THE CONSERVATION ECOLOGY

OF *Teucridium parvifolium* (Hook f.)

ON BANKS PENINSULA, NEW ZEALAND.

A thesis

submitted in partial fulfilment

of the requirements for the Degree of

Master of Applied Science

at Lincoln University

by

T.J. Boot

Lincoln University

1998

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Abstract of a thesis submitted in partial fulfilment of the

requirements for the degree of M.Appl.Sc.

THE CONSERVATION ECOLOGY
OF *Teucridium parvifolium* (Hook f.)
ON BANKS PENINSULA, NEW ZEALAND.

By Tristan Boot

The distribution of the rare endemic shrub *Teucridium parvifolium* was investigated throughout New Zealand to determine the geographic distribution of the species, and specifically on Banks Peninsula. *T. parvifolium* is spread discontinuously throughout New Zealand and occurs in widely scattered, generally small populations. Aspects of the community ecology, including floristic composition, and community/physical site relationships, were studied to determine the habitat requirements of *T. parvifolium* on Banks Peninsula. *T. parvifolium* occurred in two plant communities that differed in species composition. The healthiest populations occurred in the marginal community characterised by *Hoheria angustifolia* and *Urtica ferox* rather than the community characterised by *Macropiper excelsum* and *Melicope simplex*. Data was gathered on the size and structure of populations, plant size, seed production and viability, seedbank, plant growth and the extent of browsing. Population structures were characterised by a large number of seedlings, fewer saplings, and very few adult plants. Adult plants were capable of producing large numbers of seeds and many of these entered the soil to form a seedbank. Seedlings were capable of rapid growth under ideal conditions but growth was restricted in the wild by introduced herbaceous weeds. Agents of decline were identified as browsing animals, competitive introduced plant species, and habitat disruption. The continued decline in suitable habitat, the effects of introduced weeds, severe browsing, and the severely fragmented nature of the populations warrants the IUCN threat classification of Vulnerable. Management options include managed browsing to control introduced plant species, provision of suitable habitat, and active management to increase the size and frequency of small populations.

Keywords: *Teucridium parvifolium*, rarity, conservation ecology, browsing, introduced species, habitat disruption, fragmentation, Banks Peninsula.

ACKNOWLEDGMENTS

I would like to thank my Supervisors Glenn Stewart and David Given for their support, advice and patience during the completion of this thesis. I really appreciate the efforts that they have both made to keep me going, especially over the last year or so.

Hugh Wilson provided helpful advice and initial records on the location of Teucridium on Banks Peninsula, as did numerous Department of Conservation staff for other parts of the country. Thanks also to Peter de Lange and Brian Molloy for their helpful comments and to the land owners on the Peninsula for allowing me unrestricted access and for giving me valuable local knowledge.

Trustbank Canterbury provided financial assistance that helped immeasurably with my field expenses.

Special thanks must go to Louise and Nancy for their help with my fieldwork. To all the other Ecology Post-grads, the hours of informed and intellectual discussion in the tea room were invaluable! Thanks again to Louise and also to Gillian for the proof reading.

To the team at LHL, thanks for the support and encouragement, and also somewhere to live and some dollars to live with!

Huge thanks to my friends and family who gave me a push or a kick when I needed it and who were so willing to listen to my complaints. I hope your faith in me has been rewarded. Thanks to Shelley and Richmond who helped me retain what little sanity I have and were valuable assistants on many forays into the field.

Lastly, and most importantly, thanks to Mum and Dad. Your support over the eons that I have been here has got me through when I didn't think I could do it.

In the immortal words of Homer Simpson..... WOOOOHOOOOOOOO!!!!!!!!

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1.0 INTRODUCTION

Almost 20% of New Zealand's native flora is under some level of threat (Cameron *et al.* 1995). Few studies, however, have been conducted on threatened species in New Zealand. In this chapter I describe factors that determine the rarity of threatened species and the need for studies such as this on our threatened plants. I also discuss previous studies on threatened New Zealand plants and outline the available information on *Teucridium parvifolium*. *Teucridium* is a vulnerable species that typifies many of the species currently under threat. The purpose of the current study is to examine the conservation biology of *Teucridium parvifolium* on Banks Peninsula; to attempt to discover possible threats to the species; and discuss future management options.

1.1 DETERMINING SPECIES RARITY

Determining the rarity of a species is difficult as there are numerous degrees of rarity and seemingly as many ways of categorising them. The sheer number of factors influencing rarity may make adequate definition all but impossible.

Our concept of rarity is often subjective and is determined as much by our expectations, as by fact (Given 1981). For instance, we may think that something is rare because it is uncommon in our locality when it is widespread elsewhere. Therefore, our concept of what is rare depends on the scale of our individual experience and on the range or narrowness of our individual interests (Harper 1981). Another human influence on the definition of rarity is the complication caused by purely political boundaries, ie. a plant may be considered rare in one country when it is numerous just over the border in a neighbouring country (Harper 1981). In the case of *Teucridium* the fact that it is endemic to New Zealand provides a scale for the rarity of the species.

1.1.1 TYPES OF RARITY

Rarity consists of spatial and temporal components. The spatial component is simply a matter of how the plant occurs in space, ie. where it is usually situated. Temporal rarity looks at the distribution of the plant over time. It is important to consider this over a long period to discover historic trends. However, long term records are usually insufficient or do not exist, giving a very distorted view of the trends that have been, and still are, occurring in the vegetation. Harper (1981) describes four trends in the behaviour of plant populations as indicated in Figure 1.1.

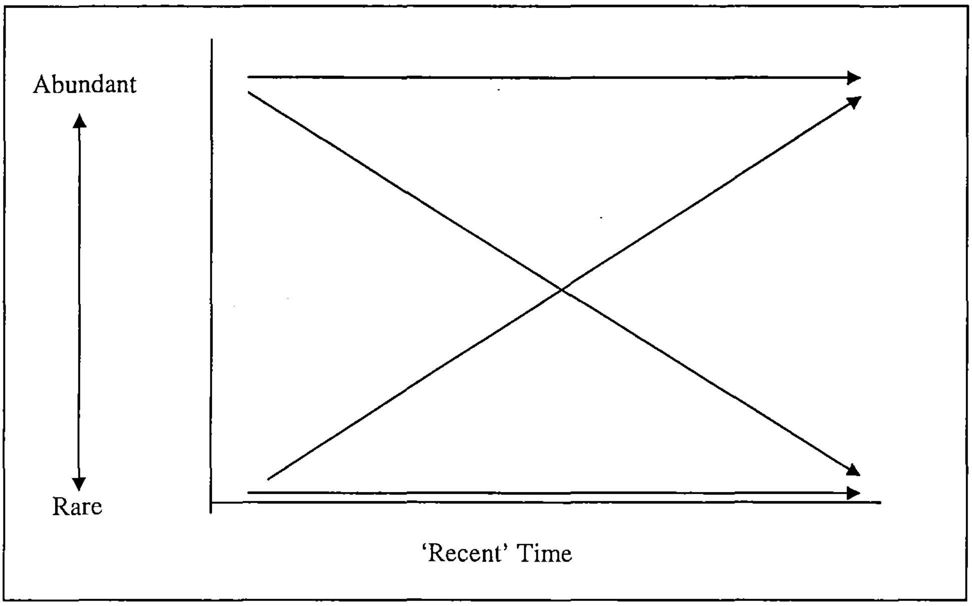

Figure 1.1: Changes in plant populations over time. (Modified from Harper 1981).

The first trend is those species which have always been common and still are, for instance Mountain Beech (*Nothofagus solandri* var. *cliffortioides*). Another type are species which have always been rare such as the Three Kings Cabbage Tree (*Cordyline kaspar*). Other species may have been rare in the past but are now more common. Finally there are the species which were common in the past but are now rare such as Pingao (*Desmoschoenus spiralis*). For many species these trends can only be inferred from inadequate historical records. It is likely that *Teucridium* has suffered through habitat destruction and modification since the arrival of Europeans and its abundance has decreased.

Another form of rarity is functional rarity which relates to something that is a natural function in the biology of the plant, such as reproduction. This may be an intrinsic factor, such as the loss of a pollinator or disperser, or extrinsic, such as habitat destruction or fragmentation. For instance *Dactylanthus taylori*, the wood rose is pollinated by New Zealand native bats, themselves now endangered.

Rabinowitz (1981) developed a flexible classification system of rarity using three commonly recognised factors in rarity: geographic range, habitat specificity, and local population size. Given (1993) presented a modified 16-celled table that distinguished between point endemics and species with a small geographic range but occurring at several sites (Table 1.1). The additional subdivisions allow greater accuracy in defining rarity (Given 1993). Particular importance is given not only to the restricted point endemic species but also to those species that are classed as predictable species but which are not recognised by Rabinowitz (1981). These are the species that are constantly sparse with small populations over a large range. This form of rarity is often overlooked as it is assumed that wide distribution will reduce the risk but the truth is that these species are just as at risk as the point endemics (Given 1993).

The importance of this form of rarity has been recognised in tropical forests (Given 1993) but is also now gaining attention in New Zealand as many of our rare shrubland species seem to have this form of distribution. For example, *Teucridium parvifolium* (Given 1981), *Pittosporum obcordatum* (Clarkson and Clarkson 1994) and *Hebe cupressoides* (Widyatmoko and Norton 1997).

1.1.2 BIOLOGICAL ASPECTS OF RARITY.

There are a number of attributes in the biology of plants that may influence rarity. Many rare taxa have lower levels of self incompatibility, a tendency towards asexual reproduction pathways, lower overall reproductive effort and poorer dispersal abilities (Kunin and Gaston 1993). Other attributes are also important; for instance the fact that plants are immobile means that they must adapt to change as they can not easily move away from threats. Other factors such as mutualisms and resource competition also impact on the rarity of some plants.

Table 1.1: A Modified 16-celled classification of rarity. (Source, Given 1993).

GEOGRAPHIC RANGE		Large		Small			
				Occurring at one or more site	Confined to one site	Occurring at one or more site	Confined to one site
HABITAT SPECIFICITY		Wide	Narrow	Wide		Narrow	
LOCAL POPULATION SIZE	All large	Common 1	Predictable 2	Unlikely Endemic 3	Unlikely Point Endemic 4	Endemic 5	Point Endemic 6
	Some small	Generally Sparse 7	Predictable 8	Unlikely Endemic 9	Non-existent? 10	Endemic 11	Restricted Point Endemic 12
	All small	Always Sparse 13	Predictable 14	Non-existent? 15		Endemic 16	

The demography of plant populations is also important in the rarity of plants. Population structure and dynamics are affected on one side by an increase in population due to birth, or germination, and immigration, and on the other by death and emigration (Caswell 1989). Population stability is dependant on a balance of these factors. MacArthur and Wilson (1967) proposed two strategies adopted by plants. Plants that were adapted for fast reproduction and colonisation are said to be r- selected. Plants adapted for persistence, producing fewer seeds but living longer, are said to be K-selected. The majority of species fall between the extremes of these strategies and different populations of the same species may occupy different positions along the r-K continuum (Grime 1979).

Plants can be classified into three strategies according to Grime (1979). These are *competitors* which grow in conditions of low stress and low disturbance, *stress-tolerators* which occur in areas of high stress and low disturbance, and *ruderals* which occur in areas of low stress but high disturbance. This can be somewhat reconciled with the r- and K- strategies proposed by MacArthur and Wilson (1967) if it is accepted that the ruderals and the stress tolerators correspond to the extremes of r- and K- selection and that the competitors are in the middle (Grime 1979).

Whichever theory is accepted it stands that some plants are adapted to certain situations better than to others. A number of rare plants can be classed as ruderals or stress tolerators. This may have serious implications for the survival of some plants, and may be a common cause of rarity. If, as it is proposed, habitat fragmentation and degradation is a major cause of plant rarity then it is possible that, for some plants at least, much of this rarity could be explained by the survival strategies that the plant is adapted for. As the habitat changes it is highly likely that a plant will find itself no longer adapted to the right environment. For instance, r-selected species, or ruderals, may be adapted to areas of high disturbance and may rely on the disturbance to provide suitable habitats for colonisation. In the landscapes of today this type of habitat is seen by humans as being unfavourable and is thus stabilised, thereby destroying valuable habitat for some plants and perhaps inducing rarity, at least in particular areas.

The use of Grime's model and of the r- and K-selection model allows us to make informed decisions about the conservation of many species. They not only provide indications of the threats to rare plants, but also suggestions as to their cultivation. This is very important not only in *ex-situ* conservation but also in *in-situ* conservation.

Other aspects of plant biology that may affect rarity are breeding and pollination systems. Reproductive strategy is important as plants have a wider range of reproductive options than most animals. The breeding system of a plant is an important determinant of genetic structure. Seed to ovule ratio and flower to fruit ratio are often determinants of rarity. If either of these is low it is quite likely that the plant will not reproduce efficiently. The pollination system influences the population structure and the effect and degree of outcrossing.

1.2 Why Conserve Rare Species?

The question has often been asked "Why do we need to bother with conserving rare plants?" There are many arguments for conserving these species including maintenance of biodiversity, the aesthetic appeal of the plants, moral beliefs and perhaps most importantly, purely for the intrinsic value of the plants themselves.

There is often an expectation that rare things will be better, or more interesting, in some way than those that are common (Drury 1974). Because we are more often exposed to rare species that have charisma, we are more likely to expect the same qualities of all rare species. Unfortunately, in the plant world, charismatic species are few and far between. It is much easier for the public to relate to the conservation of a charismatic species such as the kakapo than to a plant such as *Teucridium.* The kakapo is seen as being unique whereas divaricating shrubs are not. This perceived lack of charisma often leads to many species being overlooked or undervalued when it comes to conservation programmes.

In New Zealand we have a unique flora with a high level of endemism. The fact that over 80% of the species that occur here are found nowhere else in the world should in itself be enough of a reason to dedicate maximum time and effort into protecting these species.

1.3 Rarity Within The New Zealand Flora

Using the IUCN Red Data Book Threat Categories Cameron *et al.* (1995) recognise 319 threatened plant taxa in New Zealand. Of these taxa nine are presumed extinct, 20 are ranked as Critical, 37 as Endangered, 62 as Vulnerable, 79 as Rare, 28 as Insufficiently Known and 84 as Taxonomically Indeterminate. Added to these are 142 taxa which are classed as Local. This is a non-IUCN category and is designed to indicate species which may be threatened and require some monitoring (Given 1981). It includes plants that are not presently threatened but are potentially threatened such as regional endemics, plants of vulnerable habitats, and species that occur in frequent but small populations.

Considering the unique nature of the New Zealand flora and the number of rare and endangered species that it contains, few studies have been conducted on threatened New Zealand species. This has begun to change over recent years with an increasing number of studies on the ecology of such species (eg. Williams 1992; Clarkson and Clarkson 1994; Williams and Courtney 1995; Rogers 1996; Shaw and Burns 1997; Widyatmoko and Norton 1997). Despite this there are many species that we still know very little about.

Lack of information on these threatened species often causes confusion over their degree of rarity. As more studies are completed and more information becomes available the true status of these species becomes evident. An example of this is *Pittosporum obcordatum*, until recently known from only three locations (Given 1981). In recent years the number of known populations has increased to at least 13 and a study has been completed on the ecology of this species (Clarkson and Clarkson 1994). While this species is still rare it provides an example of the difficulty in determining the rarity of these elusive species. *Teucridium* may be another species that is more common than is currently thought. Its preference for ephemeral habitats and its similarity to so many other divaricating shrubs could cause it to be easily overlooked.

The studies that have been conducted have indicated a number of common factors in our rare flora including regeneration failure, threats from introduced species, browsing and habitat loss. If we can identify traits such as this that a number of rare species have in common then we can use the lessons learnt from existing studies in the management of other species. Regeneration failure seems to be a common problem in threatened New Zealand species (Williams *et al.* 1996). This may be due to a number of reasons including reproductive failure, poor seedling establishment and competition and predation at the seedling stage. Examples of this include *Chordospartium muritai, Muehlenbeckia astonii, Pittosporum obcordatum, Hebe cuppressoides* and *Olearia hectorii.* Other threats are faced from competition with introduced species. This is often connected to poor seedling growth as the seedlings from the native species cannot compete with those of the more aggressive weeds (eg. Williams 1992; Rogers 1996, Widyatmoko and Norton 1997). Equally important is the loss of habitat, especially since the arrival of Europeans. Many of the studies on threatened species in New

Zealand have identified this as a limiting factor for species distribution (eg. Clarkson and Clarkson 1994, Rogers 1996).

To understand the effects that these factors have on the rarity of species such as *Teucridium* and other threatened New Zealand species it is vital that we understand how rarity occurs and how these species fit into the framework of rarity.

1.4 *TEUCRIDIUM PARVIFOLIUM*

Teucridium is a genus of the family Verbenaceae containing a single species that is endemic to New Zealand. *Teucridium parvifolium* is an erect, closely branched softly wooded shrub up to c. 1.5 m tall with branchlets that are square in cross-section and small, single flowers that occur in the leaf axils (Allan 1961). Similar species include many of the small-leaved *Coprosma* species but these can be distinguished by the round cross-section of the young stems (Wilson and Galloway 1993) and the presence of stipules.

Part of the problem with *Teucridium* is that it is unknown exactly how rare the plant is (T. Partridge pers. comm.). This, along with the fact that there has previously been virtually no detailed information on the plant, means that it is vital that immediate steps are taken to increase the knowledge of the ecology and distribution of *Teucridium* before it is too late to stop the perceived decline of the species. With increased knowledge it will be possible to more adequately determine conservation strategies for the plant.

The Red Data Book of New Zealand (Williams and Given 1981) listed *Teucridium parvifolium* as a rare plant. According to the International Union for the Conservation of Nature and Natural Resources (IUCN) this category of threat includes species with small populations that are not presently Endangered or Vulnerable but are at risk (Wilson and Given 1989). These populations are usually limited to restricted geographic areas or habitats or are widely scattered over a larger area.

This is certainly the case with *Teucridium,* which has a very wide and scattered distribution. Williams and Given (1981) state that the plant is known from "scattered sites from Central North Island to Hawkes Bay and south to northern Wairarapa (Wellington), in North Island; scattered in lowland Marlborough and Nelson, coastal hills, foothills and Banks Peninsula in Canterbury, rarely in north east and east Otago, in South Island."

Cameron *et al.* (1993) listed *Teucridium* as "Insufficiently Known". This category contains species which are thought to be either rare, vulnerable or endangered but are not definitely known to be. Cameron *et al.* (1995) upgraded *Teucridium* to "Vulnerable" status. This category contains species which are believed to be likely to become endangered in the near future if the factors causing the rarity continue. The boundaries of this category are blurred. It is sometimes difficult to draw a line between what is endangered and vulnerable on the one hand, and what is vulnerable and rare on the other (Wilson and Given 1989). The vulnerable category of threat may be seen as a dynamic category that implies change and the need for active conservation (Wilson and Given 1989).

The fact that *Teucridium* has been moved in each revision of the threatened plant lists indicates very strongly that information is lacking on this plant. The authors of the list are attempting to make decisions on the fate of the species working from limited information. This study aims to at least partially rectify this situation by gathering some basic data on *Teucridium* distribution and ecology. From this it should be possible to determine whether the vulnerable rating is justified.

1.5 OBJECTIVES.

This study was developed to study the conservation biology of *Teucridium*, particularly on Banks Peninsula. I intend to describe where *Teucridium* is found, what habitats it occupies and what threats it faces. This information will be used to determine how rare the species is and to discuss options for the management of the plant.

The objectives of this study are:

1. To determine the geographical distribution of *Teucridium parvifolium* in New Zealand.

2. To outline the habitats and sites that *Teucridium* occupies on Banks Peninsula.

3. To describe aspects of the population biology of *Teucridium*.

4. To discuss possible causes for the rarity of *Teucridium*.

4. To discuss future options for the management of *Teucridium* populations.

2.0 METHODS

Most studies on threatened New Zealand shrubs have used similar methods (Williams 1992; Clarkson and Clarkson 1994; Rogers 1996; Shaw and Burns 1997; Widyatmoko and Norton 1997). These include examining the distribution and some aspects of the habitat and population characteristics of the plant in question. Where possible methodology for this thesis was modified from these studies.

To ascertain where *Teucridium* is found the national and local distributions of the plant were compiled. To determine the type of communities that *Teucridium* occurs in the species composition and physical characteristics of sites that contain *Teucridium* were studied on Banks Peninsula. To determine why *Teucridium* is rare aspects of the population dynamics of the plant including population structure, browsing effects, basic phenology and seedbank dynamics were investigated.

2.1 STUDY AREA

Banks Peninsula is a highly visible extrusion on the east coast of the South Island of New Zealand. It is approximately 50 km long by 30 km wide with an altitude ranging between sea level and 920 metres. Many of the ancient volcanic valleys have been invaded by the sea, forming picturesque bays around the perimeter of the Peninsula.

The peninsula formed as an island off the coast of the South Island during the Kaikoura Orgeny about 12 million years ago (Ogilvie 1990). Volcanic activity started at this time and continued until 5.8 million years ago (Wilson 1992). Since this time erosion has played a major role in the formation of the peninsula. The landforms that we see today are the result of erosion on the two major volcanic cones that formed the peninsula, the Lyttleton and Akaroa volcanoes. Gravel deposited from erosion in the Southern Alps formed the Canterbury Plains and connected the island to the mainland during the last 20,000 years (Weaver *et al.* 1990). The same processes that created this gravel also deposited loess, a fine silt created by the grinding action of ice on rock, on the peninsula, in some places up to a depth of 20 m (Weaver *et al.* 1990).

Soils are derived from the volcanic rocks and the layer of loess that covers a large part of the peninsula. There is a complex soil pattern that reflects the variable topography, erosion of loess, and the steep rainfall gradients (Wilson 1992). The Yellow Grey Earths that are found on the valley floors and the lower slopes are prone to waterlogging in the winter and dry out rapidly in the summer (Ryan 1987). The Yellow Brown Earths of the higher country do not dry out as readily and are freer draining.

The rainfall of Banks Peninsula differs from the surrounding areas because of its high relief and the lack of shelter from the north-east and south-west winds (Ryan 1987). There is a distinct late autumn and winter maximum rainfall on the peninsula and a minimum in spring and summer. Strong rainfall gradients are present on the Peninsula ranging from about 600 mm at the driest site to about 2000 mm at the wettest (Wilson 1992). Permanently flowing streams are present in the main valleys and many of the smaller valleys contain streams that flow during the wetter months but are intermittent in summer. The warm dry north-westerly wind that affects all of Canterbury also has notable effects on the climate of the peninsula. Although this wind blows for only about three percent of the time (Ryan 1987), it can intensify the effects of periodic summer droughts.

Prior to human settlement Banks Peninsula was covered in mixed Podocarp forest. Clearing of this forest was gradual from the time of the first human habitation about 1000 years ago until the arrival of the first European settlers early last century (Ogilvie 1990). With the arrival of Europeans the rate of forest clearance increased dramatically. Between the years of 1840 and 1890 virtually the whole peninsula was cleared of forest to make way for pasture and to provide timber to build the city of Christchurch (Ogilvie 1990). The only forest that remained survived in small refugia in the most inaccessible areas.

Most of the forest on the peninsula at present is in the form of second growth hardwood forest that has regenerated this century and covers about 9000 ha. Much of this regenerating forest is on unprotected farmland and has been severely degraded by farm stock as well as feral goats and possums. In protected areas the regenerating bush is stunning and contains a wide variety of plant, bird, and invertebrate species. The only old growth forest that remains is in tiny fragments covering around 800 ha of the peninsula. This represents less than 1% of their pre human extent (Wilson 1992).

The main emphasis of this study was on the valleys around the southern side of the peninsula. Most of these valleys contained at least one significant stand of regenerating forest as well as several smaller remnants, forming a mosaic within the surrounding farmland.

2.2 DISTRIBUTION

Teucridium has a curiously scattered distribution (Given 1981). It is known from sites spread discontinuously from Hawkes Bay to Southland, although no one is sure of the actual distribution of *Teucridium* or how rare it really is (T. Partridge pers. comm.). Therefore in this study records of *Teucridium* were gathered to develop a more accurate record of the national distribution of the plant and to determine its rarity. Historical records from the Manaaki Whenua Landcare Research Herbarium (NZCHR) and field notes from Hugh Wilson's Protected Natural Areas survey of Banks Peninsula indicated that there were several populations on Banks Peninsula, so particular emphasis was placed on those populations.

2.2.1 National Distribution

Herbarium records at the Manaaki Whenua Landcare Research Herbarium in Lincoln were studied to determine the national distribution of *Teucridium*. Other sources of information were reports on the scenic reserves of Canterbury (Kelly 1972), Southern Marlborough (Williams 1982), Otago (Allen 1978; Ward and Munro 1989), and the lower North Island (Gabities 1986).

The Department of Conservation in Wellington, Hawkes Bay and Hamilton provided information from their threatened plant database on the distribution of *Teucridium* in the Southern North Island and the Waikato. From this information maps were compiled showing the national distribution of *Teucridium*.

2.2.2 Distribution on Banks Peninsula

Field notes from Hugh Wilson's Protected Natural Areas Programme (PNAP) survey of Banks Peninsula were studied to determine the local distribution of *Teucridium* (Wilson unpublished). This survey was conducted between 1984 and 1988 and contains data on the vegetation within 600 vegetation fragments on the Peninsula where native plants are a significant part of the flora. The PNA report (Wilson 1992) was also studied to determine which populations occur on protected land and which are on land recommended for protection as this may have implications for the management of the plant.

2.3 COMMUNITY ECOLOGY

The distribution data established where *Teucridium* occurred on a national scale and on Banks Peninsula. The next step was to classify the plant communities in which *Teucridium* occurs. To establish the floristic composition of the communities, vegetation surrounding individual *Teucridium* plants was sampled and information was gathered on the frequency and size of associated species.

2.3.1 Location of Plots

The distribution of *Teucridium* presented a number of problems in sampling design. *Teucridium* often displays a highly localised "clumped" distribution. Many survey techniques are not suitable for estimating numbers of plants with this kind of distribution that occur in low densities (Given 1994).

Plot location was determined after thorough searching in the areas of Banks Peninsula identified as containing *Teucridium* in the PNA survey notes (Wilson unpublished). Every effort was made to locate as many *Teucridium* plants as possible in each location. Throughout New Zealand populations have been located mainly around stream margins and other disturbed habitats such as forest margins and canopy gaps. From site descriptions in local and national records of *Teucridium* an expectation of where *Teucridium* would occur was developed. At each location an attempt was made to survey as much of the vegetation as possible, ensuring that sampling included both areas where *Teucridium* was expected to occur, and areas where it was not expected to occur.

Many of the populations were very small and contained single, widely scattered plants. Others such as lower Prices Valley contained thriving populations of hundreds of plants spread over most of the west side of the valley. Some of the areas described in the PNA report (Wilson 1992) no longer contained populations of *Teucridium* or were found to contain few *Teucridium* plants at the time of this study. In some areas there were cliffs, high bluffs, and thick vegetation which made it difficult to conduct exhaustive searches and plants may have been missed.

2.3.2 Selection of Plants

Because of the difficulties in sampling design it was decided that a sampling method that focused on individual plants was the most appropriate. The decision on how many plants to sample at each site was made subjectively considering the number of plants in the vicinity and how far apart they were. To offset bias that may have been introduced by sampling only the largest plants or the most noticeable ones, the second plant that was sighted in each population was sampled. Where there was only one plant in the vicinity, this plant was sampled. The selected plants were marked as the centre of the plot.

2.3.3 Plot Size

Plot size was also an important consideration. Species area curves (Krebs 1978) were compiled for the bush fragments in Prices Valley and from this it was determined that a plot size of 400 m^2 contained 90% of all species present in the area (Figure 2.1). However, this was deemed to be too large for sampling *Teucridium* communities. As *Teucridium* populations are highly localised a large plot would be to heterogenous. A smaller plot size was more appropriate as in this study I focused on the immediate vicinity surrounding *Teucridium* plants rather than the composition of the entire vegetation remnants.

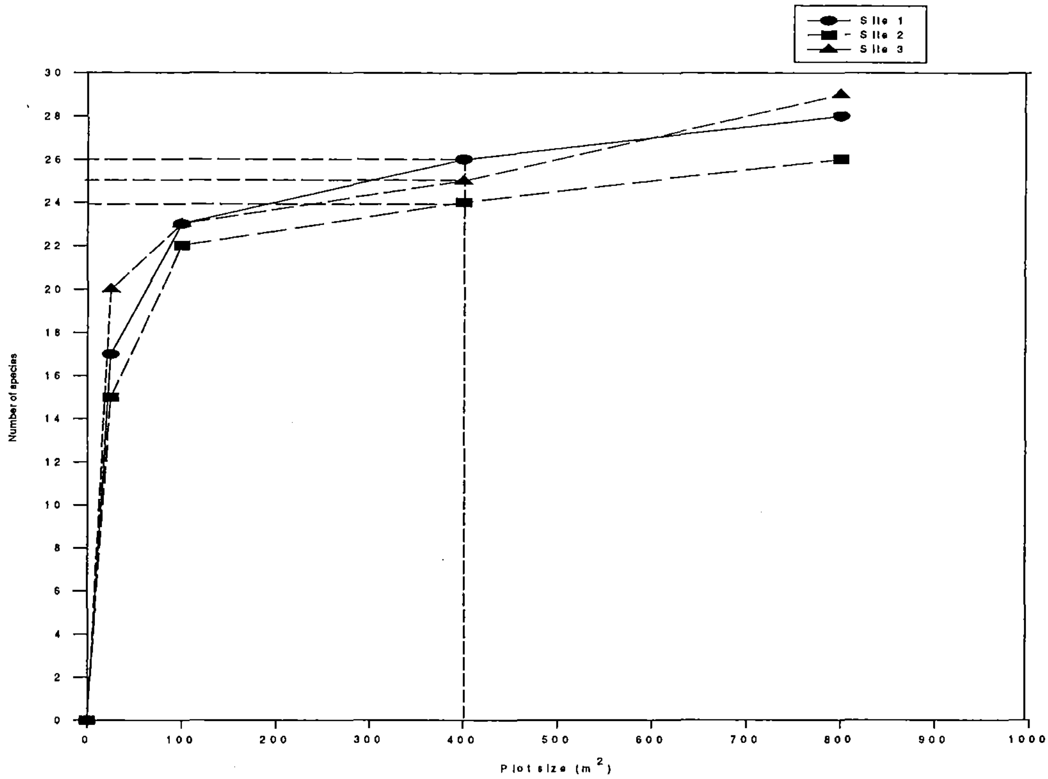

Figure 2.1: Species area curves for three sites in Prices Valley indicating that the optimum plot size for a full survey of the vegetation is 400 m^2.

2.3.4 Sampling Methods

A stratified sampling method was devised that sampled the vegetation surrounding each *Teucridium* plant at three levels, the ground tier, shrub layer and canopy layer. The tiered sampling scheme acknowledged the need to identify the environmental factors that influence the plants, and to identify the composition of the surrounding vegetation, whilst negating the need for a larger community survey.

The effect that the surrounding vegetation has on the sample plants is largely determined by the height of the surrounding plants, and their distance from the sample plant. Larger plants influence the growth of the sample plant from a greater distance than small plants. Thus smaller plants were only measured close to the sample plant whereas larger plants were measured out to a greater distance. Within each plot there were three circular plot sizes. These were circular plots of 0.7 m radius (1.5 m^2), 1.5 m radius (7.0 m^2), and 3.0 m radius (28.0 m^2) (Figure 2.2).

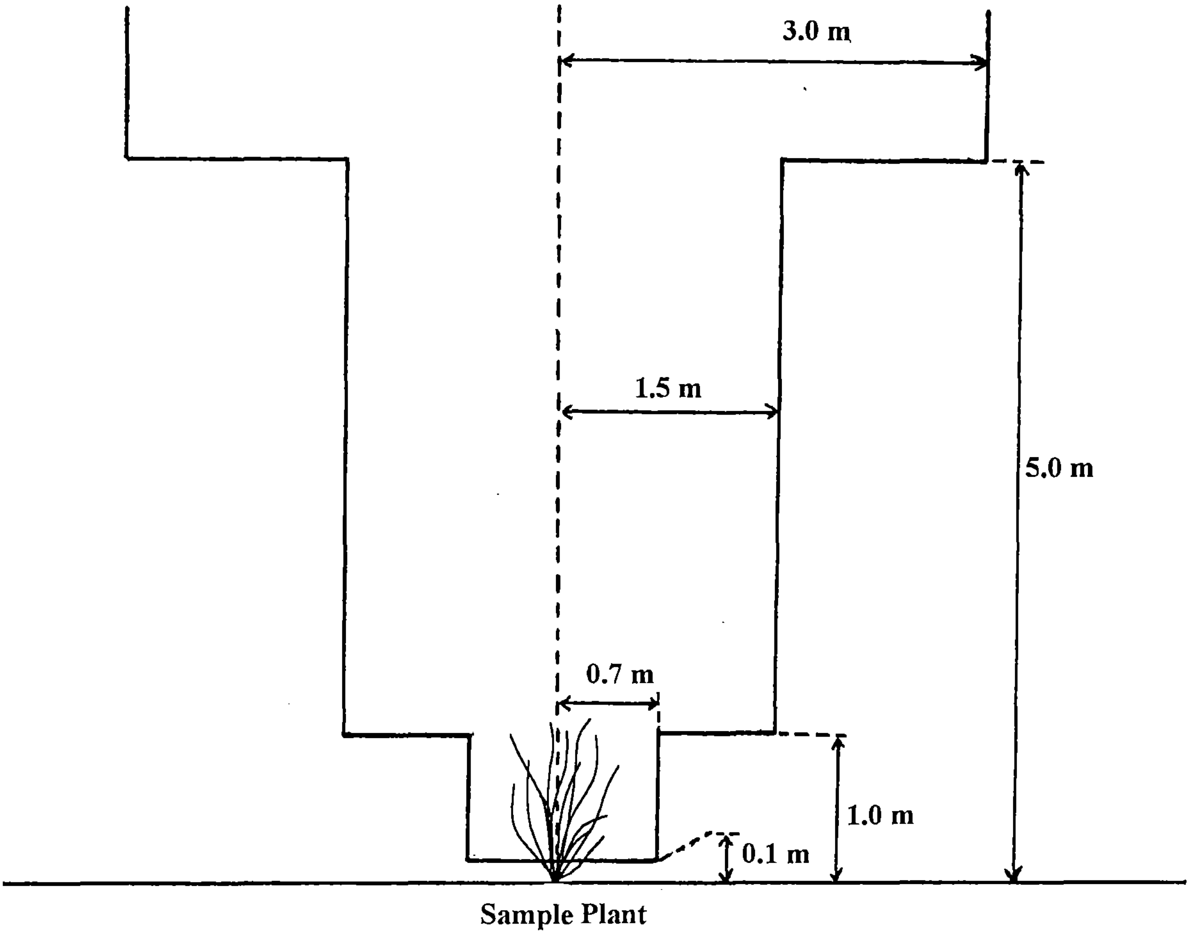

Figure 2.2: **Design of plots for tiered vegetation sampling of plant communities containing *Teucridium parvifolium.***

The 1.5 m^2 quadrat was sampled for the ground tier close to the sample plant. All native species between 0.1 m and 1.0 m tall within this quadrat were recorded and their height measured (Figure 2.2). Herbaceous agricultural weed species were largely ignored unless they were abundant or large enough to significantly affect the sample plant. However, a subjective measure of the percentage weed cover within each plot was estimated to the nearest 5%. The 7 m^2 quadrat sampled the shrub layer. Height and diameter at breast height (1.4 m) were recorded for all native plants between 1.0 m and 5.0 m (Figure 2.2). As most plots were in fragments with low canopies, any trees above 5.0 m were considered to be canopy trees. In the 28 m^2 quadrat the height and dbh of all species over 5.0 m was recorded (Figure 2.2).

2.3.5 Number of Plots

50 plots in total were sampled from 5 valleys on Banks Peninsula (Table 2.1). The majority of these were from Prices Valley where *Teucridium* populations were relatively abundant. The number of plots at each location gives a crude indication of the relative abundance of *Teucridium* in that area. Within Prices Valley plots were sampled in a number of locations ranging from alluvial flats to sites at 260 m on the surrounding hill slopes.

Table 2.1: Number of plots sampled at each of 5 sites on Banks Peninsula.

Location.	Number of Plots.
Ahuriri Valley	1
Kaituna Valley	4
Okana Valley	4
Okuti Valley	3
Prices Valley- Lowland	10
- Hillside	28

2.3.6 TWINSPAN Analysis

A TWo-way INdicator SPecies ANalysis (TWINSPAN) was carried out on the vegetation data using the PC-RECCE computer programme (Hall 1992). This was done to characterise the composition of *Teucridium* communities and to identify any differences in community composition that may occur.

TWINSPAN constructs an ordered two-way table with species as rows and samples as columns (DeVelice 1985; Hall 1992). To do this it analyses the whole data set and progressively divides it, by reciprocal averaging ordinations, into successively smaller groups until it reaches a preselected level of subdivision (Hall 1992). The programme then provides an indicator species analysis which shows the species which most differentiate one community from another.

Presence/absence data of each species from each plot was analysed to identify any differences in community composition between the plots. This was considered to be the least complicated method and precluded decisions on the importance and therefore relative weighting of each of the species involved, while still providing relevant information on the frequency of occurrence of species in each community. TWINSPAN has been used in a number of studies in New Zealand (e.g. Clarkson 1984; Stewart *et al.* 1993).

2.3.7 Environmental variables

The physical site factors and soil characteristics that may explain compositional differences in the vegetation were summarised for the communities generated by TWINSPAN. Williams (1992) used altitude, aspect, slope, physiography and soil parent material to characterise the sites on which *Scutelaria novae-zealandiae* occurred. For *Pittosporum obcordatum* Clarkson and Clarkson (1994) described site characteristics using soil type, landform and the impact of browsing animals. As these variables were deemed important in other studies it was decided to use aspect, elevation, slope, drainage, accessibility, browsing and physiography in this study.

Aspect was measured by taking a compass bearing facing downhill in the direction that the majority of the plot sloped. As most bush fragments were small it was possible to estimate elevation (metres above sea level) to the nearest 10 m by careful map reading. Slope (degrees) was measured using a Clinometer sighted on a mark uphill at the same height as the observers eye level. Drainage was judged subjectively on a scale of one to five with one being well drained and five being poorly drained. Drainage was assessed as a measure of the wetness of the soil and the health of the vegetation in the plot, taking into account recent weather. Access to stock was measured on a scale of one (no access) to five (very accessible) as a means of determining the impact that stock may have in the area. This was assessed subjectively based on topography and the availability of access routes such as stock tracks and stream beds. Browsing on all species within the plot was judged subjectively on a scale of one to five, with one being no browsing and five being heavily browsed. Physiography was divided into 12 classes: Wet, riparian, rise, crest, terrace, dip, hummock, toe, slope, cliff, lee, ridge.

2.3.8 Soil Analysis

To relate community composition as identified by TWINSPAN analysis to soil characteristics soil samples were collected for each site. At each site five soil samples were collected using a 10 cm soil corer with a diameter of two cm. These samples were combined and tagged and then air dried before analysis. For each combined sample pH, moisture holding capacity and texture were measured.

These simple tests were chosen because of the ease with which they could be conducted while still giving relevant information and because of their convenience over other expensive, time consuming tests.

Soil pH was measured according to the procedure described in Blakemore *et al.* (1987). 10 g of <2 mm soil was thoroughly mixed with 25 ml of distilled water and left to stand overnight. The resulting solution was then measured using a glass electrode pH meter and the pH was recorded.

The moisture holding capacity of the soil was measured using a simulated measure of field capacity. Although it is difficult to define field capacity precisely McLaren and Cameron (1990) describe it as the state of the soil "after rapid drainage has effectively ceased and the soil water content has become relatively stable".

As it was considered impractical to measure field capacity *in-situ* container capacity was used to measure the moisture holding properties of the soil. Container capacity was defined as "... the water content of the soil, initially thoroughly wetted, after free drainage from holes in the base of the container has ceased..." (Cassel and Nielsen 1986). A procedure similar to that described in Rosie (1994) was followed. Samples were placed in containers with holes in the bottom to allow free drainage. They were thoroughly wetted and covered to prevent evaporation. Each container was positioned so that water could drain freely. The sample was allowed to drain for 24 hrs and was then weighed. It was then dried at 105°C for a further 24 hrs.

The dried sample was reweighed, and the container capacity calculated using the following equation:

$$\frac{\text{saturated soil (kg) - dry soil (kg)}}{\text{dry soil (kg)}}$$

Container capacity is an equilibrium measure whereas field capacity estimates field conditions that never reach equilibrium. Therefore the two concepts are not equivalent. However as the current study only required comparative measures container capacity was considered sufficient.

Soil texture was determined qualitatively by manipulating a moistened soil sample between the thumb and fingers as described in McLaren and Cameron (1990). The texture classes described in McLaren and Cameron (1990) were used to describe the soil (Table 2.2).

Table 2.2: Texture determination of moistened soil. (From McLaren and Cameron, 1990)

Feel and Sound	Cohesion and Plasticity	Texture Class
Gritty and rasping sound.	Cannot be moulded into a ball.	SAND
	Will almost mould into a ball but disintegrates when pressed flat.	LOAMY SAND
Slight grittiness, faint rasping sound.	Moulds into a cohesive ball which fissures when pressed flat.	SANDY LOAM
Smooth soapy feel, no grittiness.	Moulds into a cohesive ball which fissures when pressed flat.	SILT LOAM
Very smooth, slightly sticky to sticky.	Plastic, moulds into a cohesive ball which deforms without fissuring.	CLAY LOAM
Very smooth, sticky to very sticky.	Very plastic, moulds into a cohesive ball which deforms without fissuring.	CLAY

Soil texture refers to "the particle size distribution of the solid inorganic constituents of the soil" (McLaren and Cameron 1990). As all that was required for this study was a comparison of the texture between each site and not a detailed particle size analysis it was decided to use a simple field assessment of soil texture rather than the more difficult and time consuming laboratory methods of particle size analysis.

2.3.9 Data Analysis

The data on environmental and soil characteristics was summarised for the communities identified by the TWINSPAN analysis. One Way Analysis of Variance were used to determine any significant differences in these characteristics between the two communities.

2.4 POPULATION ECOLOGY

To determine the status of *Teucridium* populations and to try and find out why it is rare a number of aspects of the population dynamics of *Teucridium* were investigated. The central question being asked in this part of the research was "Why is *Teucridium* rare?" It was hypothesised that *Teucridium* was in decline because of limited seed viability and poor germination as well as grazing from introduced stock. Population structures were studied to determine whether or not *Teucridium* populations were actually in decline as supposed. To determine if this could be attributed to the seed ecology of the plants or browsing, research was conducted into the phenology of the plants, including the seedbank, and the effects of browsing *Teucridium.*

2.4.1 Population Characteristics

Analysing population structure gives more detailed information on populations than absolute numbers by examining reproductive success and age structure. The allocation of individuals to age classes and scoring for flowering and seeding will quickly give an indication of the demographic characteristics, reproductive state and persistence of a population (Given 1994).

Data was extracted from the results of the vegetation sampling to identify the number of *Teucridium* seedlings (< 40 cm), saplings (40 cm – 100 cm), and adults (> 100 cm) in each plot. This data was used to identify the proportion of plants in each age class within each plot. However, this data did not give an accurate indication of the population structure as it did not accurately sample all of the *Teucridium* plants present. Seedlings were only recorded in the 1.5 m^2 plot. Within the 7 m^2 plot only large *Teucridium* plants were recorded and as no *Teucridium* plants were taller than 5 m, none were recorded in the 28 m^2 plot To overcome this 39 of the plots were revisited in November 1997 and the size of all *Teucridium* plants within each 28 m^2 plot was recorded. From this data size class distributions were compiled.

2.4.2 Seed Production and Viability

Seed production and viability were hypothesised to be poor. To determine if this was true seeds were gathered from adult plants and germination trials conducted.

Teucridium seeds are formed from December through to March (Wilson and Galloway 1993). During fieldwork for this study general observations were made about the abundance of seeds on the study plants. It was evident from an early stage of the fieldwork that, despite the hypothesis that seed production was poor, most plants were producing large quantities of seed. Therefore the emphasis switched from seed production to seed viability.

To determine the viability of seed five healthy plants in Prices Valley sites were selected for seed collection. These plants all had abundant seed forming in early March 1996. Seed was collected by covering six stems on each plant with nylon pantyhose. Not all stems were covered on any one plant so that interference in the population dynamics of each site was minimal. This method was chosen as it was felt that it would be the most effective way of capturing a large amount of seed with as little damage as possible to the plants.

Seed was collected in April and May 1996, counted, and stored in a cool dry place over the winter. To determine seed viability 200 seeds were sown in germination trays in late August and kept moist in a glasshouse for the next nine months. Seedlings were counted and removed as they emerged.

2.4.3 Seedbank

The presence of a seedbank can be a critical factor in the continued existence of rare species as they can then survive in areas that may become temporarily unsuitable (Given 1994). A study was conducted for one year to determine the existence of a *Teucridium* seedbank and the importance that this might play in the reproductive biology of the plant.

Soil samples around one large plant were taken in early February 1996 from five sites in Prices Valley prior to the seed fall for the 1995/96 season. Ten samples were taken from underneath the plant and ten were taken within three metres of the plant. Soil cores were taken to a depth of 5 cm using a 2 cm diameter soil corer.

The samples were air-dried in a glasshouse at a mean temperature of 22°C for a month and then layed out on sand in mushroom trays and placed in a glasshouse where they were kept moist for the duration of the experiment. A tray of sand was placed with the other samples to act as a control.

Over the course of the year there were six sampling dates: 10/04/96, 20/05/96, 05/09/96, 30/10/96, 23/01/97, 05/03/97. On each of these dates seedlings were identified and removed. Results from each site were pooled for analysis.

2.4.4 Growth

Plant growth rates are important for rare plants as they can determine whether or not the plants are capable of surviving the external pressures exerted on them. Seedling growth is important as this is the stage at which there is severe competition from a range of introduced species. Adult growth rates are also important in *Teucridium* as it must contend with browsing from introduced herbivores.

To determine seedling growth rate seedlings that were removed from the seedbank trial were grown on, initially in a glasshouse and then in a shade house, where height was measured after three months.

Adult growth rates were measured in a small field experiment in Prices Valley from December 1996 until March 1997. In December 1996 ten plants each had five shoots tagged 1 cm from the growing tip. The tags were attached so that they would not move but not so tight that they would alter the growth of the plant. The stems were also marked with indelible marker for added security. In March 1997 the sites were revisited and the plants were remeasured to determine how much the tagged shoots had grown over the summer.

Data on plant height, width and number of stems was collected from the sample plants in the vegetation plots during 1996/1997. This was repeated in the 39 plots that were re-sampled for population data in November 1997. This data was used to determine how much the plants had grown since the initial sampling.

2.4.5 Browsing

Browsing has been identified as a problem facing a number of rare species in New Zealand (Williams 1992; Clarkson and Clarkson 1994; Rogers 1996; Shaw and Burns 1997). Past records also indicate that *Teucridium* plants are affected by browsing (Wilson unpublished; Department of Conservation records). Therefore a study was also conducted to determine the effects of browsing on the growth of *Teucridium* plants. The plant that was selected as the centre of each vegetation plot was also sampled to determine the extent of browsing. Browsing was judged to be present where the stems had been obviously bitten off. In some cases it was obvious that the stems had been broken off by the action of wind, falling debris, or some similar phenomenon. These stems were not included as having been browsed. Insect browsing was noted where it was observed but was not included in sampling as it was not until later in the field work period that any plants were observed that had been heavily browsed by insects.

The main leaders that arose from the base of the plant were deemed to be the primary shoots. These were counted and then the number that had been browsed was noted. The results were converted into percentages and this was classed as the primary browsing index.

To determine a secondary browsing index the secondary leaders arising from six of the primary shoots were examined. Where there were not six primary shoots, all shoots that were present were included. The secondary leaders were counted and then the number that had been browsed were counted. The results were converted into percentages to give the secondary browsing index.

3.0 RESULTS

3.1 DISTRIBUTION OF *TEUCRIDIUM*

3.1.1 National Distribution

Teucridium is distributed discontinuously throughout most of New Zealand, occurring from Northland to Southland. The notable exception is the lack of any populations on the West Coast of the South Island. *Teucridium* occurred at 32 locations in the North Island and 34 locations in the South Island. These records span over 100 years from the earliest record in the Wairoa Gorge (1893), until the present. In many cases the records are 40 or more years old and there is no way of knowing whether or not *Teucridium* is still present at these sites. Many of the records are for single plants, or very small populations of less than 10 plants.

Throughout New Zealand there is a pattern of groups of several local populations of *Teucridium* occurring within short distances of each other but separated from the next group of populations by a considerable distance.

3.1.1.1 North Island

In the North Island (Fig 3.1) *Teucridium* occurs from Whangaroa in Northland to as far south as the Hutt Valley. There are several distinct areas where *Teucridium* populations occur. The population at Whangaroa seems to be an outlier with the closest known populations near Thames and Te Aroha. There are a number of populations around Waitomo and west of Lake Taupo, and also around Gisborne and Lake Waikaremoana. There are several populations in the lower-central North Island, mainly around Taihape but also in Hawkes Bay. From Dannevirke south *Teucridium* sites are almost common, especially in the Wairarapa.

Dates of observation are not available for the Northland or Coromandel records. There is a historical record that indicates persistence for at least 50 years in the Waitomo area. The earliest record in this area is from Piopio in 1937 and the most recent record is from Mangapu River in 1987. *Teucridium* is common in Koropupu Scenic Reserve and the records from Manunui in 1940 state that it was plentiful in that area.

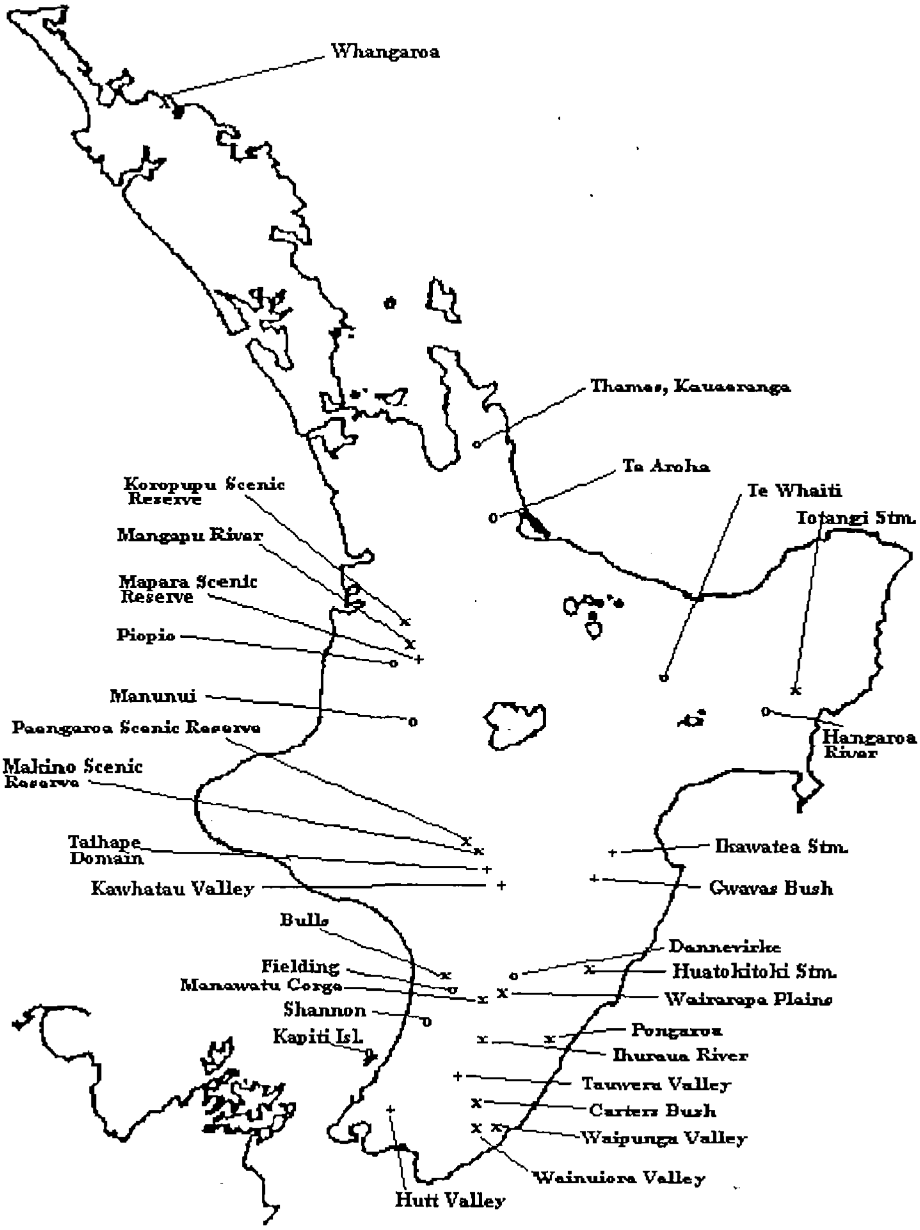

Figure 3.1 : Distribution of *Teucridium parvifolium* in the North Island of New Zealand.
(o = record previous to 1970, + = record from 1970 - 1984, x = record since 1985).

There is no measure of the abundance of *Teucridium* at the sites around Gisborne and Lake Waikaremoana but there are records that indicate it has persisted in this area for over 70 years. Although the Te Whaiti population is somewhat removed from the Hangaroa River and Totangi Stream sites it is the earliest record in this area (1920). Unfortunately there are no further records from Te Whaiti so there is no way of knowing if it is still present in that vicinity. However, the records from Hangaroa river (1967) and Totangi Stream (1991) indicate that *Teucridium* is persistent in the general area.

There are a number of populations that occur around Taihape and these indicate that *Teucridium* has been known in the area over at least a 25 year period. The earliest record in the area is from the Kawhatau Valley in 1966. *Teucridium* was still present at this site in 1979 but there have been no collections since. Collections from the Taihape Domain (1972), Mataroa (1978), Paengaroa Scenic Reserve (1991), and the Makino Scenic Reserve (1991) suggest that *Teucridium* is persistent in this area. There have also been two collections from nearer the east coast at Ikawatea Stream (1975) and Gwavas Bush (1976). Unfortunately there was no indication of abundance in these areas and there have been no further collections so it is impossible to know the status of these *Teucridium* populations.

There are many records of *Teucridium* in the lower North Island, from the 1920's until the present day. In terms of locations *Teucridium* is almost plentiful in this part of the country. However, there is not much data on the number of plants at each site and there are many one off collections with no indication of persistence at each site.

The earliest records in the Manawatu are from Fielding (1925) and Moutoa Estate near Shannon (1937). The most recent record from Fielding is 1969, indicating that it was persistent in that area during the intervening years. There are no recent records so it is not known whether or not *Teucridium* is still present at this site. However, collections from the Manawatu Gorge and Bulls in 1992 indicate that it is still present in the area.

In the Wairarapa the earliest record is from Carters Bush in 1930. The most recent record from Carters Bush is 1995, so *Teucridium* has persisted at that site for at least 65 years. There have been a number of recent collections in the Wairarapa: The Wairarapa Plains (1992), Wainuiora Valley (1993), and Alfredtown and Pongaroa (1994). These records suggest that *Teucridium* is widely distributed in the Wairarapa region.

There are also a number of records from the Hutt Valley and surrounding areas dating back to the early 1940's. The most recent record from this area is from Trentham in 1975 so it is difficult to determine the current status of *Teucridium* in this area.

There is one record from Kapiti Island in 1952 but no indication of the size of the population.

3.1.1.2 South Island

In the South Island (Fig. 3.2) there are pockets of *Teucridium* in Nelson, Marlborough, inland Canterbury, Banks Peninsula, South Canterbury, and Otago. As in the North Island, in each of these widely separated areas there seem to be several populations of *Teucridium* within short distances of each other, many of which have persisted for a considerable period of time.

There are several sites around the Takaka and Nelson areas. Although there is no information on the numbers of plants at the sites around Takaka there are records that indicate persistence over at least a 25 year period from 1951 until 1976. Near Nelson the earliest record is from the Wairoa Gorge in 1893. There is a record from the Wairoa River in 1981 which indicates that *Teucridium* has been present in this area for at least 88 years. The record from the Carlukle Scenic Reserve in the Rai Valley in 1985 may indicate that *Teucridium* is more widespread in the Nelson area, although it was uncommon in the reserve.

Teucridium occurs in a number of sites along the coast of Marlborough and North Canterbury. At two of these sites, Puhipuhi Valley and Blue Duck Reserve, it is abundant over large areas and there are vigorous populations at Boundary Creek further down the coast.

The earliest record from Marlborough is from Swale River, near Puhipuhi Valley in 1915. There are records from Puhipuhi Valley in 1978 and 1988, and from Blue Duck Reserve in 1980 and 1985. This, along with the abundance of the plants in the area, suggests that *Teucridium* is surviving well in this locality.

There are a group of populations in Mid-Canterbury that seem to be anomalous to the normal distribution of *Teucridium.* The sites at Lake Pearson and Porters Pass must be approaching the altitudinal limit of *Teucridium,* generally considered to be a lowland plant. There are two records from Porters Pass (1946 and 1980), which indicates that *Teucridium* has been persistent in this area. However, the record from Porters Pass in 1980 was for only a single plant and there is no information from any of the other sites on which to base estimates of population size.

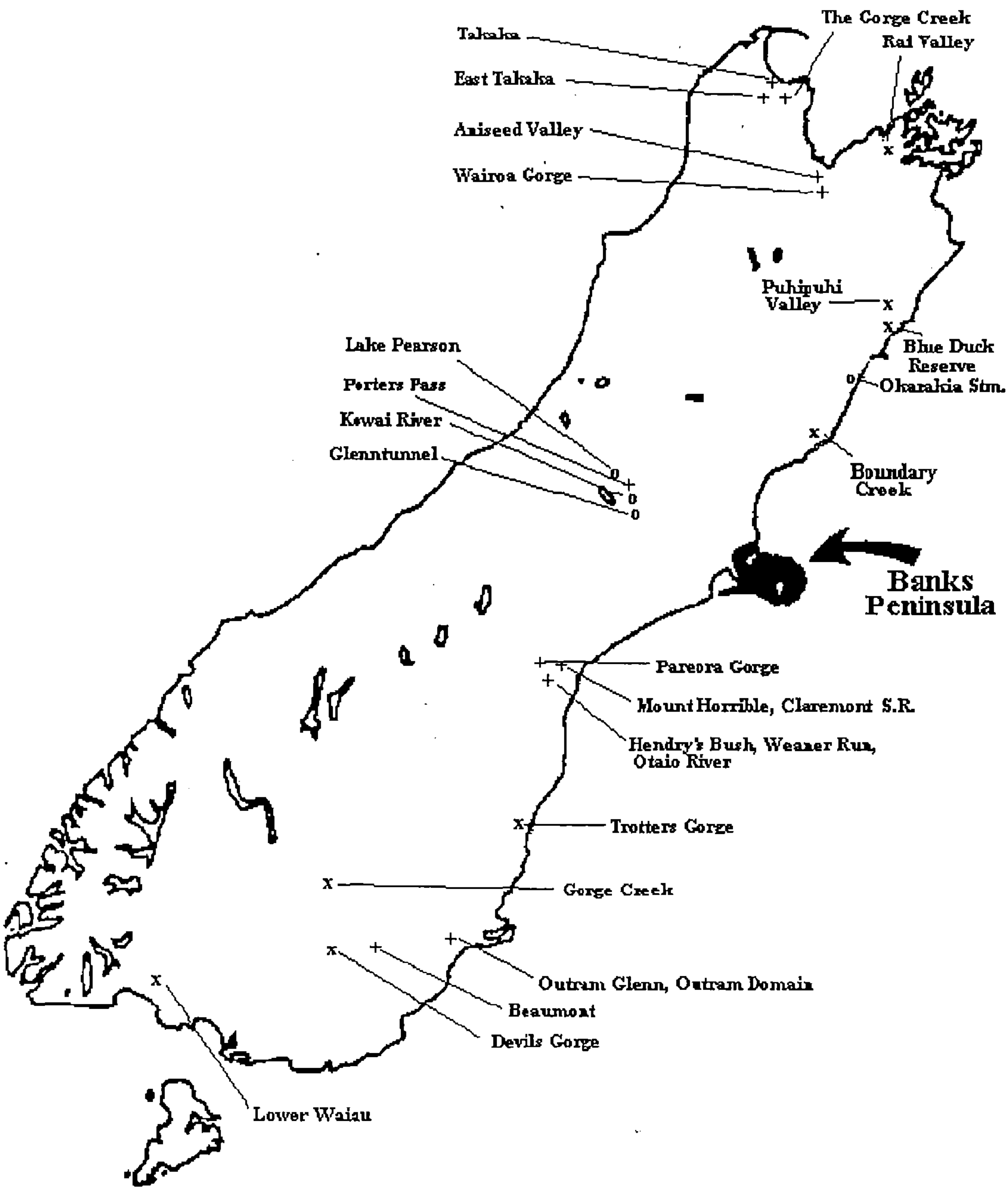

Figure 3.2: Distribution of *Teucridium parvifolium* in the South Island of New Zealand.
(o = record previous to 1970, + = record from 1970 - 1984, x = record since 1985).

In the same area there are records from the Kowai River in 1947 and from Glenntunnel in 1964. Again there is no indication of population size but it does show that there are several *Teucridium* populations in this area.

In South Canterbury there are several sites around the Pareora and Otaio Rivers. Most of the records in this area are one-off collections that do not give any indication as to the persistence at any one site. However it seems that *Teucridium* has been in the area for quite some time.

Records from the Otaio River near Mt Blythe in 1945 and from the Hunters Hills nearby in 1972 indicate that *Teucridium* was present in this area for at least 25 years. There is no record of abundance at the Mount Blythe site and there was only a small grove at Hendrys Bush, one of the Hunters Hills sites. However, at the other site in the Hunters Hills, Weaner Run, *Teucridium* was locally abundant. This suggests that *Teucridium* may still be persisting in this area.

Teucridium has also been common in the past along the Pareora River and may still be today. It was first collected from Mount Horrible, near the Pareora River in 1945, then from the Claremont Scenic Reserve in 1970 and from further up the river in the Pareora River Scenic Reserve in 1971 and 1977. At the Pareora River site *Teucridium* was common but there is no information for any of the other sites.

Teucridium is rare in Otago and Southland. There are very few sites and most of these seem to contain only one or a few plants. The population at Trotters Gorge in North Otago was first recorded in 1977 and then again in 1987 and 1993. Even though *Teucridium* seems to be persisting at this site the number of plants is described as "occasional".

Teucridium has been recorded near the Taieri River, south of Dunedin. The first of these was at Outram Domain in 1976 as part of the Biological Survey of Reserves Series and *Teucridium* was described as rare. Eight years later occasional *Teucridium* plants were recorded at Outram Glenn in the Taieri Gorge.

There are records from the Clutha Valley, from Beaumont in 1982 and Gorge Creek in 1985 and 1983. The population at Gorge Creek, consisting of at least 15 plants, is the largest in Otago according to the records gathered. The fact that this small population is the largest in the area indicates that *Teucridium* is not abundant in Otago.

There are two known records from Southland. One plant was found at Devils Gorge on the Pomahaka River in 1986 and *Teucridium* has also been described from the lower Waiau River, which is the known southern limit.

3.1.2 Distribution on Banks Peninsula

On Banks Peninsula the majority of the known populations occur in the valleys along the south western edge of the peninsula (Figure 3.3). The only exceptions are the populations near Pigeon Bay, Purau Bay, and Lyttleton.

There have been changes in the distribution of *Teucridium* on Banks Peninsula since the Protected Natural Areas survey was done in the mid to late 1980's. The healthy populations at Ahuriri Bush that were recorded in 1984 had declined significantly by late 1996. After extensive searching throughout the bush only a single population of very small and heavily browsed plants was located. At Hikuraki Bay despite a very good description of the exact location of the site and extensive searching in the area, no *Teucridium* plants were located.

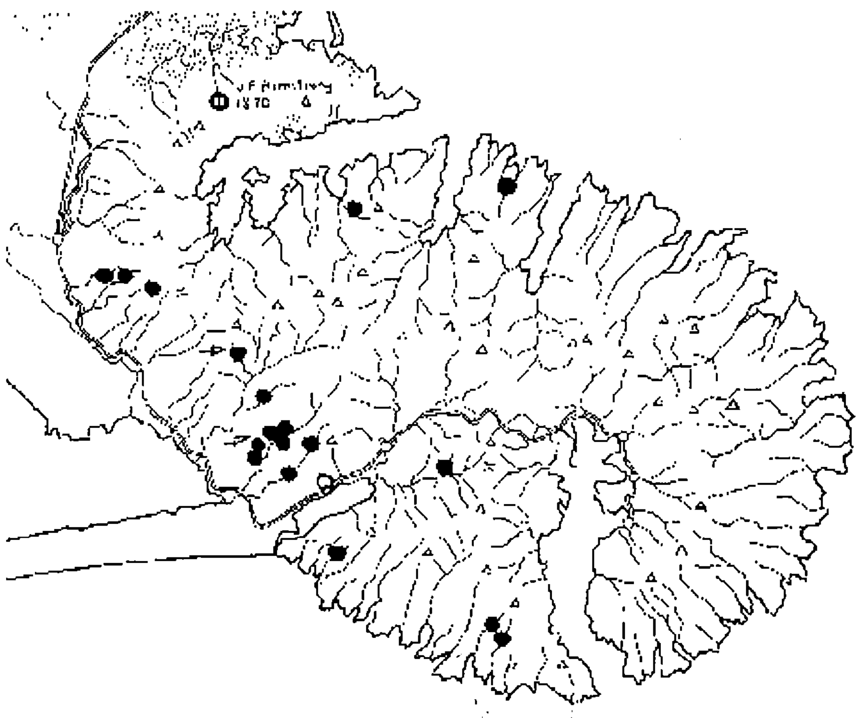

Figure 3.3: Distribution of *Teucridium parvifolium* on Banks Peninsula.
(Courtesy Hugh Wilson)

In Kaituna Valley *Teucridium* was recorded in the reserve on the valley floor in 1970. Despite extensive searches I did not relocate it. Further up the valley *Teucridium* was recorded in regenerating fragments on the hills to the south of Packhorse in 1987. The extensive patches described were not located but several single plants and two populations of over 10 plants were found in early 1997.

In Okana Valley, a side valley off Kaituna, a patch of several healthy bushes, including young plants, was recorded in 1987. In late 1996, during the fieldwork for this study, several isolated plants as well as one population of six plants and one of greater than 15 plants were located.

The most abundant populations were in Prices Valley where there are several hundred *Teucridium* plants spread over a wide area of the valley in a variety of situations ranging from river flats and terraces to higher slopes and escarpments on the surrounding hills. The first record of *Teucridium* in Prices Valley is from 1955 and it is still abundant in the area. The vegetation in Prices Valley has been highly modified by clearing for farmland and by grazing from introduced herbivores. A significant amount of regeneration has occurred on the hillsides and in the gullies within the valley. This provides a variety of habitats for a seemingly disturbance reliant species such as *Teucridium* to colonise.

A single plant was recorded from beside the stream in Okuti Valley in 1987. From the description of the site this plant, or at least one of its progeny, was located at the same site in late 1996. Three other plants were located growing along the banks of the stream within a short distance of the original plant. It is possible that these plants have spread down the stream from a parent population further up the valley but to establish this a more extensive search would be necessary.

Long Bay Scenic Reserve contains one of the most stunning remnants of bush on Banks Peninsula. From previous records it appears that *Teucridium* has never been particularly abundant in this area. In 1971 one patch of plants was recorded and in 1985 several plants were recorded growing alongside the stream that flows through the reserve. Despite searches in late 1996 and early 1997, *Teucridium* was not located in this area. This is likely to be due more to the impenetrable nature of the vegetation in the reserves rather than that *Teucridium* has died out. In some areas it was impossible to get through the bush without causing significant damage so it is possible that suitable habitats, and possibly *Teucridium* populations, were missed.

Other sites that have been described on Banks Peninsula but were not included in this study are Radford, Waikoko Valley, Pigeon Bay, Purau Bay, and Lyttleton. The site on Radford was described in 1985. It contained one bush about 2 m by 0.75 m, in a windswept rock crevice.

Two sites were noted in Waikoko Valley during 1986 and 1987. The first was in bushy tree land on the valley bottom. There were several healthy bushes under a light canopy along a stream. The second site was nearer the head of the valley. *Teucridium* was growing with juvenile matai (*Prumnopitys taxifolia*) and adult, juvenile, and seedling totara (*Podocarpus totara*). Much of the bush was kanuka (*Kunzea ericoides*), *Hoheria angustifolia* and kowhai (*Sophora microphylla*).

Teucridium was found in Big Bay Bush in 1991. It was browsed but persistent in an area that was very dry and heavily grazed. Patches of bush were mainly *Plagianthus regius, Hoheria angustifolia*, *Coprosma virescens* and *C. crassifolia* with some *Melicytus ramiflorus* and kanuka. No records were available for sites at Purau Bay and Lyttleton.

Records indicate that *Teucridium* is at least persistent at a wider level within the landscape. Local persistence may be a different story, closely related to local conditions. Some examples of this are evident from the sites on Banks Peninsula.

As described, following Hugh Wilson's notes from 1987 a plant, or one of its progeny was relocated at the same site in Okuti Valley 1996. It is likely that this was the same plant and this may give an indication of the persistence of the plants. The plant in question was obviously well established and had been there for a some time due to its size and the large basal area of the plant. This suggests that it was the original plant.
The site in Hikuraki Bay described by Hugh Wilson in 1987 contained a grove of *Teucridium* plants at the base of a large waterfall. The waterfall was located in early 1997 but there were no longer *Teucridium* plants present. This area had been extremely heavily browsed and the forest floor was all but bare in many places.

The sites in Okuti Valley and Hikuraki Bay demonstrate that although *Teucridium* is obviously capable of persisting this does not always happen. In this case browsing seems to have eliminated the populations but this may not be the sole cause as there are a number of other factors that may have contributed to the demise of the population. Other causes may be as simple as increased canopy growth decreasing the available habitat for the plants in Hikuraki Bay. The plant in Okuti Valley is in a location that it is not vulnerable to stock browsing but it also gets light. There are other plants in the area, however these are persisting in very low numbers.

There is also a very real risk to *Teucridium* from habitat destruction or modification. In a spectacular example of the speed at which this can affect *Teucridium* populations a group of at least six plants totally disappeared from one site in Kaituna Valley between January 1997 and November 1997. Despite intensive searching there was no sign of any of the plants. There was significant growth in a number of other species in the area such as *Helichrysum lanceolatum* and kanuka. The most likely explanation for this change is that a large area of kanuka had been cleared just downhill from the site. There was still a small strip of bush to protect the site but the removal of the kanuka has undoubtably had an effect on the microclimate of the area. This may have altered the habitat to such an extent that it was no longer suitable for *Teucridium.*

3.1.3 Distribution Within Banks Peninsula Valleys

Within the valleys on Banks Peninsula *Teucridium* plants were distributed according to the degree of canopy cover. The larger plants were growing in and around canopy gaps whilst between the gaps there were a number of smaller plants growing under the canopy (Figure 3.4).

These smaller plants were often growing towards the light. Most of the smaller plants in heavy shade had few if any seeds while the plants that were in the gaps carried large seed loads.

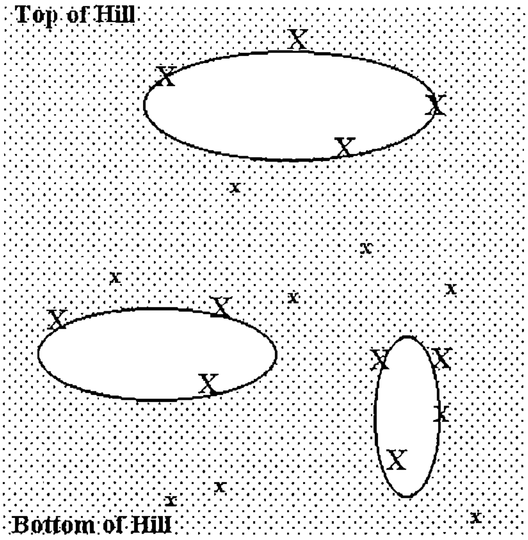

Figure 3.4: Stylised representation of the patch dynamics of *Teucridium parvifolium,* showing larger plants growing around the edges of canopy gaps and smaller plants growing under the forest canopy.

In many cases the populations on the hillsides have spread via the numerous streams that flow down side gullies into the main Prices Valley Stream. It seems as if the populations are spreading downhill. The most likely explanation for this is dispersal through water transport.

3.2 COMMUNITY ECOLOGY

3.2.1 Floristic Composition

Two compositionally different plant communities were identified from the TWINSPAN analysis.

The first community (the *Macropiper* community) was distinguished by the indicator species *Asplenium bulbiferum, Macropiper excelsum* and *Melicope simplex* (Table 3.1). *Macropiper excelsum* is a species that occurs as an understorey species in lowland forest with Banks Peninsula as its southern limit (Allan 1961). *Melicope simplex* is a forest margin species (Allan 1961). These species often occurred in and around canopy gaps.

There were a number of other species present in the *Macropiper* community that it is essentially forest habitat. *Pittosporum tenuifolium, Melicytus ramiflorus* and *Pellaea rotundifolia* all occurred in more plots in the *Macropiper* community than in the second community (Table 3.1).

The indicator species for the second community (the *Hoheria* community) were *Urtica ferox* and *Hoheria angustifolia* (Table 3.1). These are species which occur along forest margins (Allan, 1961). The presence of *Sambucus nigra, Clematis vitalba*, and *Acacia dealbata* indicate that these are marginal sites prone to invasion by exotic species. A number of other species such as *Kunzea ericioides* and *Haloragis erecta* are also species that are common on forest margins.

Teucridium plants occurred in almost twice the number of plots in the *Hoheria* community than in the *Macropiper* community (Table 3.1).

The two different communities varied in their occurrence at each of the study sites. The *Macropiper* community had one plot from Kaituna Valley, one from Okana Valley, two from Okuti Valley, and 21 from Prices Valley. The *Hoheria* community contained one plot from Ahuriri Bush, three from Kaituna Valley, three from Okana Valley, one from Okuti Valley, and 17 from Prices Valley.

Table 3.1: Frequency of occurrence of each species within plots in the two groups indicated by TWINSPAN Analysis. Indicator species for each community are indicated by shading.

Species	*Macropiper* community (n=25)	*Hoheria* community (n=25)
Fuchsia excorticata	1	0
Malus sp.	1	0
Pseudopanax crassifolius	1	0
Hedycarya arborea	1	0
Scandia geniculata	4	0
Pittosporum tenuifolium	7	0
Asplenium bulbiferum	17	1
Macropiper excelsum	21	7
Melicope simplex	19	9
Helichrysum lanceolatum	10	2
Melicytus ramiflorus	22	12
Coprosma virescens	17	11
Pellaea rotundifolia	20	14
Pseudopanax ferox	4	1
Myoporum laetum	5	2
Coprosma rotundifolia	5	3
Myrsine divaricata	3	2
Parsonsia capsularis	11	9
Coprosma areolata	10	9
Polystichum richardii	10	9
Coprosma crassifolia	9	7
Muehlenbeckia australis	4	3
Plagianthus regius	3	3
Alectryon excelsus	1	1
Pittosporum eugenioides	1	1
Hebe sp.	1	1
Lophomyrtus obcordata	3	5
Urtica ferox	2	14
Hoheria angustifolia	7	16
Pennantia corymbosa	7	11
Teucridium parvifolium	9	17
Coprosma propinqua	2	5
Sophora microphylla	6	12
Acacia dealbata	0	1
Podocarpus totara	0	1
Carmichaelia sp.	0	1
Haloragis erecta	0	2
Rubus sp.	0	2
Clematis vitalba	0	3
Sambucus nigra	0	3
Kunzea ericoides	0	5

3.2.2 Community / physical site relationships

3.2.2.1 Overall site characteristics

The majority of *Teucridium* plants were located at the forest margin or around canopy gaps within forest remnants. Most would receive at least some partial sun for part of the day and many full sun for part of the day. Those plants that were in full sunlight were often more divaricate than plants in more shaded locations. The leaves on plants in full sun were smaller and often brown, rather than the larger, fresh green leaves on the plants in more shaded situations.

The populations were found predominantly on toe slopes and hill slopes. Approximately a third of the sites were riparian to some degree, although some of these were beside small streams that would only flow during winter. Many plants occurred on sites that suffer climatic extremes throughout the year, being very wet in the winter and very dry in the summer.

The mean altitude of *Teucridium* populations was 142 m a.s.l. with a range from 80 m to 260 m (Table 3.2). Slope ranged from 10° to 45° with a mean of 24° and aspect ranged from 20° to 270° with a mean of 126° (South east) (Table 3.2). This illustrates the variation that was present in the location of *Teucridium* populations. Many of the plants were growing on very gentle slopes while others were in a much more precarious position on very steep slopes.

The range in aspect is consistent with the pattern for the majority of regenerating bush fragments in New Zealand. Most *Teucridium* populations were located in the valleys on the south western edge of the peninsula. The bush fragments that support *Teucridium* populations have either survived periods of habitat destruction, or are regenerating, on the cooler, moister slopes and gullies within these valleys.

Table 3.2: Physical site characteristics of plots containing populations of *Teucridium parvifolium*. Data is presented as the mean of plots in each of the groups indicated by TWINSPAN analysis, and the overall mean.

p is the level of significance associated with differences between groups, ns indicates $p > 0.05$.

Variable	***Macropiper* community (n =25)**	***Hoheria* community (n = 25)**	**P**	**SE**	**Mean (n = 50)**
Altitude (m)	164.2	119.0	0.001	6.9	141.5
Slope (°)	26.8	21.4	0.04	1.3	24.5
Aspect (°)	121.8	129.2	Ns	8.0	125.5
Drainage	2.4	2.4	Ns	0.1	2.4
Access	2.9	3.7	0.01	0.2	3.3
Browsing	3.0	3.6	0.01	0.1	3.3
pH	6.4	6.4	Ns	0.1	6.4
Container Capacity (%)	38.8	35.2	0.05	1.9	36.9
Rock on surface (%)	22.0	22.2	Ns	4.9	22.1

Mean drainage for all sites was 2.4. This was a subjective measure of the condition of the soil and may not be as reliable as the measure of container capacity which actually measured the amount of water that the soil could hold.

The scores for access and browsing were both higher than average (Table 3.2). This indicates that browsing stock were having effects in the area and possibly on the *Teucridium* plants.

Teucridium occurs on relatively fertile soils (DSIR 1968). Throughout the South Island most of the sites where *Teucridium* occurs are on Yellow Grey Earths and Yellow Brown Earths (DSIR 1968). The sites on Banks Peninsula were also predominantly Yellow Grey and Yellow Brown Earths, with some Brown Granular Loams and Clays, Recent Soils, and Yellow Grey Earth to Yellow Brown Earth Intergrades (DSIR 1968).

The mean pH of all sites was 6.4 with a range from 5.4 to 7.1 (Table 3.2). The mean container capacity of the soils was 37% and ranged from 19% to 51% (Table 3.2). On average 22% of the surface of the plots was covered in rock with a range of 0% to 60% (Table 3.2). The high level of surface rock in some of the plots is due to the disturbed nature of the sites, such as stream beds and marginal hill slopes.

The majority of the soils were sandy loams (mean = 42%), Loamy silts (mean = 28% and Loamy Sands (mean = 12%). Other soil textures present in the samples were Silt (6%), Silt Loams (4%), Sandy Clay Loams (6%), and Clay Loams (2%). These soils were mainly alluvial, derived from the loess deposits on the peninsula.

3.2.2.2 Variation in Community Site Characteristics

Sites in the *Macropiper* community generally occurred on steeper slopes at significantly higher elevations than the *Hoheria* community (Table 3.2).

The higher altitude and steeper topography limited stock access in the *Macropiper* community as indicated by significantly lower access and browsing values than the *Hoheria* community (Table 3.2).

Aspect and drainage also differed between the communities, but not significantly so. Plots in the *Macropiper* community occurred on sites that faced slightly more east than those in the *Hoheria* community. Drainage was lower in the *Macropiper* community than the *Hoheria* community.

Soil analysis showed little difference in soil qualities between the two communities (Table 3.2), though soil moisture was significantly higher in the *Macropiper* community than the *Hoheria* community, despite the fact that the *Macropiper* community was dominated by sandy soils whilst the *Hoheria* community was dominated by silt soils (Table 3.3). This may be due to the fact that the sites in the *Macropiper* community were growing in more sheltered areas and may not have been subjected to the same drying conditions of the lower, marginal *Hoheria* community sites (pers. obs.).

Table 3.3: Soil texture of sites containing *Teucridium* parvifolium presented as means of each TWINSPAN site group and means of all samples.

Soil Texture (%)	*Macropiper* community (n=25)	*Hoheria* community (n=25)	All Plots (n=50)
Sandy Loam	56	28	42
Loamy Silt	20	36	28
Loamy Sand	12	12	12
Sandy Clay Loam	4	8	6
Silt	4	8	6
Silt Loam	4	4	4
Clay Loam	0	4	2

3.3 POPULATION ECOLOGY

3.3.1 Plant Size

Mean *Teucridium* plant height was 1.25 m and ranged from 0.30 m to 2.00 m (Table 3.4). Mean plant width was 0.87 m, with a minimum of 0.20 m and a maximum of 1.50 m. The mean number of stems was 10.6 per plant. Observation showed that the largest plants were growing on sites that were in partial shade whilst the smallest plants were under dense canopies.

Plants were larger in terms of width in the *Hoheria* community than in the *Macropiper* community (Table 3.4). The height of the plants in the *Hoheria* community was not significantly different from the *Macropiper* community, but the mean width of the plants in the *Hoheria* community was significantly higher than the *Macropiper* community (Table 3.4). Plants in the *Hoheria* community also had more stems than plants in the *Macropiper* community, though this was not significant. This may be due to the higher proportion of silty soils in the *Hoheria* community as it is likely that they were higher in nutrients than the sandy soils of the *Macropiper* community. However without soil nutrient analysis this cannot be proven.

Table 3.4: Population characteristics of sites containing *Teucridium parvifolium* presented as means of each TWINSPAN community and means of all samples. Results are from the initial sampling conducted during 1996/1997.

p is the level of significance associated with differences between groups. ns indicates $p > 0.05$.

	Macropiper community ($n = 25$)	*Hoheria* community ($n = 25$)	*p*	SE (±)	Mean (n = 50)
Mean Height (m)	1.19	1.32	ns	0.11	1.25
Mean Width (m)	0.76	0.99	0.01	0.09	0.87
Mean No. of stems	8.48	12.64	ns	2.19	10.56

3.3.2 Population Structure

Size class distributions show that *Teucridium* populations are characterised by a large number of seedlings, fewer saplings, and very few adult plants (Figure 3.5). This pattern was similar in both communities. The distribution follows the classic reverse J shaped curve except that *Teucridium* populations contain a small peak of individuals between the height of 1.2 m and 1.8 m. This represents the normal distribution of the adult plants. This pattern indicates a high level of seedling mortality. While recruitment does seem to be occurring it appears to be limited by some factor that is preventing seedlings reaching adulthood. This may be an external influence such as browsing or a functional problem with *Teucridium's* physiology or phenology.

While the pattern was the same for both communities there were differences in the number of plants in each size class. The *Hoheria* community had more small seedlings than the *Macropiper* community (Figure 3.5). There were more plots sampled in the *Hoheria* community but not enough to account for such a difference in the number of seedlings. Sites in the *Hoheria* community provide a more suitable habitat for the germination and survival of seedlings than the *Macropiper* community. *Teucridium* is generally regarded as a seral species and the marginal sites in the *Hoheria* community are generally more disturbed than the gaps in the *Macropiper* community (pers. obs.).

It is also possible that there is simply more seed available in and around sites in the *Hoheria* community due to the larger plants, or that the increased browsing in the *Hoheria* community provides more sites that are cleared and available for germination. Alternatively the silt soils that are more common in the *Hoheria* community may be more suitable for seed germination and growth.

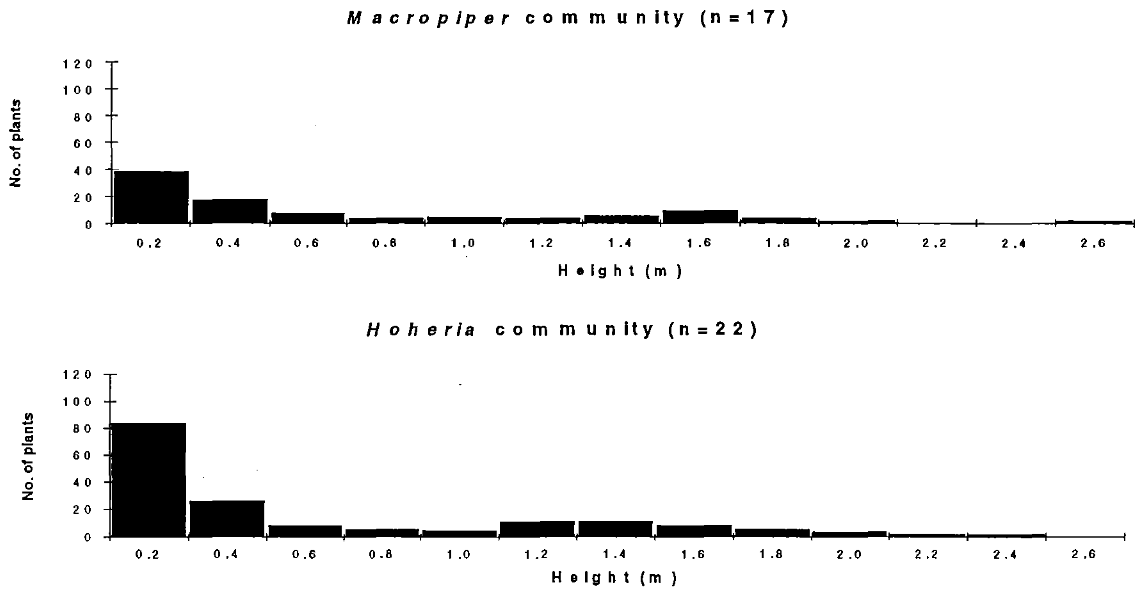

Figure 3.5: Height class distributions of *Teucridium parvifolium* populations for 39 sample sites. Data is presented as distributions for each of the communities indicated by TWINSPAN analysis. Seedlings (< 40 cm), saplings (40 cm – 100 cm), and adults (> 100 cm).

Poor dispersal is one factor that may contribute to the geographic rarity of *Teucridium*. There were more seedlings within the 0.7 m plot than within the 1.5 m and 3.0 m plots indicating that *Teucridium* seed does not disperse far from the parent plant (Figure 3.6).

There were few large plants within the 0.7 m plot. Larger plants established at greater distances from the sample plant. There were not as many seedlings around these plants as there were around the original sample plants. The reason for this is unclear.

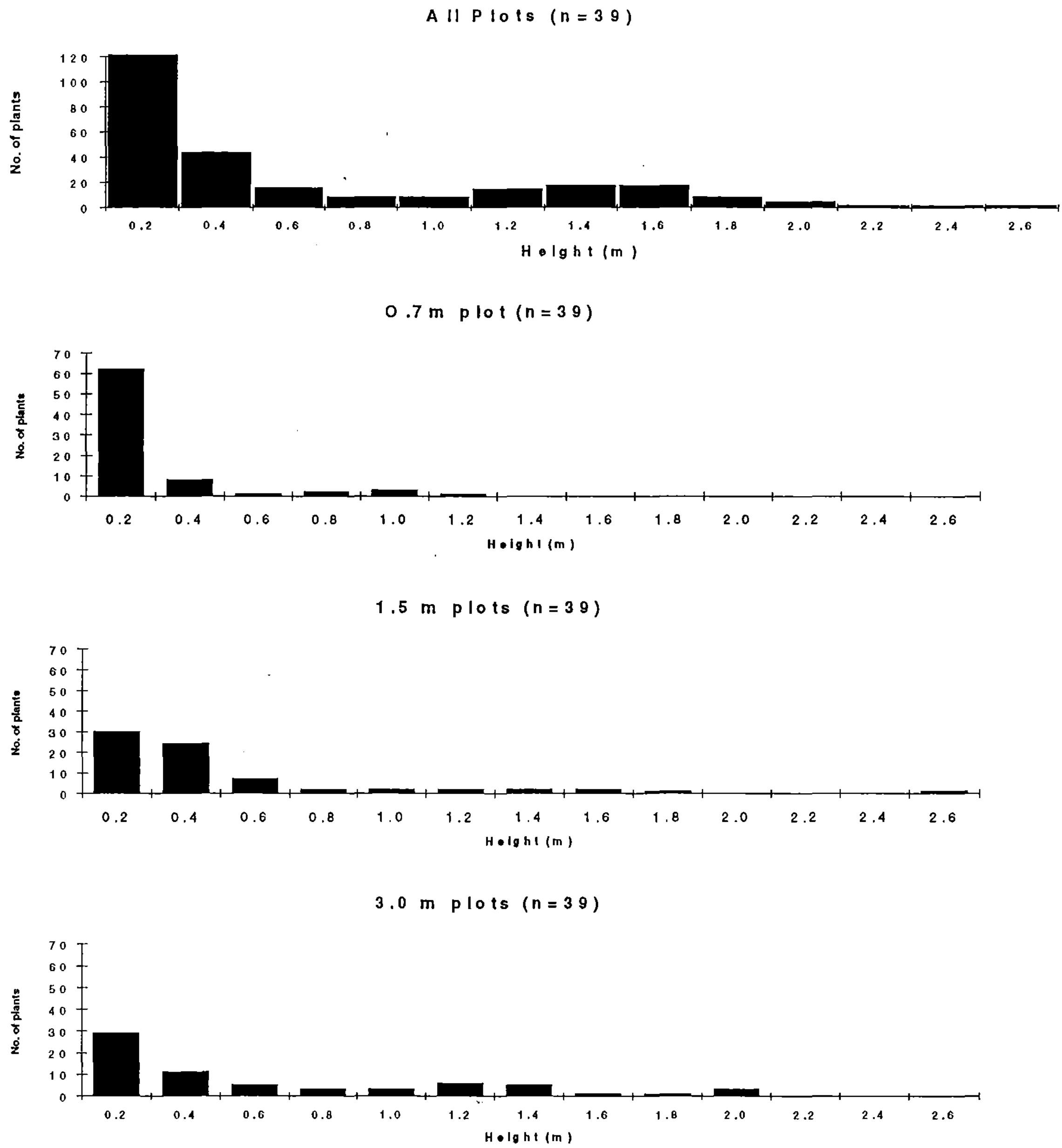

Figure 3.6: Size class histograms of *Teucridium parvifolium* in the different plot sizes sampled. Seedlings (< 40 cm), saplings (40 cm – 100 cm), and adults (> 100 cm)

3.3.3 Seed Production and Viability

Early observations and results indicated that seed production was high on most adult plants. The 30 stems that had seed collected from them produced a total of over 10,500 seeds. If an average adult plant has 10 stems (Table 3.4) then each plant is capable of producing over 3,000 seeds per year.

As seed production was obviously not a restricting factor for *Teucridium* the emphasis was placed on seed viability through the germination and seedbank trials. From an initial sample of 200 seeds only 44% had germinated after a period of 37 weeks (Figure 3.7). While this seems to indicate low seed viability the seedbank trial indicated that a seedbank of viable *Teucridium* seeds was present. Therefore there is reason to believe that a number of the seeds which had not germinated after 37 weeks could germinate at some stage in the future.

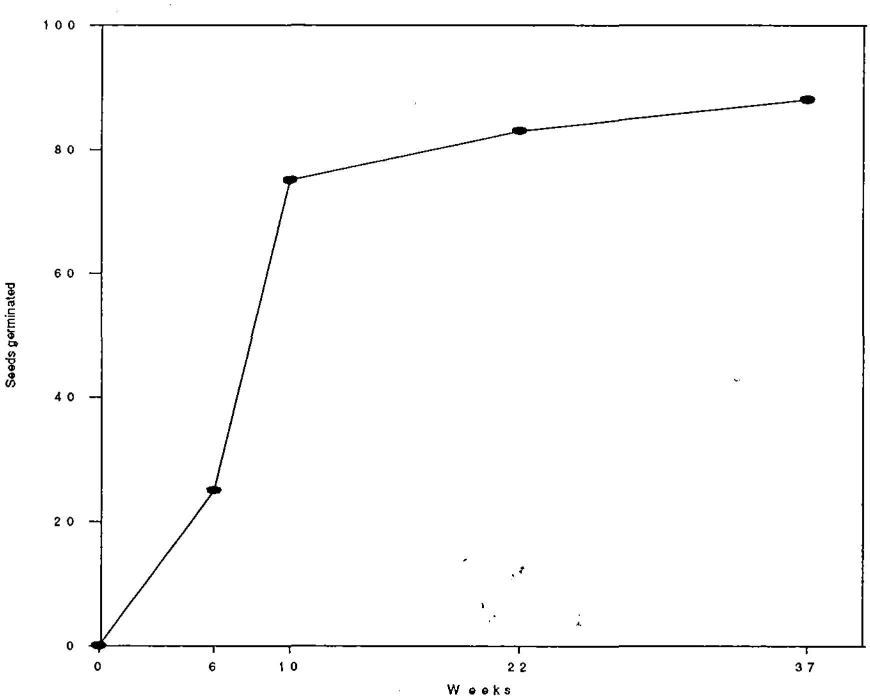

Figure 3.7: Number of *Teucridium parvifolium* seeds germinated from germination trial over the course of 37 weeks from August 25th 1996.

3.3.4 Seedbank

Teucridium seeds persist in the soil as a seedbank. It is not known how persistent the seed is but it is at least two years and is likely to be longer. As the seed was collected before the seed fall of the 1996 season it had already been in the soil for one year and was still germinating in early 1997, two years after it had entered the seedbank.

Table 3.5: Adventive species present in the seedbank at five sites in Prices Valley.

Species	Seeds / m^2	No. of sites	% of Total
Digitalis purpurea	1624	5	25.12
Grasses	1597	5	24.70
Hydrocotyl sp.	790	5	12.22
Cardamine hirsuta	228	5	3.53
Gallum aparine	174	5	2.69
Stellaria sp.	81	3	1.26
Cerastium glomeratum	53	4	0.82
Bellis perennis	45	5	0.70
Verbascum thapsus	42	5	0.64
Chenopodium album	31	1	0.48
Trifolium sp.	29	5	0.45
Oxalis sp.	14	3	0.22
Crepis capillaris	11	5	0.17
Hypochaeris radicata	10	4	0.15
Solanum nigrum	6	3	0.09
Rannunculus sp.	6	4	0.09
Aphanes sp.	5	4	0.08
Malva sp.	4	3	0.06
Sonchus oleraceus	3	3	0.04
Vicia sativa	2	1	0.03
Cirsium vulgare	2	3	0.03
Polygonum persicaria	2	2	0.02
Plantago lanceolata	1	1	0.01
Solanum chenopodioides	1	1	0.01
Polygonum aviculare	1	1	0.01

Forty four species were represented in the seed bank sampled in Prices Valley. This consisted of 25 exotic or weedy species, 16 native woody or shrubby species, and three species of fern. Although the seedbank was variable between sites it was dominated by a small number of species, such as *Digitalis purpurea*, the grasses, and *Hydrocotyl* species which were present in large numbers at all sites (Table 3.5). Most other species were present in low numbers and many of these were not present at all sites.

The native species seedbank was dominated by *Teucridium* and *Urtica ferox* (Table 3.6). These species were present at all five sites and represented almost 90% of the native seedbank. *Helichrysum lanceolatum*, *Fuchsia excorticata*, the ferns, and *Melicytus ramiflorus* were the only other species that represented more than 1% of the seedbank. Of the 16 native species (the three ferns, *Asplenium bulbiferum, Pellaea rotundifolia* and *Polystichum richardii* are counted as one due to seedling identification difficulties), six were present at all five sites, three were present at four sites and seven were present at three or less sites.

Table 3.6: Native species in the seedbank at five sites in Prices Valley.

Species	Seeds / m^2	No. of sites	% of Natives	% of Total
Teucridium parvifolium	867	5	50.86	13.40
Urtica ferox	621	5	36.48	9.61
Helichrysum lanceolatum	38	5	2.25	0.59
Fuchsia excorticata	36	4	2.10	0.55
Ferns	35	5	1.92	0.53
Melicytus ramiflorus	24	5	1.43	0.38
Muehlenbeckia sp.	16	5	0.94	0.25
Sophora microphylla	15	3	0.86	0.23
Kunzea ericoides	14	2	0.83	0.22
Haloragis erecta	13	4	0.79	0.21
Scandia geniculata	12	4	0.71	0.19
Macropiper excelsum	6	1	0.34	0.09
Rubus sp.	4	3	0.26	0.07
Hoheria angustifolia	2	1	0.11	0.03
Coprosma virescens	1	1	0.08	0.02
Solanum sp.	1	1	0.04	0.01

The composition of the seedbank varied between each of the sites (Figure 3.8). This may be related to the characteristics of the sites. Site P1 was in a stream bed, open to stock and surrounded by short grass. Site P4 was on the margin of a bush fragment growing along the base of a steep bank, surrounded by long grass. Stock had restricted access. Site P6 was in a gap near the margin of the same remnant as P4 but on a gentler toe slope and was surrounded by a thick grove of *Urtica ferox,* limiting stock access. Site P8 was in a rocky stream bed and was open to stock. The stream was larger than the one at site P1 and the surrounding area had been bared by stock and the action of the water. Site P9 was in a canopy gap higher on the hillside than the other sites. This site was very dry and was open to stock.

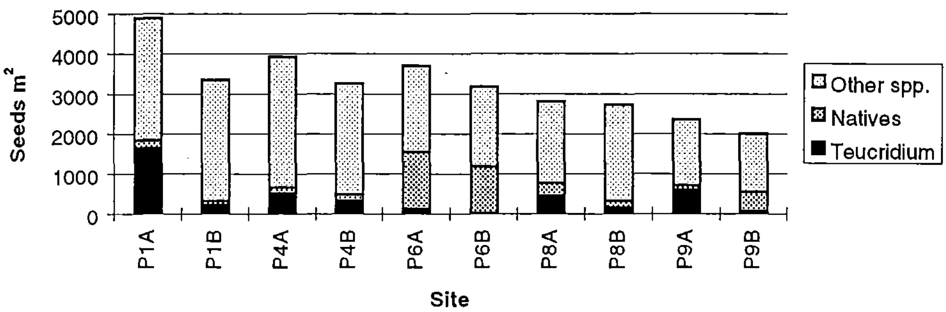

Figure 3.8: Abundance of adventive species, native species, and *Teucridium parvifolium* in the seedbank at five sites in Prices Valley. Data is presented as number of seeds per m² from samples under the plant (A), and surrounding the plant (B).

Germination of seedlings over time was plotted to determine how *Teucridium* behaved in the seedbank and how it compared to the other native species present. Native seedlings in the seedbank generally showed a slow continuous germination pattern (Figure 3.9). Site P6 had extremely high numbers of seeds which germinated more rapidly that the other sites. This was mainly *Urtica ferox.* Most sites, except for P6 and P9, had a small delay before germination took place. All sites containing *Teucridium* had an initial delay in germination followed by a period of rapid germination and then a longer period of slow continuous germination (Figure 3.10). Germination of *Teucridium* was much higher than for other natives at all sites except for P6, suggesting that there was a great deal more *Teucridium* seed available or perhaps that other native seed had already germinated. Site P1 had much higher numbers of *Teucridium* seed than the other sites (Figure 3.10).

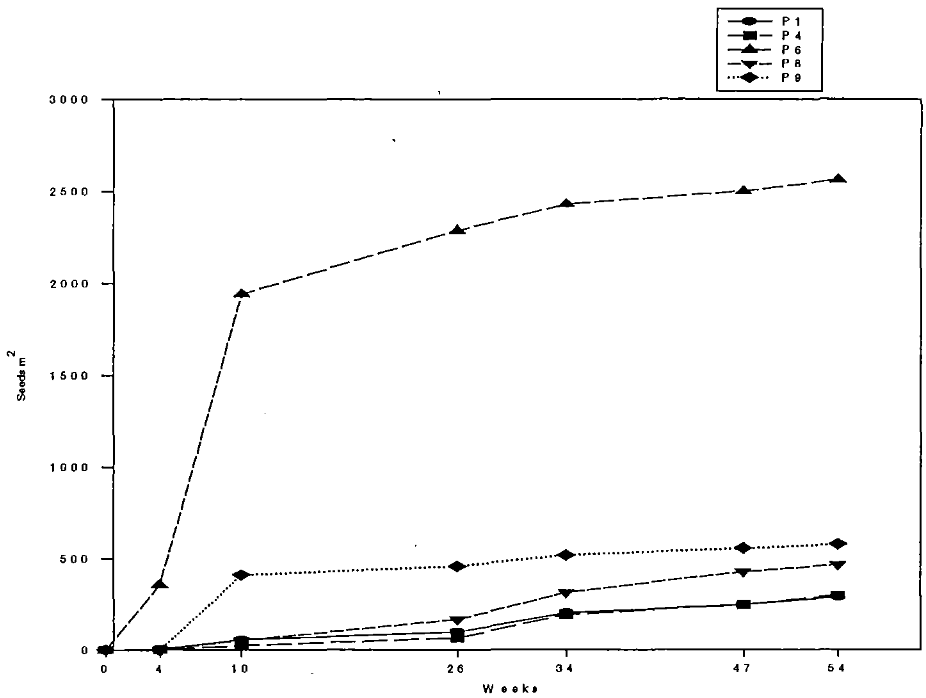

Figure 3.9: Number of native seedlings (excluding *Teucridium parvifolium*) germinated over a period of 54 weeks from samples taken from five sites in Prices Valley.

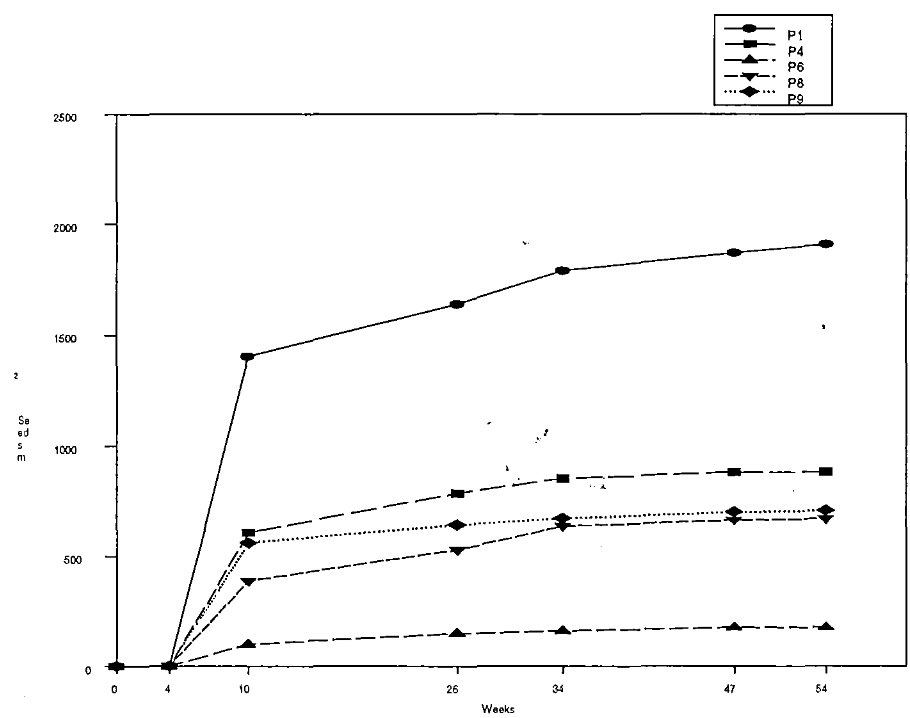

Figure 3.10: Number of *Teucridium parvifolium* seeds germinated over 54 weeks from five sites in Prices Valley.

There was significantly more *Teucridium* seed under the sample plants than there was in the surrounding area (Figure 3.11). This illustrates the passive dispersal mechanism that the plants use, as much of the seed must have fallen straight onto the ground directly underneath the plant. This is further illustrated by the fact that there were much lower numbers of *Teucridium* seed surrounding the plants. The number of other native species was similar both under and around the plants (Figure 3.11).

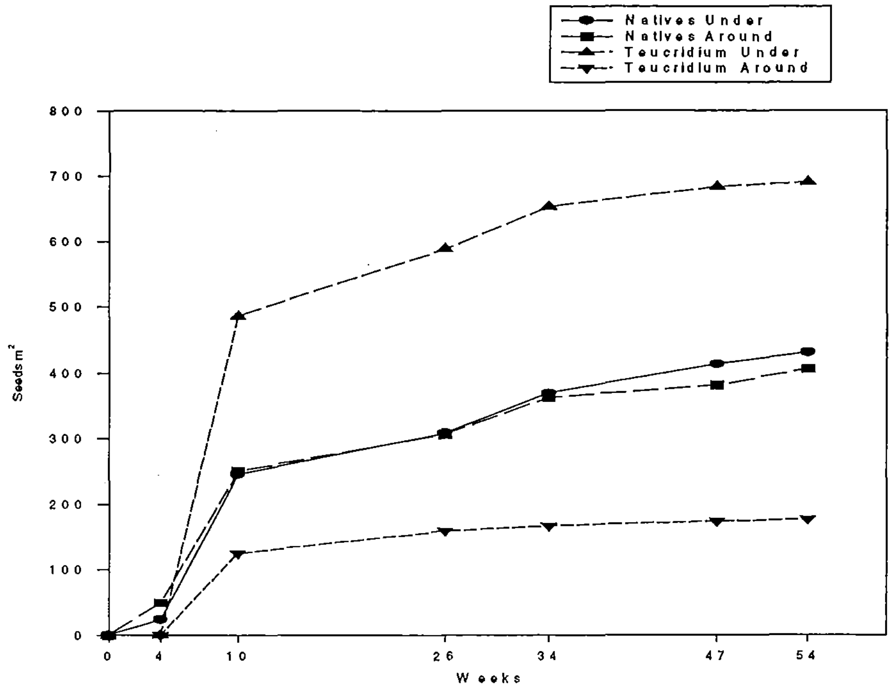

Figure 3.11: Number of seedlings germinated from samples taken from under and around sample plants for *Teucridium parvifolium* and other natives.

3.3.5 Growth

Teucridium seedlings in the shade house grew on average 30 cm in three months. This illustrates that under ideal conditions *Teucridium* seedlings can grow rapidly. This is an advantage for species which must be able to colonise disturbed areas quickly.

Growth of the adult plants in the field over the summer months was variable. Mean growth for the tagged shoots ranged from less than 0.5 cm to more than 10 cm (Figure 3.12).

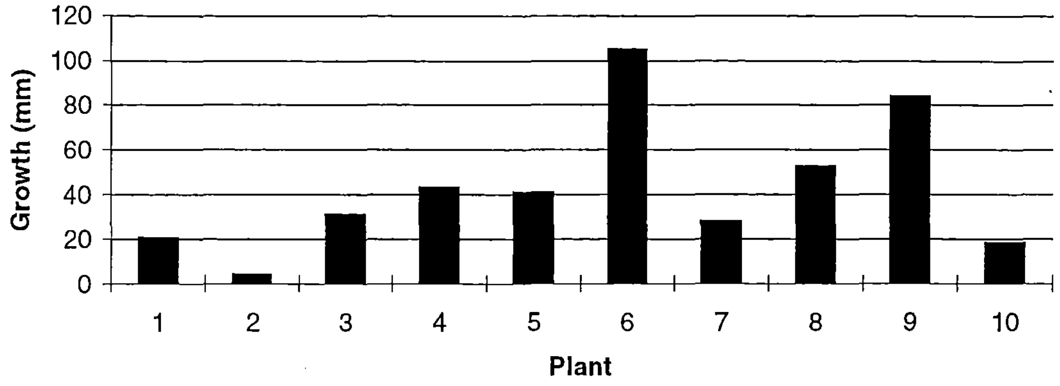

Figure 3.12: Growth of 10 plants from December 1996 to March 1997. Data is the mean of five shoots from each plant.

When the original plants were remeasured in November 1997 height had increased by an average of 10 cm and width by an average of 20 cm. The mean number of stems per plant had decreased from 11.5 to 10.2.

The decrease in stems may be a consequence of the natural high stem turnover of these plants. While no data were gathered on the rate of death and replacement of stems it was noted that for some plants up to a third of their stems were dead and there were often a number of young healthy stems on each plant. This suggests a pattern of continual shoot replacement. If this is the case then rapid growth of new shoots is likely to be more important than continued growth of older shoots.

3.3.6 Browsing

Browsing has been implicated in the rarity of *Teucridium*. To establish the effect that browsing was having on the populations, size class distributions were compiled for the sites that had less than 50% browsing and those that had more than 50% (Figure 3.13).

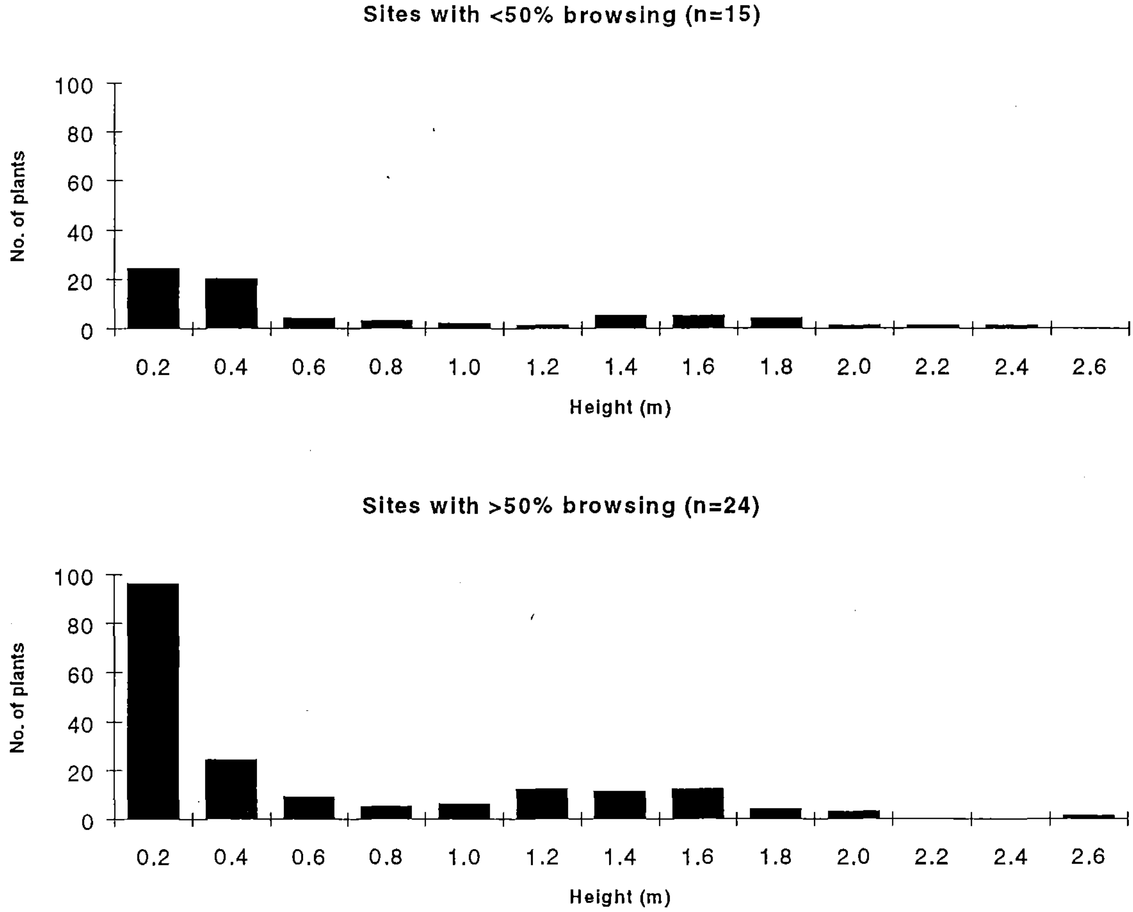

Figure 3.13: Size class distributions for *Teucridium parvifolium* populations with less than 50% browsing and with greater than 50% browsing.

Population size was greater in the populations that had greater than 50% browsing. This is partially explained by the greater number of plots, but the extra plots are not enough to explain the differences (Figure 3.13). This is especially evident in the number of small seedlings that are present. There were four times as many seedlings in the plots with greater than 50% browsing but only about 1.5 times as many plots.

As browsing in the surrounding area was significantly higher in the *Hoheria* community than in the *Macropiper* community (Table 3.2) this suggests that browsing may promote *Teucridium* growth. This may be simply through reducing competition in the surrounding area. However as *Teucridium* plants themselves are subjected to browsing the effect of this was also investigated.

While browsing is an obvious factor controlling the size of *Teucridium* plants it is unclear exactly what the magnitude of the browsing effect is. Both primary and secondary browsing were extremely variable and there was no obvious relationship between them (Figure 3.14).

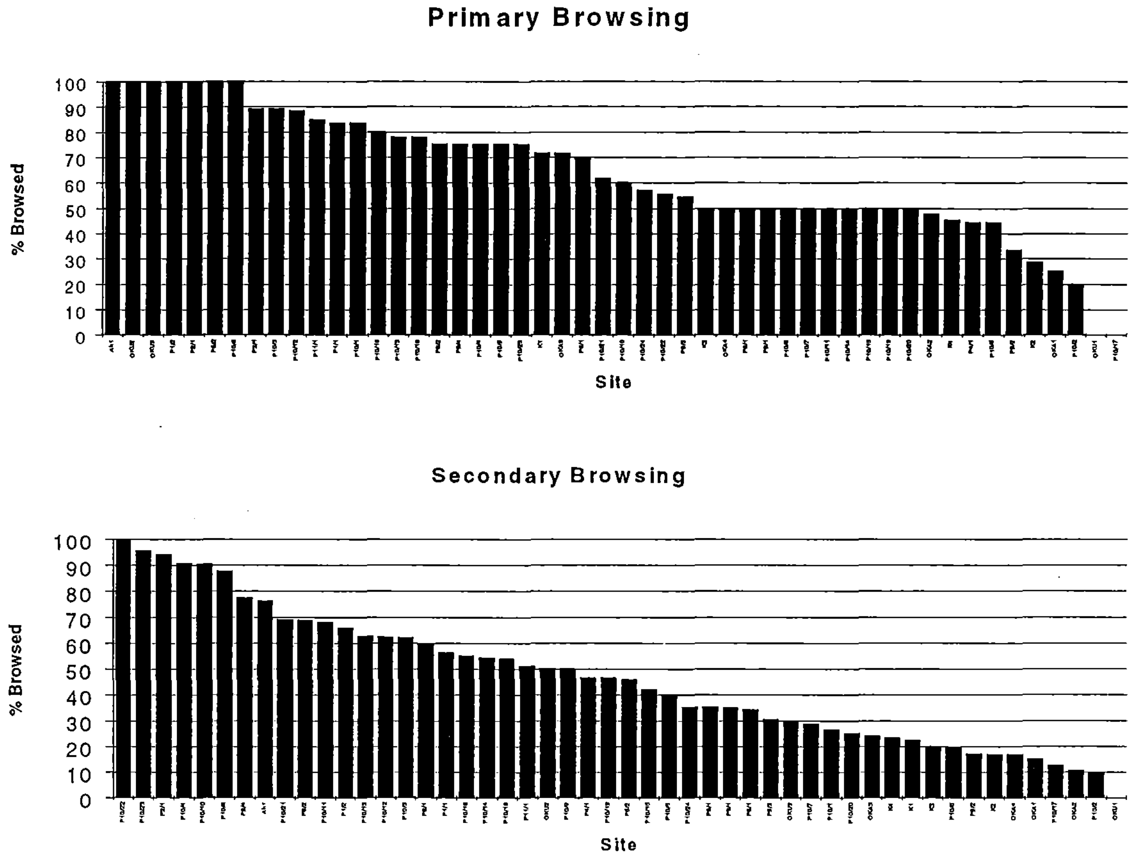

Figure 3.14: Primary and secondary browsing at all 50 sites. Sites are ordered from highest to lowest browsing to show the variation in the amount of browsing between sites.

There were no significant differences between browsing in each of the communities. However, primary browsing was higher in the *Hoheria* community (mean = 67%) than in the *Macropiper* community (mean = 59%) and secondary browsing was lower in the *Hoheria* community (mean = 44%) than in the *Macropiper* community (mean = 48%). Although browsing on lateral shoots was lower in the *Hoheria* community than the *Macropiper* community the difference is not enough to account for the significantly greater width of the plants in the *Hoheria* community. It is possible, however, that the higher level of browsing on main leaders stimulates increased lateral growth and may account for the greater width of the plants in the *Hoheria* community.

4.0 DISCUSSION

Geographic range, habitat specificity and population size can all be used to determine the status of rare species (Rabinowitz 1981). However, once the level of rarity is established it is vital to gain an understanding of the functional causes of the rarity (Given 1994). In this section I discuss the rarity of *Teucridium* in relation to its range, habitat and population size and then discuss factors that may influence its rarity. Comparisons will be drawn with other threatened New Zealand species and directions for management and future research discussed.

4.1 SPATIAL RARITY

Species such as *Teucridium* often have a discontinuous distribution on both large and small scales, seemingly without apparent reason (B. Molloy pers. com.) and most plant species are patchily distributed at some spatial scale due to habitat heterogeneity and their sedentary habitat (Hanski 1985, Schemske *et al.* 1994). It is not surprising that some scrub species are locally distributed as they often occur in recently disturbed sites and only persist at any one site for a few years before they are succeeded by other vegetation in which they cannot survive (Given 1981). *Teucridium* fits this pattern with its small scattered populations, high juvenile growth rates, large seed loads, and large seed bank indicating that it can colonise suitable disturbed sites quickly.

Using Rabinowitz's (1981) classification, *Teucridium* is a "predictable" species. Plants such as this can often easily be found once habitat requirements are known as their occurrence is often as predictable as their habitat (Rabinowitz 1981; Rabinowitz *et al.* 1986). Three main factors affect the rarity of *Teucridium* it occurs over a wide geographic range, in specific habitats, and with many small and few large populations.

4.1.1 Geographic Range

Geographic range of the species is an insufficient measure of rarity status, we must also consider scale. Even if we concede that *Teucridium* has a wide distribution within New Zealand it must be remembered that the genus is endemic to this country. On a global scale less than 100 small, discrete, and perhaps temporary populations makes the species uncommon and rare.

The wide distribution of species such as *Teucridium* can be an advantage. When rare species are confined to one or a few sites there is a very real risk that stochastic events may cause extinction of the species and this is believed to be diminished when populations are spread out over a large geographic range. However, these species are probably equally at risk, and sometimes more so, than restricted point endemics, especially as human perceptions may be that because they are widespread then they must be secure (Given 1993).

4.1.2 Habitat Specificity

Teucridium seems to have a high degree of habitat specificity. Wilson (1993) describes the habitat of *Teucridium* as "Lowland dry forest, especially along the sides of mostly dry creek beds and on river terraces, also on forest margins and in shrubland." This is a fairly broad description and is similar to descriptions on many herbarium record sheets. For Banks Peninsula we can now be more specific as to the habitat requirements of *Teucridium.* The physical characteristics that were measured at each site describe the habitat that *Teucridium* occupies on Banks Peninsula. This supports but adds more precision to previous descriptions such as Wilson and Galloway (1993). *Teucridium* occurs mainly on slopes, toe slopes, and alluvial terraces along forest margins, stream beds, or under broken canopies. Many of the populations are surviving within fragments of remnants or regenerating native bush in the cooler, sheltered valleys on the south western side of the peninsula. This fits descriptions on herbarium record sheets from populations throughout New Zealand.

One explanation that has been advanced to explain the national distribution is that *Teucridium* appears to be part of a group of species that are found together, often on base rich soils (P. de Lange pers. com.; B. Molloy pers. com.). This theory fits in the

North Island but climate and rainfall leaching rates also appear to be significant as *Teucridium* is most abundant on weakly leached soils in lower rainfall zones in the East (B. Clarkson pers. Com.).

Without soil tests at each site this cannot be stated conclusively but many of the sites are in areas that are associated with base rich soils. For instance limestone is common around Waitomo, and many of the other North Island sites are derived from calcareous sandstones, limestones or alluvium. In the South Island, limestone is also common around Takaka. Banks Peninsula soils are derived from volcanic and alluvial deposits and the sites in South Canterbury are predominantly in areas that have formed from either limestone or volcanic parent materials. Trotters Gorge in North Otago and the Waiau River in Southland are also both in areas that have soils derived from limestone. While this is mainly based on broad observations it is an area that warrants further study as it may provide the key to the national distribution of *Teucridium.*

The sampling design of this study only took into account areas where *Teucridium* occurred. It is not possible, therefore, to make any comparisons between sites where *Teucridium* does occur and where it does not. *Teucridium* appears to be found in two distinct plant communities on Banks Peninsula (as identified by TWINSPAN analysis). The importance of recognising these two communities is that they represent two significantly different habitats and vegetation types and give an indication of the conditions which best suit *Teucridium.* Although *Teucridium* occurs in the *Macropiper* community, it is the populations in the *Hoheria* community that are larger and healthier, despite the fact that they are subjected to more stress than those within the *Macropiper* community.

Although observations on light were limited they may still be valuable in determining some of the reasons why *Teucridium* occurs where it does. Given (1981) suggests that *Teucridium* does not persist under dense canopies. Observation shows that the largest plants are those that get filtered sunlight for a large part of the day. Those plants that grow in full sunlight often appear to be stressed and lack the vigour of the plants with some protection (pers. obs.). Plants are also found under dense canopies but these tend to be small and non reproductive, supporting Given's (1981) statement.

It is conceivable that *Teucridium* passively keeps pace with any movement in the forest margin through a negative response to both high light levels and shade (D. Given pers. com.). As it seems that *Teucridium* does not thrive in full sun or full shade, any plants that are left out in the open by a retreating margin would eventually die while those plants that were growing in the deep shade would be able to exploit the increased light.

There are two extreme types of adaptive strategy (Drury 1974). This may be either becoming a good competitor at the cost of being able to grow in extreme habitats, in which case the species will tend to be widespread and abundant, or adapting to extreme habitats at the cost of being able to compete in biologically favourable habitats. This strategy may lead to a species with a discontinuous distribution and widely scattered populations. *Pittosporum obcordatum* may be a species that has adapted to extreme habitats (Clarkson and Clarkson 1994) and I believe that *Teucridium* also fits this category.

4.1.3 Local Population Size

Many of the known *Teucridium* populations are isolated and consist of a small number of plants, often only one or two in a given area. Nationally there are perhaps less than 10 populations that contain more than 100 plants, including Prices Valley and the average size of populations seems to be between 10 and 20 plants. As with other species, such as *Hebe cupressoides* (Widyatmoko and Norton 1997), the small size of many of the *Teucridium* populations is likely to reflect the effects of changes in habitat.

However, it is not only the size of the population that is important but also its stability. Caughley (1994) differentiates between two paradigms that are important in conservation biology, the small population paradigm and the declining population paradigm. He suggests that large populations are governed by the law of averages, whereas the dynamics of small populations are governed by the fate of each individual. Small populations are more prone to the effects of variation and demographic and environmental variation and spatial uncertainty are of particular importance (Caughley 1994). Small populations can die out entirely by chance, even when the individuals are healthy and growing in favourable environments (Caughley and Gunn 1996).

Stochastic events have effects on the demographic and genetic compositions of populations and therefore on the birth, growth and death of species (Schemske *et al.* 1994). These effects are most profound in small populations and the probability of small populations becoming extinct is higher than in large populations (Schemske *et al.* 1994).

Demographic variation may not be of particular importance for *Teucridium* as the species is self fertile. Environmental variation is important as small populations are more prone to unpredictable changes in environmental variables. These may be major, such as flooding or drought, or may be minor such as small variations in mean temperature or rainfall. This is of particular importance to species such as *Teucridium* which demonstrate a high degree of habitat specificity. Many species consist of an assemblage of sub-populations which make up a metapopulation. The applicability of metapopulation theory to population biology has been debated and is inconclusive (Harrison and Quinn 1989; Harrison 1994; Schemske *et al* 1994; Karieva and Wennergren 1995; Nee and May 1992; Husband and Barrett 1996). However, patch dynamics of such species are of particular importance to small populations as extinction and recolonisation within patches affects the chance of extinction of the larger population (Caughley 1994). Small populations are prone to local extinction through disturbance, especially where there are no other populations nearby to provide for recolonisation (Pavlovic 1994).

The small population paradigm treats an effect (smallness) as if it were a cause and only provides an answer to a trivial question "How long will the population survive if nothing unusual happens?" (Caughley 1994). For this reason the declining population paradigm is more relevant to conservation biology as the decline of a species has a cause which can be identified and controlled (Caughley 1994).

While the distributions of species such as *Hebe cupressoides* have clearly declined since the arrival of Europeans (Widyatmoko and Norton 1997), this pattern is not as obvious for *Teucridium*. The temporal side of *Teucridium*'s rarity is unclear as, even though there are records for the last 100 years, few populations have been precisely relocated following the initial record. Current records can only be used to show persistence within general geographic areas and few records indicate persistence at specific sites.

Teucridium may always have been rare. Some species are naturally occurring in low numbers and although rarity is often seen as a symptom of a failing species population size and frequency may not be the best measure of biological success (Drury 1974). However, it is suspected that since the arrival of European settlers *Teucridium* has declined through a reduction in available habitat (D. Given pers. com., B. Molloy pers. com.).

Diamond (1984, 1989) classified agents of decline under four headings which he called the 'evil quartet'. These were overkill, habitat disruption, impact of introduced species, and chains of extinction. Each of these has been implicated in at least some of the studies on threatened New Zealand species but the most common agents identified in New Zealand are habitat disruption and the impact of introduced species (Taylor *et al.* 1997).

4.2 Agents of Decline

4.2.1 Extrinsic Factors

4.2.1.1 Habitat Disruption

The distribution of *Teucridium* may be a relict of a previous wider distribution that has been constricted by habitat destruction and modification. Plants such as *Teucridium*, which rely on ephemeral habitats, are particularly at risk today. Modern intensive farming practices including reduction in areas of scrub and low canopy forest, and developments such as roads and housing, not only modify the habitat but also disrupt the natural patterns of disturbance to such an extent that plants become trapped and are cut off from other suitable sites by a sea of farmland or residential development.

This leads to landscape "fixation" (D. Given pers. com.) which is a fixation of land use practices so that there is a progressive loss of opportunity for species that rely on disturbed marginal habitats because little of the landscape is unstable. Farmland stays as farmland, conservation land is managed as conservation land, rivers are channelled and there is a progressive loss of unoccupied, temporarily disturbed land for successional species to colonise. This is critical in the survival of species such as *Teucridium* which are dependant on a fluctuating, dynamic, highly heterogeneous landscape.

Species that are similarly affected are *Loxoma cunninghamii*, a rare fern of the northern Kauri forests which relies on disturbance to create new habitats (Given, 1981). It has probably always been locally distributed, moving on to new sites created by disturbances such as wind, fire, and flooding. The amount of new habitat available for colonisation is restricted by the human control of these disturbances. *Pomaderris hamiltonii* is a threatened shrub which occurs in a small area north of Auckland and near Miranda, south of the Hunua ranges (Given 1997). Previously this species inhabited slips and unstable ground which have now been practically eliminated and the species is now virtually restricted to road banks, where it is at risk from over zealous road maintenance crews (Given 1997). *Pittosporum obcordatum* may also have been affected by habitat modification through fragmentation of river flat forests and the control of flooding within these habitats (Clarkson and Clarkson 1994).

It is quite conceivable that forest clearance may have opened up some new areas of habitat suitable to *Teucridium* through the provision of a more fragmented landscape matrix (B. Molloy pers. com.). However even though increased fragmentation may be an advantage as far as increased habitat goes, without ongoing processes of disturbance the fragments may rapidly become unsuitable, especially when prone to invasion by aggressive exotic weeds.

4.2.1.2 Competition from Introduced Plant Species

Disturbance can also have negative effects on threatened species by promoting rapid colonisation of invasive naturalised species which may outcompete threatened species for preferred establishment sites (Wardle 1991). Examples of this include *Scutellaria novae-zealandiae* (Williams 1992), *Hebe cupressoides* (Widyatmoko and Norton 1997) and *Clianthus puniceus* (Shaw and Burns 1997). For *Olearia hectorii,* establishment sites were probably abundant early on in the process of land clearance before the smothering effects of grasses and introduced herbs became widespread (Rogers 1996). Vigorous grass growth on recently disturbed sites may also limit regeneration by attracting introduced herbivores (Widyatmoko and Norton 1997).

Growth under all but ideal conditions may be insufficient to compete with more vigorous introduced species and this could restrict *Teucridium* to the more shaded locations where these weeds will not grow. Williams (1992) found this pattern in populations of *Scutellaria novae-zealandiae.* Many of the populations of *Teucridium* on Banks Peninsula are growing in marginal situations and are surrounded by established thick swards of grass that may make it difficult for the seedlings to establish.

4.2.1.3 Browsing

Regeneration of threatened plants can be significantly affected by browsing from introduced species (Loope and Medeiros 1994). This has been shown to be important in other studies of threatened plants in New Zealand (Williams 1992; de Lange and Silbery 1993; Clarkson and Clarkson 1994; Rogers 1996).

It seems that all but the most severe browsing may not in fact be harmful to *Teucridium.* This may be due in part to the constant replacement of older stems by new vigorous stems. This is a similar growth strategy to *Clianthus puniceus* (Shaw and Burns 1997) and in *Muehlenbeckia astonii* (D. Given pers com.). There is evidence of severe browsing having a detrimental effect on some populations, such as at Hikuraki Bay and Ahuriri Bush. However, elsewhere plants seem to be growing and reproducing in areas of quite high browsing and large established plants do not seem to be harmed by continued light browsing. The interlaced leafy branches of divaricating shrubs such as *Teucridium* restrict browsing and although species of divaricating plants are browsed they still survive (Atkinson and Greenwood 1989).

Many of the sites in the study area had been bared by grazing. While this has the advantage of clearing sites for germination and establishment of *Teucridium* seedlings, the absence of young *Teucridium* on bare, severely grazed sites does indicate that these seedlings are also prone to browsing.

4.2.2 Intrinsic Factors

4.2.2.1 Seed ecology

Adult *Teucridium* plants produce a large number of viable seeds. Germination rates are not high but there seems to be slow continued germination and in protected situations the plants seed and establish readily. This then does not seem to be a significant problem in the life history of *Teucridium* and is not the cause of its rarity (cf. *Chordospartium muritai* : Williams *et al.* 1996 and *Clianthus puniceus*: Shaw and Burns 1997).

Seedlings are often difficult to locate in the wild. Observations and results from the germination and seedbank trials suggest that there should be numerous seedlings present around large plants in the wild but this is not always the case. This suggests that although there is seed entering the seedbank important factors are preventing the germination or survival of many of the seedlings.

4.2.2.2 Seedbank

Many papers have shown that New Zealand species generally lack dormancy mechanisms and can often germinate almost immediately after they ripen (Burrell, 1965; Wardle, 1984; Enright and Cameron, 1988; Fountain and Outred, 1991; Burrows, 1994, 1995a, 1995b, 1995c, 1996a, 1996b, 1996c). This explains the low numbers of native seeds generally present in the seedbank. Most of the native seedlings had already germinated by the time the samples were collected and therefore the only native plants present in any numbers were those that had some form of dormancy. By far the largest numbers of seedlings were *Teucridium parvifolium* and *Urtica ferox*, suggesting that they exhibit more dormancy than other species in the area, although the total longevity of the *Teucridium* seedbank has yet to be fully established. However, the presence of a seedbank, no matter how limited may ensure that the species can survive in areas where the habitat becomes temporarily unsuitable.

4.2.2.3 Dispersal

Dispersal in *Teucridium* has been shown to be predominantly local due to limited dispersal capabilities (cf. *Clianthus puniceus*: Shaw and Burns 1997), and in many cases this has led to clumped populations. One of the curious aspects of the ecology of *Teucridium* is the abundance of apparently suitable sites near existing populations that have not been colonised. While there may be some limiting environmental factor, another explanation could be relatively poor dispersal.

The seed ecology of many New Zealand species is markedly different from Northern Hemisphere species (Burrows 1994). More New Zealand tree species have fleshy fruit than in the Northern Hemisphere. However, New Zealand has fewer fleshy fruited shrubs. Shrubs such as *Teucridium* cannot rely on dispersal by frugivorous birds and must therefore rely on other dispersal methods. On a local scale water transport is obviously important for dispersal. The majority of plants in Prices Valley occurred on hillsides in areas that were very wet in winter and where there was often surface water flowing downhill. This could carry seed downhill to new establishment sites. However, this does not explain how the plants get up the hill in the first place. Possible explanations of this could be slow natural migration up the hill over large time periods, or alternatively some external factor could play a part. Possible explanations for this may be chance dispersal by birds and animals, for instance, seeds imbedded in mud and adhering to the feathers and feet of birds, or infrequent wind transport over short distances during storms. Alternatively, populations may have previously occurred at higher altitudes, the current populations were dispersed downhill and then the upper populations disappeared.

How then has *Teucridium* managed to spread around the country with such limited dispersal? I believe that while dispersal is mainly localised there must be the occasional large scale occurrence that disperses seeds over a greater distance, thus establishing new populations. Despite the predominantly local dispersal there is evidence of dispersal over longer distances as in Okuti Valley where individual plants growing along the stream bed must have originated from a parent population at a distance from the existing plants. The populations on the far (eastern) side of Banks Peninsula also indicate that occasional large scale dispersal does occur. The alternative to this is that the current populations are all remnants of a previously much wider distribution that has diminished due to habitat fragmentation.

This situation is similar to the situation discussed by Clark *et al.* (1998). Although they deal with the paradox of rapid migration as it applies to large tree seeds dispersing after ice ages, this theory has applications to the biology of species such as *Teucridium*. The paradox, put simply, is that the ranges of many Northern Hemisphere tree species are exceedingly wide given that they have limited dispersal mechanisms and have had limited time to achieve their current ranges.

The rate of diffusive migration is generally determined by the dispersal distance and the rate of population growth (Clark *et al.* 1998). In many cases neither of these were enough to explain the rate of migration and there must have been some external factor aiding the dispersal. This also seems to be the case with *Teucridium.*

4.3 COMPARISON WITH OTHER SPECIES

There are a group of threatened species in New Zealand which seem to occur in similar habitats and have similar life histories. For *Teucridium*, the most obvious similarities are with *Scutellaria novae-zelandiae* (Williams 1992), *Pittosporum obcordatum* (Clarkson and Clarkson 1994), *Olearia hectorii* (Rogers 1996), *Clianthus puniceus* (Shaw and Burns 1996) and *Hebe cuppresiodes* (Widyatmoko and Norton 1997) (Table 4.1).

These species generally all occur in small localised populations over wide geographic ranges and are associated with disturbed habitats. They produce abundant seed which germinates readily and yet there is often an apparent regeneration failure. There is evidence that some of these species are associated with base rich soils. The major agents of decline for these species have almost always been identified as habitat disruption, browsing and competition from introduced plants.

Table 4.1: Similarities between six threatened New Zealand shrubs.

Y = Characteristic present, N= Characteristic not present, - = Unkown.

	Teucridium parvifolium	*Scutellaria novae-zealandiae*	*Pittosporum obcordatum*	*Clianthus puniceus*	*Olearia hectorii*	*Hebe cupressoides*
Wide distribution	Y	N	Y	Y	Y	Y
Localised populations	Y	Y	Y	Y	Y	Y
Generally small populations	Y	Y	Y	Y	Y	Y
Vegetation type	Forest/Scrub	Forest	Forest/Scrub	Scrub	Forest/Scrub	Shrub
Marginal species	Y	Y	Y	Y	Y	Y
Base rich soils	Y	Y	-	Y	Y	-
Asexual reproduction	Y	Y	-	Y	Y	-
Abundant seed	Y	Y	Y	Y	Y	Y
Fresh seed germinates readily	Y	Y	Y	Y	N	Y
High seedling mortality	Y	Y	Y	Y	Y	Y
Seed bank	Y	N	Y	Y	N	N
Passive dispersal	Y	Y	Y	Y	N	-
Occurs in sites prone to flooding	Y	Y	Y	Y	Y	Y
Habitat disruption	Y	Y	Y	Y	Y	Y
Browsing	Y	Y	Y	Y	Y	Y
Interspecific competition	Y	Y	Y	Y	Y	Y

There is evidence that some of these species occur together. Clarkson and Clarkson (1994) indicate that *Pittosporum obcordatum* is found at three sites with *Teucridium.* Rogers (1996) also identifies one site (Hautapu Valley, Rangitikei) where *Olearia hectorii* occurs with both *Teucridium* and *Pittosporum obcordatum. Olearia hectorii* also occurs in several other areas where *Teucridium* is present, including the Wainuioru Stream in the Wairarapa and the Pomahaka River in Southland (Rogers 1996). Williams (1992) identified one site where *Scutellaria novae-zelandiae* and *Teucridium* occurred together.

While it is vital to identify the threats to individual species, identifying suites of species such as this may allow conservation managers to develop programmes that make better use of resources by aiding more than one species at a time.

4.4 Management and Future Research

There are a number of aspects of the ecology of *Teucridium* that do not seem to offer constraints to the continued existence of the species. These include the seed ecology where there is sufficient viable seed to ensure the continued existence of the species. This is aided by the presence of a seedbank. The species is wide spread and probably capable of persistence in many locations given the right habitat with an appropriate disturbance regime. *Teucridium* displays medium vulnerability to browsing and the effect of this is probably not generally excessive at the present time.

There are however, a number of factors that are constraints to the continued existence of *Teucridium* and these must be addressed when devising management strategies for the species. The distribution pattern of *Teucridium* matches a number of species such as *Pittosporum obcordatum* (Clarkson and Clarkson 1994) and *Clianthus puniceus* (Shaw and Burns 1997). Species such as these are receiving more attention from conservation managers. These species present difficulties for conservation managers as they occur in generally low numbers over wide ranges. This may make it difficult to devise conservation strategies that suit all of the extant populations.

Lack of knowledge is still a constraint to the long term conservation of species such as *Teucridium*. Knowledge of the life history characteristics of this species is incomplete, especially longevity and persistence of individual plants. In particular the cause of the high levels of post germination mortality needs to be identified so that management practices can be put in place to minimise these effects. As with *Hebe cupressoides* (Widyatmoko and Norton 1997), limitation of regeneration through browsing has a major influence on *Teucridium*. Although research is being conducted on the effects of introduced animals on rare plants, more attention needs to be given to the effect of introduced plant species on the regeneration of threatened plants (Widyatmoko and Norton 1997). *Teucridium* requires active management to control invasive species that may outcompete it.

The majority of *Teucridium* populations are located on private land. This means that any management initiatives are going to require the consent and cooperation of the landowners. As many *Teucridium* populations occur on land that is already marginal for farming and is not heavily utilised, conservation of *Teucridium* does not necessarily have to interfere with farming practices. Slight modification of grazing practices and the continued availability of a small amount of fallow land may be sufficient to ensure the continued existence of *Teucridium* populations in most localities.

Timing of stock access is important. Browsing before seed fall and germination may in fact be beneficial, provided not too much foliage is eaten from the mature plants. Browsing after germination is likely to be detrimental. Clarkson and Clarkson (1994) suggest fencing off *Pittosporum obcordatum* populations so that browsing can be manipulated to control the vigour of introduced weed species. Williams and Courtney (1995) suggest, that in the case of *Olearia polita*, continued light grazing may help to reduce the harmful effects of herbaceous weeds on seedling growth. Rogers (1996) suggests that light grazing may suppress the vigour of weeds and create establishment sites for *Olearia hectorii.*

If, as has been suggested *Teucridium* occurs on relatively fertile base rich soils then there may be a conflict in land use as these soils are often in demand for agricultural use. Landscape fixation in these areas may mean that there is less available habitat in the form of fallow or marginal land. *Teucridium* seems to have a high degree of habitat fidelity, relying on disturbed, ephemeral habitats. It is specific in the sites that it requires and it is therefore important to maintain a mosaic within the landscape to provide suitable habitat.

The small size of many *Teucridium* populations is also a management issue. Again the need for some large reservoir populations is an issue that highlights the need to provide a suitable mosaic of habitats for ephemeral species such as *Teucridium.* If any of the existing large populations were destroyed the rarity status of *Teucridium* would change dramatically.

Without the large populations to buffer against stochastic events or catastrophes the conservation status of *Teucridium* could become more precarious, as the survival of *Teucridium* would then rely on single plants or very small populations. Therefore we need to protect these large populations but at the same time we need to increase the size and frequency of the small populations.

The genetics of *Teucridium* populations are still unknown. This is the case with most of the rare species in New Zealand (D. Given, pers comm.). Moran and Hopper (1987) investigated the conservation of genetic resources in widespread *Eucalyptus* species. They suggest that it is important to understand a number of aspects of the genetics of rare species and that a number of questions need to be answered. These include the patterns of genetic diversity within populations and across the whole range of the species, the relationship between population size and genetic diversity, the role of outlier populations and the genetic structure of subpopulations. Population genetics theory suggests that fragmentation of species into populations with low numbers may reduce genetic variability (Moran and Hopper 1987). There is a likelihood that species such as *Teucridium*, which may have passed through genetic bottlenecks and exist as widespread mosaics of populations, can develop genetic mechanisms to counter the effects of genetic stochasticity. This is the kind of possibility that needs to be investigated. It is therefore vital that we gain an understanding of the population genetics of species such as *Teucridium* so that if necessary management can be aimed at conserving genetic variation.

There are a number of aspects of the ecology of *Teucridium* that make this species a good subject for integrated conservation management. It lends itself to both *ex situ* and *in situ* conservation. The prolific seed production and good germination rates, fast juvenile growth rates and ease of nursery production mean that large numbers of plants can be made available for translocations in a short period of time. This could also help with the establishment of experimental populations to further study aspects of the ecology of *Teucridium*.

It is essential that active management and monitoring occurs not only for this species but also for others that are in similar situations such as *Pittosporum obcordatum, Clianthus puniceus* and *Olearia hectorii*. Sites indicated by existing records should be revisited and at least some of the current populations should be monitored to determine any decline in numbers or range. An effort to locate new populations would also be helpful in this regard.

4.5 CONSERVATION STATUS

Teucridium is a difficult species to allocate to a threat category. It is widespread with many populations differing in size and security. There are several likely reasons for the distribution and rarity of the species with no single reason appearing to dominate. It is likely that this is a species that prefers disturbed marginal habitats and is quite capable of persisting at low numbers within that habitat. Although it has poor local dispersal of propagules, it has a large seed production and generates a sizeable seedbank so it has the potential to persist and for a small number of seeds to disperse to and colonise new sites.

This is an example of a species where I believe that we must play it safe and allocate the species to a rarity status that fits its seemingly precarious position. Small populations, marginal habitats, perceived decline in number and size of populations and threats from habitat disruption, introduced species and variable effects from browsing all indicate that the conservation status of *Teucridium* is not secure. At this stage there is little evidence that the species is in danger of extinction in the short term. However, until more evidence is forthcoming on the status of populations throughout New Zealand I believe that *Teucridium* should retain the classification of Vulnerable.

My reasons for this allocation are based on the trigger points for the IUCN threat categories described by Mace and Stuart (1994). In this classification species are considered to be Vulnerable when they are not considered to be Critically Endangered or Endangered but do face a high risk of extinction in the future. It is unlikely that the inferred reduction in numbers of *Teucridium* is enough to trigger the classification at this level. However, the critical trigger factors are the severely fragmented nature and small size of many of the populations. From the available records it seems likely that the number of mature individuals is below the critical level of 10,000 suggested by Mace and Stuart (1994). When this is combined with the fragmented nature of the distribution it illustrates the vulnerability of the species. The diffuse nature of threats to *Teucridium* and the distribution of populations of variable size with few large populations and many small ones, provides problems in assessing threat using the revised IUCN categories which are best suited to point endemics or species with evenly sized populations and few well-defined threats.

I believe that, although there are no obvious signs of serious and sudden short term decline in the numbers and range of *Teucridium*, continued habitat loss through fragmentation and fixation and the effects of introduced animals and plants pose serious threats to the long term survival of *Teucridium parvifolium.*

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