking of specific questions, treatments designed to answer these questions, and a sound experimental layout with replication and controls. This is time-consuming and therefore costly. Experiments should not be undertaken unless it is clear that substantial savings in other restoration costs are a likely outcome.

12.1 Trials

Although one meaning of the word "trial" is that of an experiment, in this context it is treated as a less rigorous kind of experiment than the procedure outlined above. There are many situations in restoration work in which the question being asked is whether a particular method will work; not whether the method is more or less effective than some other method. It is important to know if the method is feasible, but a full-scale experiment is not justified. Thus a trial is required and the "control" for comparison is the *status quo* when the method is not applied. It must be recognised that such "single replicate" experiments cannot then be inflated with inappropriate statistics.

Some examples of where trials are appropriate are testing whether certain plant species can survive or grow on difficult sites, whether browsing animals must be completely excluded to get significant natural regeneration, whether a particular method of weed control is effective, or whether establishing some small animals is possible in the presence of both native and introduced predators. Whenever a threatened species is translocated to a new habitat, we are making a trial. The limited numbers of a threatened species and the limited availability of suitable habitats exclude any possibility of a properly replicated experiment. The most crucial aspect of any trial is that all steps are properly recorded so that should failure result, there is a real chance of identifying the reason. Historically, trials or "management experiments" have been our principal source of new understanding of restoration processes.

No substantial planting effort should ever be initiated without trials on the various kinds of site to be restored. The greater the investment required to complete a phase of restoration, such as planting, the stronger the justification for proper experimental testing of the methods to be used.

12.2 Controlled experiments

The essential components of an experiment have been summarised by Hurlbert (1984):

- There must be a *hypothesis,* i.e., an explanation for a question that has been advanced. The most valuable hypotheses are those that are testable.
- Sound experimental design.
- Successful experimental execution.
- Statistical analysis of the results.
- Interpretation of the results.

12.2.1 Sound experimental design Sound design requires specification of the objectives of the experiment, the nature of the experimental units, the number and kinds of treatments including the control treatments, and the parameters that will be measured. It will also specify the manner in which treatments are assigned to the experimental units, the number of experimental units and often the sequence in which treatments are applied. The positions of the experimental units, and arrangement of treatments within them, should always be mapped. A good experimental design will allow separation of any spatial heterogeneity of the site from the added controlled variability of the experiment.

A "control" is any treatment against which one or more other treatments can be compared. Usually controls are "untreated". They are necessary because all biological systems change with time, regardless of treatment, and these changes must if possible be separated from those that result from the treatments.

Replication reduces the effects of "noise" or random variation, thus increasing the precision of an estimate. Random positioning of the treatments eliminates possible bias on the part of the experimenter, thereby increasing the accuracy of such estimates. Accuracy and precision are not the same. Precision measures the dispersion or spread of the estimates whereas accuracy measures how close the mean estimate is to the true value.

Treatments in a manipulative experiment must be interspersed with each other in space and time. This is achieved by randomising the positions of the treatments. However, when there are few replicates of treatments, a check should always be made to ensure that the randomisation has not by chance placed too many similar treatments in only one part of the experimental area.

The most widely used design for an ecological field experiment is that of randomised blocks of treatments. Completely randomised designs should only be used in experiments where the area is homogeneous on a large scale and the number of experimental units is not too small (Dutilleul 1993). A systematic layout of treatments is sometimes the most effective way of achieving adequate interspersion, but the spacing interval must not coincide with a property of the area that varies spatially with a similar interval.

Hurlbert (1984) emphasised that if treatments are spatially or temporally segregated, if all replicates of a treatment are somehow interconnected, or if "replicates" are only samples from a single experimental unit, the replicates are not independent. Use of data from such experiments to test for treatment effects is what Hurlbert calls **pseudoreplication**. The most common type of "controlled" experiment in field ecology involves a single "replicate" per treatment. This is far from valueless, but it does mean that only gross effects can be detected and any statistical measures of error will not be possible.

12.2.2 Successful experimental execution Successful experiments depend on the experimenter's insight and judgement as much as it does on technical skill. It requires the experimenter to avoid introducing systematic error (bias) and to minimise random error. For an example of bias, if using exclosures to measure the effects of an introduced herbivore on regeneration, the exclosures must have no direct effect on variables in the system other than the herbivore. Decisions about how much initial heterogeneity among experimental units is acceptable are largely a matter of subjective judgement, but they will affect the magnitude of random error and thus the sensitivity of the experiment to detect effects. Such errors of execution are generally more difficult to detect than design errors and their effect on the results is more insidious (Hurlbert 1984).

The reader is referred to Hurlbert's (1984) paper for more details on designing effective field experiments and to the more recent work by Hairston (1989), which is easy to read and gives rules that help to avoid pitfalls in field experiments.

Many kinds of restoration questions could be answered with field experiments. They include questions of conditions necessary for maximising germination, effects of different nursery procedures on subsequent survival and growth rate, different methods of planting, fertiliser application and weed control, and comparisons between the effects of artificial and natural shelter on growth rates. Vegetation responses on different site types within exclosures against browsing mammals is another question, although here, as with many other experiments involving larger mammals, the cost of adequately replicating the treatments begins to escalate. Questions on responses of invertebrate populations are more amenable to field experiments.

12.3 Value of the experimental approach

Both trials and experiments are relevant to the principle of applying more than one technique to restoring a particular system. Trials may be all that is needed to test the possible advantage of a new technique, but if the advantage is small it will not be detectable without a controlled experiment.

A pragmatic procedure is advocated for testing more than one restoration technique. Trial it properly by documenting both procedure and results; then decide whether a controlled experiment is justified.

The value of restoration programmes as management/research experiments will be realizable only to the extent that trials are properly documented. There is a place for controlled experiments, but in the writer's view the difficulties of achieving proper replication will restrict opportunities for such experiments.

It is appropriate to close this section with a quote from Diamond (1987: 330):

> *"There is no doubt that the controlled experiment with preselected perturbations and randomised experimental design is the most powerful tool of ecology, just as it is the most powerful tool of the other sciences. In ecology, however, most of the perturbations that would yield far-reaching insights are either immoral, illegal or impractical. Our field experiments usually run for a very short time - rarely more than a few years - on tiny spots rarely as big as a hectare. Even within these small areas we are confined to those small perturbations, those modest additions or subtractions that we can carry out without being persecuted by our governments, our neighbours, or our consciences. "*

- ***Fully recorded trials should be used to test the feasibility of new methods of restorative action.***
- ***Where differing kinds of restoration methods are being compared, it may be necessary to use controlled field experiments with adequate replication of treatments that allow valid statistical comparisons.***

13. GENERAL CONSIDERATIONS

13.1 A national database on restoration techniques

The Department of Conservation has already acquired a large amount of information concerning restoration techniques which is growing steadily. On a broader front, New Zealand is recognised internationally as a world leader in methods of eradicating problem mammals, particularly on islands. Some of this information is readily available but much important detail is widely dispersed and not quickly accessed. There is need for an EDP storage/retrieval system that will increase the exchange of information between conservancies and thus increase the effectiveness of restoration programmes. Control of alien species is often an integral part of a restoration programme. Information relating to techniques for control should be held in the same database thus allowing it to perform a dual function: assisting both restoration and protection programmes.

13.2 Potential value of ecological restoration

Some people have felt that restoring biotic communities of a former period is too difficult because we often know too little of their composition or no longer have all the original species.

If indeed we only have a vague idea of community composition, then we should not be trying to restore that community. With respect to both of the above concerns it is helpful to recall the point made by Simberloff (1990): partial restorations are acceptable if they enable us to meet our goals; we do not have to re-establish "exactly the same species and processes in the same proportions as the original system".

There is a growing worldwide attention to restoration ecology as it becomes clearer that protection and preservation of global biodiversity is failing to meet human needs. On the New Zealand mainland, restoration can involve many people in an active role and thus widen the base of public support for the Department and for nature conservation in general. On the offshore and outlying islands there are special opportunities for comprehensive restoration that are seldom paralleled elsewhere. All that is needed is commitment by the individuals and organisations that support conservation.

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APPENDIX 1 Ecological restoration in DoC Conservancies

Please return completed form to Ian Atkinson, Landcare Research NZ,
Private Bag 31-902, Lower Hutt.

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1. What ecological restoration projects are currently in progress in your conservancy?

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2. What procedures for monitoring and documenting progress of restoration projects are in place?

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3. What problems are being encountered with these projects?

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4. What successes have been achieved so far with these projects?

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5. Are there other comments you would like to make? *(Please don't be confined by this space!)*

APPENDIX 2 Summary of DoC restoration programmes

Programme/Goals[2]	Action/Monitoring	Problems	Successes
NORTHLAND CONSERVANCY			
Kaimaumau Scientific Reserve Repair of wetland	Proposed maintenance and restoration of natural water tables.	–	–
Lake Ohia Repair of wetland; habitat for threatened black mudfish and threatened orchids	Proposed weir to restore natural water profiles of lake and adjacent wetlands. Monitoring of orchids and birds under differing water regimes.	Accommodating the requirements of both plants and animals.	–
Mangawhai Sandspit* Repair of dune community	Planting of pingao. *Ad hoc* monitoring.	Identifying factors impacting on dunes. Anticipate some site-specific problems affecting plantings.	First plants established in June 1993.
Matakohe (Limestone)Is., Whangarei Harbour Island restoration for multiple use	Eradication of possums, cats, rats, mice; historic and archaeological sites protected; 30,000 native trees planted. Ad hoc monitoring at present.	Problem weeds: *Vinca major.*	Good public support for programme.
Motuopao Is., Cape Maria van Diemen* Island restoration	Kiore eradication completed. Monitoring of plants, lizards and birds.	–	Measurable responses in plants, lizards and birds.
Motupapa Is., Bay of Islands* Island restoration	Weed control, planting. Plantings are being mapped to allow monitoring.	Over-enthusiastic help resulted in some unsuitable plantings, now rectified.	Plantings generally successful.
AUCKLAND CONSERVANCY			
Motuora Island* Island restoration	Planting of native trees; exclusion of cattle from western slopes. Trees monitored for survival.	Problem weeds: kikuyu grass.	Approximately 2000 trees planted.

1 Included in this table are DoC restoration programmes and others in which the Department has at least some involvement.

2 Where goals have not been stated they have sometimes been inferred from other information supplied.

* Few programmes listed are associated with clearly defined restoration goals. Those marked with an asterisk * seem to be particularly in need of goal clarification.

Programme/Goals[2]	Action/Monitoring	Problems	Successes
Motutapu Island* Island restoration	Planting of native trees; eradication of wallabies and possums in train.	Rabbits; problem weeds; problems of communication between interest groups.	Approximately 3000 trees planted; possums and wallabies almost eliminated; improved communication between parties; support from NGOs. Plant nursery established.
Tiritiri Island Island restoration as an open sanctuary	Planting of trees, which have been monitored for survival; introduction/re-establishment of native birds: brown teal, little spotted kiwi, North Island robin, saddleback, takahe and whitehead. These birds monitored to varying levels of intensity, sometimes for productivity and survival.	Most planting by volunteers, some with little planting experience, which sometimes reduces survival rate of trees. Some plantings made too late in season, others destroyed by pukeko or ring-barked by kiore. Problem weeds: Japanese honeysuckle.	Efficient plant nursery; over 240,000 trees planted in 9 years. Kiore eradicated. Significantly improved habitat for forest birds. Extremely successful programme in terms of advocacy for conservation.
WAIKATO CONSERVANCY			
Lakes B and C, Horsham Downs* Peat lake restoration	Re-establishment of satisfactory water table levels. Field inspection.	Public consultation necessary to alter water tables.	Resource consents granted.
Mt Pureora Repair of bulldozer-damaged areas	Re-establishment of subalpine scrub. Field inspection.	Difficult climate, particularly rainfall and frost-heave.	Reasonable survival of new plantings.
Whangamarino Restoration of an extensive wetland	Construction of weir to raise minimum water level. Monitoring of water levels is a consent condition.	Relationships with the public, especially adjoining landowners.	Resource consent granted.
Mercury Islands: Korapuki & Double Islands Island restorations towards pre-European condition	Eradication of kiore and rabbits. Re-establishing animals including threatened species and rare lizards. Monitoring of vegetation recovery and all translocated species.	Re-establishing self-maintaining populations of k-selected species such as Whitaker's skink.	Eradications complete. Notable recovery of vegetation on Korapuki I. Whitaker's skink beginning to breed. Comprehensive monitoring system in place.

[1] Included in this table are DoC restoration programmes and others in which the Department has at least some involvement.

[2] Where goals have not been stated they have sometimes been inferred from other information supplied.

* Few programmes listed are associated with clearly defined restoration goals. Those marked with an asterisk * seem to be particularly in need of goal clarification.

Programme/Goals[2]	Action/Monitoring	Problems	Successes
BAY OF PLENTY CONSERVANCY			
Kaharoa Restoration of habitat for kokako	Control of rodents, possums, cats and stoats. Monitoring of kokako numbers and chick production; monitoring of numbers of introduced mammals.	Lack of effective monitoring techniques for mustelids and cats.	Increase in kokako density from 7 to 13 pairs in 3 years. Chick production increase from 15 to 85% in 3 years.
Matata lagoon Restoration of a dune lake	"Rehabilitation" of a "range of aquatic and terrestrial components"	–	–
Ohiwa Hb., Whakatane R. mouth* Restoration of dune communities	Planting of pingao on sandspits adjoining river or estuary mouths. File records of plantings.	–	Sponsorship from Tasman Pulp and Paper Co.
Wharawhara, Kaimai–Mamaku Forest Park **Restoration of forest on quarry site**	Plan for comprehensive restoration completed. To be implemented progressively as quarrying proceeds. Monitoring is a condition of the consent.	–	Robins and saddlebacks established. Measurable recovery of vegetation.
Mokoia Island, Lake Rotorua Island restoration	Eradication of Norway rats; re-introduction of native birds. Monitoring of vegetation changes and numbers of robins, saddlebacks and weka.	–	Eradication of goats, rabbits and Norway rats. Main planting programme completed.
Motuhora (Whale) Island Island restoration	Monitoring of vegetation by photo points and vegetation plots. Monitoring for re-invasion by rodents. Monitoring of breeding success of grey-faced petrels.	Some controversy over the balance to be struck between natural revegetation and plantings.	Increase in breeding success of grey-faced petrels. Survival rate of planted stock >90%.
EAST COAST CONSERVANCY **Cook's Cove** Restoration of coastal cliff community	Proposed to re-plant a cliff area and adjacent slope to establish vegetation similar to that described at time of Cook's visit.	–	–

1 Included in this table are DoC restoration programmes and others in which the Department has at least some involvement.

2 Where goals have not been stated they have sometimes been inferred from other information supplied.

* Few programmes listed are associated with clearly defined restoration goals. Those marked with an asterisk * seem to be particularly in need of goal clarification.

Programme/Goals[2]	Action/Monitoring	Problems	Successes
Matawhero Conservation Area Restoration of alluvial forest	Planting of trees in an old river meander. (Area divided between restoration and botanic garden).	–	–
Nuhiti dunes* Dune restoration	Planting of pingao. Fencing to exclude stock.	–	Significant regeneration within fenced areas.
HAWKES BAY CONSERVANCY **Cape Kidnappers*** Restoration of coastal forest between two main gannet colonies	Planting of native trees. No formal monitoring.	–	–
Lake Tutira* Forest restoration	Tree lucerne established as a nurse crop. No formal monitoring.	Loss of some plantings to drought or hares. Inappropriate genetic stock used in some cases.	–
Mohi Bush Scenic Reserve* Forest restoration	Planting in progress including tree lucerne. No formal monitoring.	Loss of some plantings to hares.	–
Motu-o-kura (Bare Island)* Island restoration: goals yet to be finalised in discussion with owners.	Monitoring recovery of invertebrate populations; maintenance of rat-bait stations.	–	Eradication of Norway rats. Completion of a predator contingency plan. Recovery of vegetation, lizards and invertebrates.
TONGARIRO/TAUPO CONSERVANCY **Replacement of *Pinus contorta* plantations, Erua** Restoration of former vegetation; habitat for *Pittosporum turneri*	Cutting of pines to release native understorey. Planting trials in some areas. Monthly to annual visits; permanent photopoints; variety of treatments monitored.	Compaction of soils resulting from logging. Drought-induced mortality in some plantings. Re-growth of *Pinus contorta*.	–

1 Included in this table are DoC restoration programmes and others in which the Department has at least some involvement.

2 Where goals have not been stated they have sometimes been inferred from other information supplied.

* Few programmes listed are associated with clearly defined restoration goals. Those marked with an asterisk * seem to be particularly in need of goal clarification.

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