Physiognomic and taphonomic studies in New Zealand and Australia; implications for the use of palaeobotany as a tool for palaeoclimate estimation

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by

Lena Stranks

Department of Earth Sciences

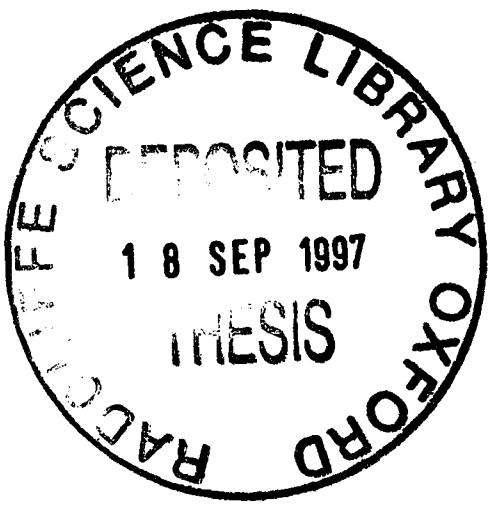
and

St Hughs College

University of Oxford

Trinity, 1996

Supervisors: Dr. Philip England: Oxford University
Prof. Robert Spicer: The Open University



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Abstract

Measurements of surface uplift rate potentially hold the key to understanding the tectonics of mountain belts and areas of uplift. Wolfe (1993) compiled a multicharacter data set (CLAMP) of the physiognomy of woody dicotyledon leaves with a view to using it to extract climatic information from fossil floras. The limited extent of this data set, along with the anomalous behaviour of some outliers cause me to question the global relationship between physiognomy and climate which has been implicitly assumed in all analyses of the data conducted todate.

Additional data collected from native vegetation in New Zealand and Australia are compared to the CLAMP data set. These data include samples along altitudinal transects and from different forest types growing in the same climatic regime. In addition taphonomic samples were collected from lake bottom sediments and their physiognomic signals compared to those of the adjacent living vegetation.

The possibility that the relationship between climate and physiognomy is sufficiently non–linear that only local relationships should be sought is investigated. To estimate the climate at a certain flora, resemblance functions are used to select physiognomically similar sites. Estimations of climate are formed using only these sites. The power of this approach to estimate mean annual temperature, mean annual precipitation, mean growing season precipitation, and moist enthalpy is investigated using the modern sites, and varying the number of nearest neighbours and dimensions used as well as the type of ordination.

The collection of altitudinal transects has allowed the study of physiognomic change with altitude. Because these transects were collected over a very restricted area it was possible to observe this change without the superimposed effects of changing continentality and variation in latitude. In addition studies made of adjacent floras in similar climatic regimes and taphonomic studies of leaves in lacustrine sediments has allowed the beginning of a realistic assessment of possible errors in climate estimation for fossil sites.

Fossil sites examined using CLAMP and related methods are re–examined using the nearest neighbour approach.

Long Abstract

Within the geological literature, the word 'uplift' is used to refer to three distinct processes. These are : the exhumation of rocks, i.e. their displacement relative to the surface; the displacement of rocks relative to the geoid; and the displacement of the earths surface relative to the geoid. Of these processes, only the latter requires work to be done against gravity.

Consequently, if successfully quantified, the uplift of the earths surface relative to the geoid could be used to provide important information about the tectonics and dynamics of mountain belts. Rates of increase in surface elevation that cannot be accounted for by crustal thickening must be caused by stresses applied to the lithosphere by the convecting mantle beneath. Thus an understanding of regional rates of surface uplift would allow us to assess tectonic models in those regions. Unfortunately because neither exhumation nor rock uplift are equivalent to surface uplift, there are problems with using fission track dates, geochronology or geothermometry to draw quantitative conclusions about surface uplift.

One method that appears to offer great promise in determining palaeoelevations in mountain ranges relies on the use of palaeobotany as a means of determining palaeoclimates. Because climates vary markedly with altitude these palaeoclimatic observations can yield information about palaeoaltitude. Local climate changes over geological time, corrected for regional secular climate change by comparison to sea level climates, can then be used to infer changes in palaeoelevation.

A combination of the immobility of plants after germination, and their reliance upon atmospheric processing, water, and sunlight, means that plants must be particularly well adapted to their physical environment. As a consequence, the environment in which they grow is strongly reflected in their structure and architecture. This is no more so than in leaves, whose function is to photosynthesise whilst minimising water loss. Plants produces leaves in abundance, and this in combination with their reasonable strength gives them a very high preservation potential. Unlike pollen however which is also produced in abundance, leaves are not physically robust enough to, be transported a long way from their source before deposition, or to be reworked once deposited. For this reason fossil leaf assemblages have both good spatial and temporal resolution which is essential if they are to be useful for the assessment of surface elevation and uplift rates.

Physiognomic methods for extracting palaeoclimatic information from fossil assemblages use the morphological adaptations to environment of woody dicotyledon leaves. These are favoured over floristic methods which use the climatic affiliations of the nearest living relatives of fossil plants because the latter assumes that climatic tolerances do not change over time; a counter–evolutionary concept. Until recently the physiognomic approach had been applied in a univariate way using the variation in either leaf margin, or leaf size. CLAMP (Climate Leaf Analysis Multivariate Program) is a method developed recently by J. A. Wolfe Wolfe [1993, 1995] and represents a departure from this. He identifies 29 foliar physiognomic character states that

are to some extent controlled by the climate in which the leaves grow. A total of 106 floras from the northern hemisphere were collected and scored according to the proportion of species that display each character state. The resultant 106x29 data matrix was then used in conjunction with climatic data to search for a relationship between physiognomy and climate that could be used to extrapolate climatic conditions from the physiognomy of fossil assemblages. This task was performed by using an indirect ordination, correspondence analysis, to reduce the dimensionality of the data. The first two axes produced by correspondence analysis between them summarise ~70% of the variation within the data set. Within this plane Wolfe selects the vectors that best rank the data in terms of climatic variables, and uses the distance along these vectors that fossil sites project to estimate the climate in which they grew. This approach works well for mean annual temperature (MAT) except at low temperatures where there are large errors. The root mean square error for estimating the MAT of modern sites using this approach is 3.0°C The anomalous subalpine (cold) sites plot apart from the others on correspondence analysis axis three. By choosing to discard these as outliers Wolfe [1993] improves his MAT estimates greatly. This ad–hoc adjustment allows him to keep the assumption of a global response to climate but at the same time, must call it in to question.

CLAMP, and other methods based on the same physiognomic data set, have been applied to the fossil record to estimate palaeoaltitude with some success Gregory & Chase [1992]; Gregory & McIntosh [1996]; Povey [1995]; Povey *et al.* [1994]; Forest *et al.* [1995]; Forest [1996]. The majority of this work uses mean annual temperature as the climatic variable which varies with altitude. Recently however Forest *et al.* [1995]; Forest [1996] moist enthalpy has been used, on the grounds that its relationship with altitude is based not on an empirical relationship, but on the principal of the conservation of energy.

The extent of the sampling of the modern data set, both in terms of geography and climate makes CLAMP vulnerable to some criticisms. A premise that forms the basis of the methodology is that the physiognomy of the entire woody dicotyledon clade, both modern and ancient, responds to environment consistently. Wolfe's data set is biogeographically limited with the vast majority of sites coming from the North American continent. Even within this limited sample, anomalous groups exist, that do not conform to Wolfe's model. I therefore question the assumption of a global relationship between physiognomy and climate.

The use of only the first two axes for climate estimation is also questioned. The fact that anomalous subsets within the data may be identified on the basis of their position on the third axis after correspondence analysis suggests that important information is contained within this axis which should not be discarded if climate is to be assessed successfully.

Even if Wolfes analysis of modern floras is an accurate model for how ancient floras responded to climate, there are additional questions that should be addressed before the methodology can confidently be applied to fossil record. The first is whether plants respond to climatic change quickly enough, on a geological time scale, such that there is no time lag between climate change and our perception of it through the fossil record. Also our understanding of the amount

of noise in the climatic signal introduced by taphonomic bias and non climatic environmental variables is minimal.

For these reasons I have made further collections of modern native vegetation from New Zealand and Australia and added these to the CLAMP data set.

In contrast with the original CLAMP data set which is Laurentian in ancestry, New Zealand and Australia have a Gondwanan heritage, thus testing the assumption that foliar physiognomy has a uniform response to climate throughout the whole woody dicotyledon clade. A broad range of climates were sampled, including several floras from wet temperate climes which are poorly sampled in the original data. Where possible samples were collected from different forest types in the same climatic regime so that the amount of noise in the climate signal could begin to be assessed. New Zealand's large altitudinal range also allowed for the collection of local altitudinal transects so that changes in physiognomy with elevation could be examined, free from the complications of changing continentality or latitude.

High altitude floras in New Zealand are a relatively new feature. Until ~3Ma ago when the topography had changed vastly because of the uplift of the Southern Alps, New Zealand had no microthermal climate. Her geographic remoteness means that since then, there can only have been a limited influx of pre–adapted species to radiate into this new environment. Several upland floras were collected with a view to seeing how well adapted they are to the microthermal climate and assessing the risk of a significant temporal lag in climate signals from the fossil record.

The west coast of the South Island in New Zealand contains some of the most continuous tracts of native rain forest in the country. This area is also subject to heavy orogenic rainfall. The resulting lakes are ideal for live/dead taphonomic experimentation. Two transects were conducted in one such lake and the physiognomy of lake bottom samples compared to that of the surrounding vegetation.

When the new southern hemisphere sites were added to the CLAMP data set and ordinated using correspondence analysis it was clear that their position in axis one–axis two space after correspondence analysis, where they plotted within the confines of the northern hemisphere data, was anomalous in terms of the climate in which they grew. On axis three however they were distinct, rather like the subalpine set of outliers. When the CLAMP methodology was applied to the combined data set of northern and southern hemisphere samples its power to estimate mean annual temperature was reduced drastically. If however the southern hemisphere data set is treated separately the CLAMP methodology was able to predict MAT very well indeed. This shows two things: first that a global continuous relationship between climate and physiognomy throughout physiognomic space does not exist and second that locally a consistent relationship does exist. To–date all the analysis of the CLAMP data set have looked for a global relationship. This suggests that we need to look at the data in a much more localised way.

A method of interpretation of the data based on resemblance analysis is developed here. Physiognomically similar (i.e. local) sites only, are used to form climatic estimates. The Euclidean distance in transformed orthogonal space was chosen as a metric for measuring the

physiognomic similarity of sites. Experiments estimating climatic values at modern sites were carried out, varying the ordination, the number of dimensions and the number of nearest neighbours used in the analysis. The best estimates of MAT were obtained when the first three dimensions produced by correspondence analysis and 19 nearest–neighbours were used. MAT estimates with a root mean square error of 2.1°C were produced for the northern hemisphere data and 2.3°C for the combined northern and southern hemisphere data set. CLAMP's problem of poor estimates at low temperatures was much improved upon by using the nearest–neighbour approach.

The estimation of other environmental parameters using the nearest–neighbour method also proves to be successful. Limitations for the estimation of precipitation however proved to be similar to those encountered by Wolfe [1993]. As with his work, mean growing season precipitation showed a stronger signal in foliar physiognomy than mean annual precipitation. For both of these precipitation variables the errors were significantly worse at high levels of precipitation. This is because water is only a limiting factor on physiognomy when it is itself limited. These limitations appear to be inherent to the data itself, rather than the means of interpreting it.

In recent work moist enthalpy (H) has been estimated from the CLAMP data set (only North American sites) and used to estimate palaeoaltitude Forest *et al.* [1995]; Forest [1996]. With the New Zealand sites incorporated into the CLAMP data set the nearest–neighbour methodology is able to estimate the values of moist enthalpy to a degree of accuracy only 0.1kJ/Kg less than the North American data alone.

All results were obtained without any arbitrary division of the data into subsets by inspection. Whilst the nearest–neighbour methodology does in effect split the data set, this is on a mathematical rather than subjective basis. An additional advantage of the nearest–neighbour method is that the resemblance structure reveals the proximity of each site to its neighbours. The fact that the relationship between physiognomy and climate varies through physiognomic space means that climate estimates from isolated fossil sites cannot be treated with the same degree of confidence as those that plot within the space defined by the modern sites. As with all empirical models there is a real danger in extrapolating beyond the extent of the collected data, which is enhanced by its non–uniform nature. The resemblance structure offers a way of assessing that danger.

The altitudinal transects collected in New Zealand were inspected in the light of the estimates of MAT and H made using their physiognomy. Given the relationship used in the fossil record to link these variables with altitude, we would hope to see an approximately straight line with negative slope of 5.5 and 9.8 respectively when these values are plotted against the altitude of the site from which they were collected. In both cases the resultant graphs did approximate the expected relationship but with large fluctuations and even some reversals in slope. These results show that estimates based on single fossil floras may be erroneous, but that if a number of coeval fossil floras from the same region, are analysed a reasonable picture of palaeoaltitude

should be obtained.

Floras collected from different vegetation types within very similar climatic regimes suggest that the climatic signal from foliar physiognomy contains little background noise. Estimates for MAT at adjacent sites were within 1°C of one another, except when the samples plotted in an isolated region of physiognomic space. Larger errors here could be attributable to the fact that the estimates were based on more (physiognomically) distant floras.

Taphonomic investigations of foliar physiognomy have to–date been confined to univariate studies. This work forms the basis for the sampling procedure used by Wolfe [1993]. Multivariate taphonomic investigations are presented here. These were conducted at Lady Lake in Westland, New Zealand, where several taphonomic studies have been carried out in the past, giving an integrated picture of the floristic and physiognomic taphonomy of the field area. Two transects were collected: one perpendicular and one parallel to the delta front of the in-flowing Sam Creek. A series of samples taken from the sediment at the lake bottom were examined for leaf material. This in turn was scored for the CLAMP variables exactly as a fossil flora would be, and the results compared to the CLAMP scores of the surrounding vegetation. Physiognomic variation in the lake sediment was investigated both in terms of individual character states and the overall physiognomic signal. Results showed that the size category displayed the most taphonomic bias, especially in distal sediments. Correlations in the living flora between leaf size and other character states, notably apex and margin type, result in taphonomic bias also being displayed in these categories. Ordination goes some way to cancel out the multiplicity of this effect.

Characters displayed in a small proportion of the leaves of living species, especially those which are scored as either present or absent, such as apex–emarginate are underrepresented in the lake bottom samples. This serves to illustrate that fossil assemblages should be sought not only with high species diversity, as Wolfe [1993] advocates, but also with the number of specimen within species maximised.

The results show that multivariate techniques for extracting climate information from foliar physiognomy are more robust to taphonomic bias than univariate approaches.

Fossil floras that have already been investigated using the CLAMP data base were reexamined using the newly developed nearest–neighbour methodology. This entailed a closer inspection of their position in physiognomic space, which showed that most of the oldest fossil sites investigated plot beyond the extent of the modern northern hemisphere data set. This was not apparent, when transformed using the northern hemisphere data set alone, and was only visible when the southern hemisphere sites were included in the ordination. This result has important consequences, showing that care must be taken in selecting an appropriate way of viewing the physiognomy of fossil floras relative to the modern data set.

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Chapter 1

Introduction

1.1 Aims of the project

The ultimate aim of the research, of which this project forms a small part, is to obtain a picture of surface elevation history during the Tertiary of the Basin and Range region of the United States, using a palaeobotanical method developed by Wolfe [1993]. This method extracts climatic information from the foliar physiognomy of fossil woody dicotyledon leaves. This thesis concentrates on investigating and testing the method, rather than applying it to the fossil record of the region. It is essential however to place the work into the broader context of this research. The following paragraphs discuss why, if valid and accurate, Wolfe's method is of such great importance for developing an understanding of the tectonic evolution of regions such as the Basin and Range, and its potential input into more general theories about mountain building.

1.2 The importance of the potential for using palaeobotany to estimate surface uplift

1.2.1 Surface elevation in the dynamics of mountain building

The dynamics of mountain ranges are controlled by differences in the gravitational potential energy of entire columns of continental lithosphere [Molnar & LyonCaen, 1988]. In studying the dynamics of mountain ranges, it is important to quantify work done against gravity which is related to surface uplift. In the geological literature, the word 'uplift' has been used to describe three distinct processes. These are first, exhumation: the uplift of a rock with respect to the earth's surface, second, rock uplift: the uplift of rocks with respect to the geoid, and finally, surface uplift: the displacement of the earth's surface with respect to the geoid. These three processes are not equivalent to one another [see England & Molnar, 1990]. Exhumation is the measure of the decrease in distance between the surface and the rocks in question. It is not equivalent to either rock uplift, surface uplift, or work done against gravity. This is because

erosion is coupled with isostatic rebound, such that the uplift of rocks with respect to the geoid is less than with respect to the surface, and the uplift of the surface itself is negative, (see Figure 1.1). Neither can rock uplift be equated with work done against gravity, again because such uplift is generally coupled with erosion and hence isostatic readjustment. Of the three processes referred to as uplift in the literature, only surface uplift can be used as a measure of work done against gravity. If change in surface height represents isostatically compensated change in potential energy, then the rate of change of potential energy per unit surface area, dPE/dt, is proportional to the rate of increase of average surface height, dh/dt.

$$\frac{dPE}{dt} \approx C\frac{dh}{dt} \tag{1.1}$$

Where C is a constant, t is time and h is average surface height.

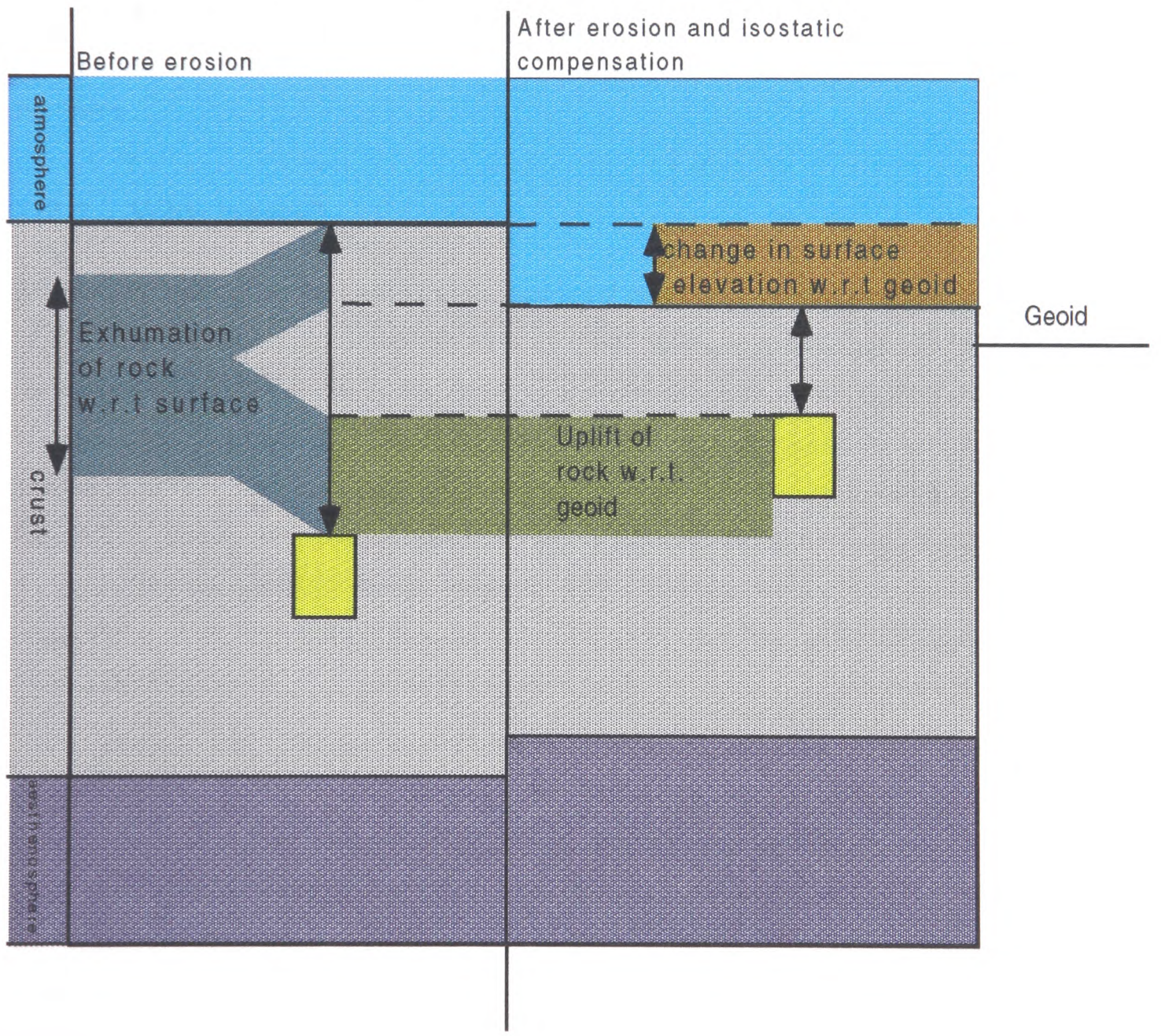


Figure 1.1: The difference between exhumation of rocks, surface uplift with respect to the geoid and uplift of rocks with respect to the geoid.

A measure of the rate of change in surface elevation may therefore be used as a proxy for work done against gravity, with the constant C being proportional to crustal thickness. Consequently surface elevation history is an important quantity to measure if information about the tectonic forces involved in mountain belt dynamics is sought [England & Molnar, 1990].

An improved understanding of the tectonic forces involved in the dynamics of orogenic belts could be used to place constraints onto tectonic models of the tectonic forces in mountain belts. The driving forces for uplift in mountain ranges are largely due to crustal shortening and thickening. Such shortening takes place at the rate of a few centimetres per year and produces uplift rates of the order of 0.1 mm/year.

In recent years, there have been many reports of uplift rates (treated implicitly or explicitly as rates of surface uplift) that are too great to be explained using crustal thickening alone [Copeland *et al.*, 1987; Benjamin *et al.*, 1987; Molnar *et al.*, 1993]. Such uplift must presumably be explained by stresses applied to the lithosphere by the convecting mantle beneath. If rates of surface uplift could actually be measured, along with the timings of such events in relation to tectonic activity, this would be a significant step towards understanding the processes involved. Indeed a similar approach has already been applied to oceanic crust. Parsons & Daly [1983] have shown that surface height changes in the oceans can be used to shed light on mantle processes.

1.2.2 Why leaves?

To measure rates of surface uplift in the geological past, we need to have preserved a sequence of rocks that has been deposited during that uplift, and which contains within it evidence of the surface elevation relative to the geoid, or a similar horizon, at the time of deposition. The biosphere is a thin layer that lies at the interface between the lithosphere and the atmosphere. The locus of this interface over geological time, is equivalent to the surface uplift history (see Figure 1.2). Species evolve to adapt to the environment in which they live. Many of the factors to which they are sensitive change markedly with elevation. If, as this suggests, parts of the biosphere contain information pertaining to elevation, then the palaeontological record may contain information of great potential for tracking the changes in elevation of the surface.

As primary producers, land plants make sugars using water, carbon dioxide and light energy from the sun. They also use oxygen to respire. To compete with their neighbours they must be adapted to use these as efficiently as possible. For this reason they have developed an intimate relation with their physical environment, and through selection pressures imposed by competition from other organisms, have developed a suite of morphological characters that reflect the climate in which they live. Land plants are spatially fixed after germination, and this enhances their close relationship with the environment.

Plant fossil assemblages are different in several ways from faunal assemblages. Plants are composed of, and produce throughout their lifetime, a large numbers of organs that are shed into the environment individually. Each of these has differing potential for transport, deposition preservation and climate study. Spores and pollen for example are produced in great numbers. They are easily and widely dispersed and extremely durable. Their durability means that they may be reworked and deposited several times. Their potential for wide distribution and for

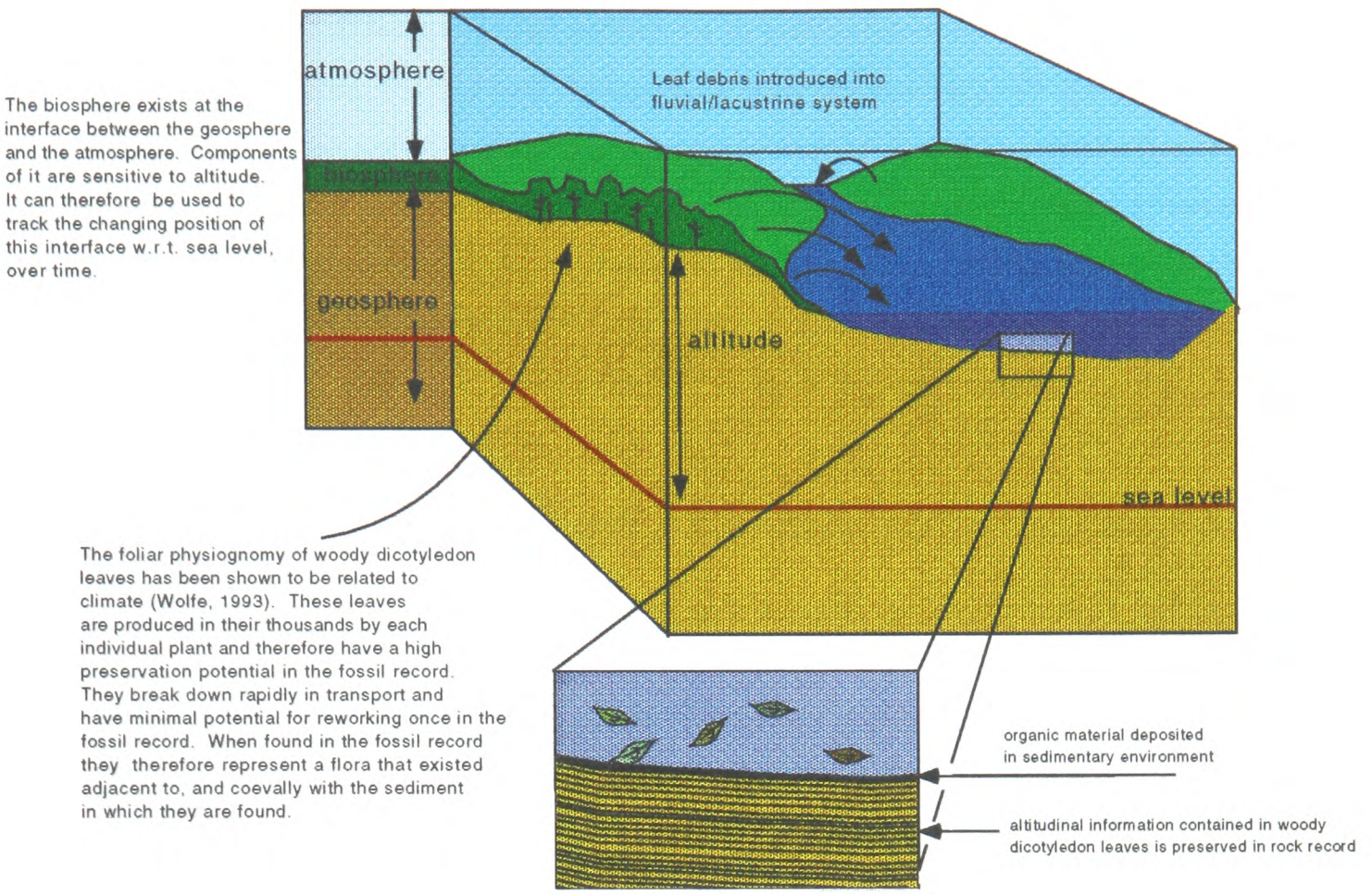


Figure 1.2: Cartoon showing why woody dicotyledon leaf floras have the potential to hold altitudinal and climatic information about the time and place in which they grew

reworking makes them inappropriate for palaeoclimate estimation because it means that both their spatial and temporal resolution in the fossil record is poor. Leaves on the other hand, whilst also produced in large numbers, and robust enough to be relatively easily preserved, are degraded during transport, rarely travelling a great distance from their origin [Spicer & Wolfe, 1987] and have virtually no potential for surviving reworking. They are accordingly found in deposits that are both proximal to and contemporary with the flora in which they originally grew. Of all plant parts, leaves carry the strongest climatic signal because they are the organs with which the plant photo-synthesises and have evolved morphological characteristics that allow them to do this as efficiently as possible in the environment in which they exist [Spicer, 1989]

1.2.3 The Basin and Range Province

The Basin and Range Province, situated in the southwest of the United States, underwent Mesozoic compression followed by late Tertiary extension [Wernicke, 1981; Hamilton, 1987]. This extension was coupled with major magmatism [Gans *et al.*, 1989; Axen *et al.*, 1993; Armstrong & Ward, 1991], although the degree to which they are temporally and spatially linked is disputed [Best & Christiansen, 1991; Taylor & Bartley, 1992]. The mechanism behind this extension and magmatism is also the subject of some controversy. Models can be divided into two groups Jones *et al.* [1996]. The first appeals to interactions along plate margins or at the base of the lithosphere [Glazner & Supplee, 1982; McKee, 1971], whilst the second relies on forces intrinsic

to the lithosphere produced by spatial differences in gravitational Potential Energy [Molnar & Chen, 1983; Sonder *et al.*, 1987]. Much chronological work has been done on the geological history of the Basin and Range province placing temporal constraints on both extension [e.g. Fitzgerald & Wernicke, 1991] and magmatism [e.g. Gans *et al.*, 1989]). Little is known however, of the surface elevation history. Well dated estimates of mean elevation, made using palaeobotanical techniques described below, would allow us to relate changes in surface height (work done against gravity) to tectonic activity and place new constraints on tectonic models.

1.3 A resumé of past work that uses palaeobotany for the estimation of palaeoclimates and palaeoaltitudes

The potential for using fossil plants to glean information about climates of the past has long been recognised. Indeed, the concept of using this relationship to extrapolate information about changes in surface height is not new [Axelrod, 1965]. These approaches have generally been based upon two different methodologies. The most commonly used of these is based upon the floristics of the fossil flora in question. In this approach the taxonomic composition of the flora is examined and the climatic tolerances of their nearest living relatives used to construct a picture of the environment in which they lived [Axelrod, 1965; Axelrod & Bailey, 1976]. A second approach, first developed in the very early part of this century [Bailey & Sinnott, 1915, 1916] assumes that some aspects of the physiognomy of leaves have evolved because of environmental selection pressures upon them. Further it assumes that such adaptations happen repeatedly in unrelated species responding to similar environmental pressures. It uses the physiognomy of the leaves of fossil floras to tell us about the climates in which they grew.

1.3.1 Nearest living relative versus physiognomic methodology

To use the climatic tolerances of the nearest living relatives of ancient plants to infer palaeoclimate is problematic for several reasons [Wolfe & Schorn, 1989]. The classification of an ancient plant, and therefore the selection of its nearest living relative, is to a certain extent subjective. Also the nearest living relatives of plants found in the same fossil floras may have conflicting affinities. Even if this were not the case, to assume that modern climatic preferences reflect those of ancient relatives, is to ignore the effects of evolution. This may be legitimate, for example, in the case of a large modern group such as the palms. These are uniformly extremely sensitive to frost due to the nature of their vascular material. Extrapolating a similar lack of tolerance of cold for ancient palms is not considered dangerous because of the diversity of the modern group [Wing & Greenwood, 1993]. Conversely, the modern cycads, whilst also limited in terms of the range of climates in which they live, are not diverse. In the past this taxon contained many more species. To assume the climatic affinities of this limited modern group, for a diverse ancient group is unwise [Spicer & Parrish, 1987]. With regard to diverse and vigorously evolving

groups the floristic methodology is particularly vulnerable.

The physiognomic approach on the other hand, is independent of inferred phylogenetic relationships with modern plants. Instead it depends upon the adaptive relationship between environmental variables and certain physiognomic character states. The assumption made here is that unrelated plants growing in similar environments that are spatially and/or temporally separated, evolve similar physiognomic solutions to their environment. This assumption has been shown to have a theoretical basis [Parkhurst & Loucks, 1972; Givnish, 1979, 1986; Givnish & Vermeij, 1976] and is discussed below in 1.5.1. For this reason, it is considered that the physiognomic approach is more theoretically rigorous than the nearest living relative methodology.

1.3.2 Advantages of multivariate approach over univariate approach

Early work in physiognomic characteristics and climate used a single leaf characteristic, margin type and yielded only general results. Raunkiaer [1934] recognised that leaf size measurements might also contain valuable palaeoclimatic information, noting a positive correlation between leaf size and available soil moisture. Dolph & Dilcher [1980a,b] studied the variation of leaf size with respect to climate but found that this univariate approach can not be used to discriminate between narrow differences in climate. Dilcher [1973] had pointed out that plants do not respond to single climate variables but to the total environment. However, regardless of the number of climate variables they used, Dolph and Dilcher were unable to obtain a clear picture of the relationship between leaf size variation and climate. Perhaps the main reason for this is that plants can and do respond to environmental changes in numerous different ways, and that these responses are interlinked. To observe the changes in average leaf size in isolation, is to ignore many other adaptations which plant species may utilise to be well adapted to the environment in which they grow. Physiognomy must be regarded broadly if useful relationships between it and climate are to be obtained. Wolfe [1993] developed a methodology called CLAMP (Climate Leaf Analysis Multivariate Program) which identified 29 physiognomic characteristics of potential climatic significance and searched for a systematic way of quantifying these characteristics in a fashion suitable for quantitative analysis. In more recent work the number of physiognomic characteristics has been increased to 31 [Wolfe, 1995; Herman & Spicer, 1996] by adding two more size categories. In the work presented here however, only the original 29 characters have been used so that a direct comparison with the most comprehensive publication of the methodology can be made.

1.3.3 How climate estimates have been used to estimate palaeoaltitudes

The step from plant physiognomy to altitude is not a simple one. Locally many environmental parameters vary with increasing altitude, including temperature and rainfall parameters. These parameters however also tend to vary strongly with climate and latitude such that a physiognomic

signal for altitude alone is not discernible. Palaeoaltitudes can be extrapolated from climatic data obtained from palaeobotanical studies in several different ways. Axelrod ([Axelrod, 1957, 1962] used rainfall estimates obtained from nearest living relative techniques to look for increases in rain shadow over geological time as a proxy for increasing relief and therefore uplift.

Qualitative palaeoaltitude estimates have also been obtained, using a two step approach. The first step is to use palaeobotanical methods (either floristic or physiognomic) to estimate an environmental variable known to vary with altitude, for two coeval fossil sites. One of these sites is known to have been deposited at sea level and one is an upland flora from an unknown altitude. The second is to use the modern relationship between altitude and the variable in question, to calculate the difference in altitude between the two fossil sites. Traditionally the variable used for this purpose has been mean annual temperature (MAT) [Axelrod, 1962; Gregory & Chase, 1992; Meyer, 1992; Povey *et al.*, 1994]. Recently however, the use of MAT have been criticised and the more theoretically defensible variable, Moist Static Enthalpy (MSE) based on the law of the conservation of energy, proposed to replace it [Forest *et al.*, 1995].

1.4 Outline of Wolfe's CLAMP methodology for palaeoclimate estimation

Wolfe's methodology as described in Wolfe [1993, 1995] identifies 29 physiognomic characteristics of climatic significance and measures these in a fashion suitable for quantitative analysis. The central aspect of this approach is that each site, whether modern or fossil, is represented by a 29–component vector describing the percentages of the total number of species at the sites that exhibits each of the characteristics. As is commonly the case in multivariate problems, the 29 characteristics are not independent of each other and Wolfe shows, by the transformation of the data, that relatively few orthogonal vectors formed from a combination of the characteristics account for most of the variance in his data. One can therefore imagine each site as occupying, a position in a space of a few dimensions defined by these orthogonal vectors. Wolfe derived relations between the position of sites in this space and the climate conditions at the site that allowed him to recover from the physiognomic data alone, the climate conditions to a degree of precision. Palaeoclimatic analysis of fossil flora consists of measuring the position of the fossil flora in physiognomic space, and deriving an estimate of climatic conditions from the relations derived from modern sites.

1.5 Problems with CLAMP methodology

1.5.1 Limited nature of data set

The limited geographical extent of the modern CLAMP data set collected thus far lays open to criticism its use in extrapolating climatic information from fossil flora. This problem of

the limited nature of the data set is probably best discussed by looking at one of the central assumptions to the methodology in the light of constructional morphology. The assumption I intend to discuss is that different taxa of plant follow similar evolutionary paths when presented with similar environmental conditions.

When considering the constructional morphology of dicotyledons, it is helpful to use the conceptual framework of Reif *et al.* [1985]. Here, observed structures and morphology are explained using the constraints of a) phylogenetic tradition; b) biological function; and c) morphogenetic fabrication. These can be illustrated qualitatively on a ternary diagram [Seilacher, 1989] (see Figure 1.3). The functional corner defines the adaptational paradigm [Rudwick, 1964]. This is the ideal solution towards which natural selection should move an organism in a given environment. The fabricational corner, takes into account the constraints introduced by the biomaterials in use. Finally, the phylogenetic constraints are defined as the normative force of 'tradition' on the architecture of the organism. This conceptual framework has been used in an evolutionary sense [Seilacher, 1989]. He states that the phylogenetic constraints have both functional and fabricational roots. Whether a morphological element is consigned to this corner is dependent upon the taxonomic level that is under consideration. At higher taxonomic levels an element that in lower groups might be considered as part of the bauplan must be placed in the field of functional and developmental experimentation.

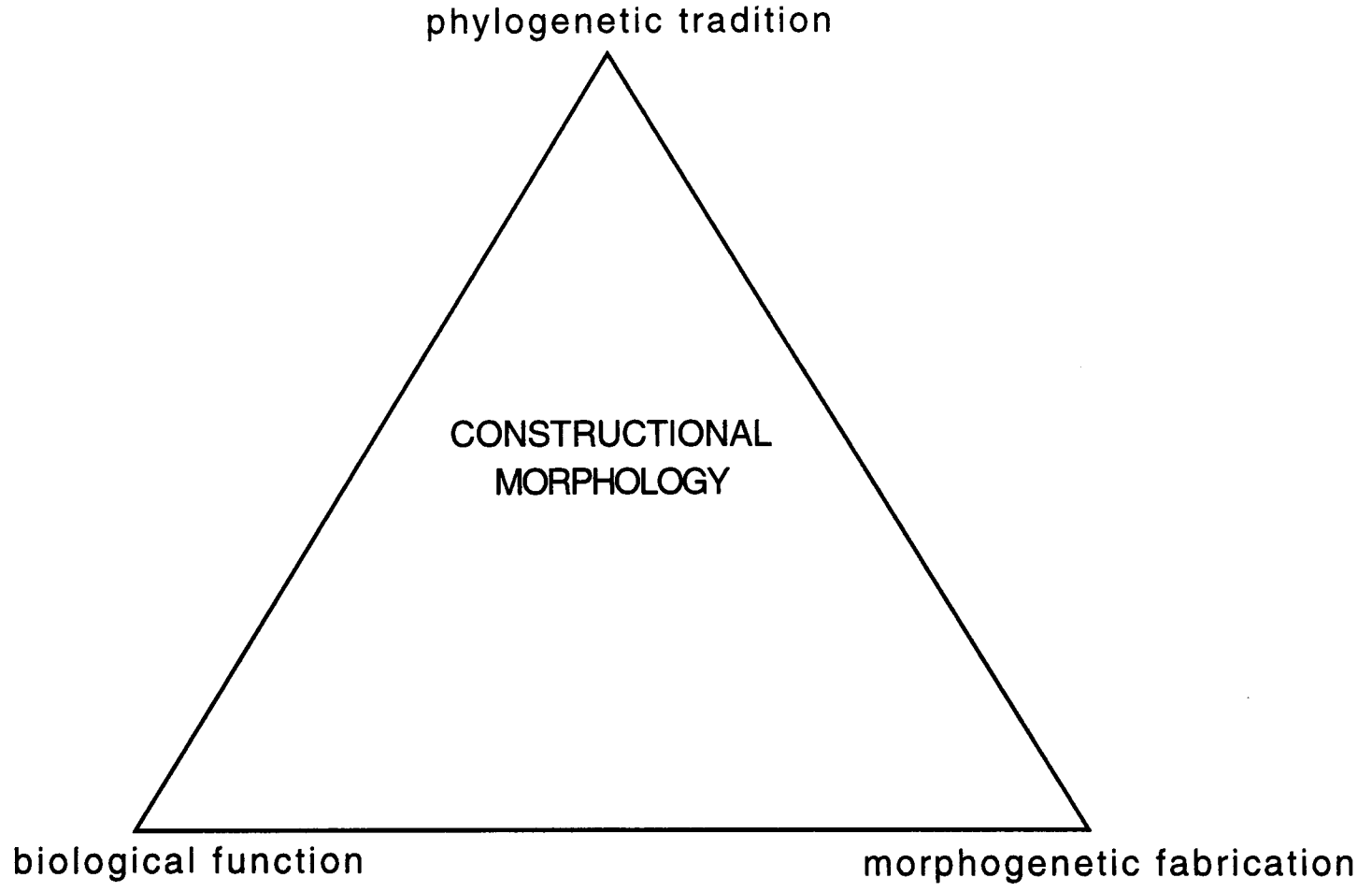


Figure 1.3: A ternary diagram Seilacher (1989) showing the constraints on the constructional morphology of an organism. The functional corner defines the adaptational paradigm i.e. the ideal solution towards which natural selection should move an organism in a given environment. The fabricational corner, takes into account the constraints introduced by the biomaterials in use. Finally, the phylogenetic constraints are defined as the normative force of 'tradition', on the architecture of the organism.

When considering the usefulness of the foliar physiognomy of woody dicotyledons for palaeoclimate estimations, it is useful to look at those morphological characteristics considered, using this framework. The evolution of any of the chosen physiognomic characteristics towards the idealised functional paradigm, must be independent of any taxonomic subdivisions within the woody dicotyledon clade if it is to be of use in the context of CLAMP. Some characters such as venation for example are highly dependent on taxon at a specific level, [Hickey, 1973] i.e. the phylogenetic constraints vary from species to species. Such characters cannot be used in the CLAMP methodology. Wolfe [1993] endeavours to avoid such physiognomic characteristics in his work linking climate with leaf physiognomy. The 106 sites in the CLAMP data set however, were all collected from the northern hemisphere, and almost entirely from North America, with only three from Japan, six from Puerto Rico and one from Panama. The data are limited in terms of biogeography, with three continents: Australasia, Africa and Eurasia having no representation whatsoever. Neither is the range of modern climates fully represented, with wet temperate samples lacking. Because of this it is difficult to see whether the characters selected are as free from the influence of taxonomy as one might hope. Whilst this limited sample shows a good degree of internal consistency, we must question how confidently it can be used to draw conclusions about other spatially and/or temporally remote floras. To further our understanding of how successful this methodology might be for the prediction of climatic parameters from fossil floras, a more diverse range of modern floras must be collected and compared to the existing data set

1.5.2 Limited understanding of taphonomic factors.

As with all palaeontological studies, taphonomy will introduce bias into fossil samples that are collected. In this quantitative study, there is potential for that bias to be picked up in the climatic signal obtained from the physiognomy of the fossil flora under investigation. Wolfe [1993] has gone to some length to ensure that such biases are minimal. Firstly his collections are made with an in–built bias towards riparian vegetation, since these are the plants with the highest chance of getting into a sedimentary environment where they are liable to be preserved. His physiognomic scores are based purely on presence or absence of species and characteristics, rather than taking into account the abundance of species. As a result, in a fossil flora, a species with only one example is given the same weighting as a species with hundreds of examples. In addition a character need only be present once in a particular species to receive the same weighting as all other variables present in that category. Indeed, in the categories where continuous data are divided into discrete variables, such as size, all variables that fall between the two extremes represented in that species, are given equal weighting, even if some are not actually represented in the fossils themselves. Wolfe also advocates that leaf fragments be used in scoring, so that species and size categories more prone to disaggregation will be represented. The degree to which these aspects of the sampling and scoring methodology of CLAMP counter the potential biases introduced by preferential preservation in the fossil record is unknown. Such biases could introduce error into

climatic signals from fossil flora and therefore into estimates of palaeoclimate drawn from these signals. Consequently the size of these errors must be assessed if the palaeoclimatic information derived is to have any meaning.

1.5.3 Analysis of the Data

Wolfe [1993] identifies a link between the foliar physiognomy of woody dicotyledons and climate. The multivariate nature of the physiognomic and climatic data sets that he collates means that choosing a method of analysis is far from trivial. Implicit in Wolfe's analysis is the assumption of a continuous relationship between climate and physiognomy, throughout data space. The possibility that different regimes may exist locally in physiognomic space is not allowed for, although outliers to the main data set are recognised [Wolfe, 1993].

1.5.4 Speed of adaptation to environmental change

There is an implicit assumption in palaeoaltitude estimation, of geologically instantaneous adaptation to changing environment. If there is a significant delay before the flora equilibrates with its environment then climatic estimates will lag behind actual events. We can only be confident of climatic signals from plants if we are also confident that adaptations to a changing environment occur at a geologically insignificant rate, such that the time-scale of the lag is less than the resolution of our dating techniques for the floras. Any lag might be accentuated in areas of low diversity or geographical isolation, where the source flora that evolves into a new niche is limited. Radiometric dates can routinely have errors of up to $\pm$ 2My but can be as good as $\pm$ 0.2My. These dates rarely apply to the sediments in which the flora lies, and more usually for sediments that lie conformably above or below. Ideally adaptations of the flora to a changing environment should occur on a time-scale less than the resolution of our ability to date that flora.

1.6 Outline aim of research: to investigate these factors in greater detail.

Whilst the ultimate aims of this research are still to apply the CLAMP model to fossil floras of the Basin and Range region of west central America as a sister project to that of Povey [1995], I have chosen first to tackle more thoroughly the question of the validity of the CLAMP methodology. Early work using this approach [Povey, 1995; Wolfe, 1995; Povey *et al.*, 1994] has shown the technique to have great potential for palaeoclimate and palaeoaltitude estimation producing internally consistent results for coeval floras [Wolfe, 1995]. Whilst these early results have convinced some workers of CLAMP's potential, many of the assumptions upon which the foundations of the methodology are laid can be questioned. It is only by challenging these assumptions that we can begin to see the true value of the approach. This research's aim is to

investigate and consolidate the CLAMP methodology itself. Recognising only that a relation exists between the physiognomy of a limited modern data set and climate, I question first, how widely, both temporally and spatially, such a relationship may be described and second, whether, if such a relationship exists, the signal can be picked up in the fossil record.

The question of the limited nature of the data set has been tackled by the collection of new CLAMP samples from New Zealand and Australia. These new floras, with their Gondwanan affinity are biogeographically remote from the CLAMP samples of Wolfe [1993]. In addition the wet temperate climate of New Zealand has allowed collections from poorly sampled areas of climate space. This opportunity to explore as yet uncharted areas of data space has also allowed me to examine closely at the way the data set is analysed. This is discussed fully in Chapter 3. Taphonomic experiments were conducted in a lacustrine setting in New Zealand. The results from these and the implications for the CLAMP methodology are discussed in Chapter 4. In Chapter 5, fossil floras already analysed using CLAMP are re–examined in the light of these results.

Chapter 2

The collection of new CLAMP samples

2.1 Introduction

As discussed in Chapter 1 the use of the foliar physiognomy of fossil floras to calculate palaeoclimate has been shown to have great potential. Moreover, the use of a multivariate data set including numerous foliar physiognomic character states has more chance of fully documenting leaves' complex response to environment than a univariate methodology such as leaf margin analysis. A data set of modern woody dicotyledon floras consisting of 106 sites has been collected [Wolfe, 1993], and multivariate analysis of these data along with climate information from where they grew has shown that there is a strong relationship between climate and physiognomy. Whilst this work is of great importance in establishing palaeobotany as a valid palaeoclimatic tool, it is open to criticisms (see Chapter 1). These can be at least partially addressed by the collection and study of new modern floras.

2.2 Outline of the CLAMP analysis (Wolfe, 1993)

2.2.1 The physiognomic character states used in the CLAMP analysis

Wolfe defined and uses 29 physiognomic character states (see figure 2.1) to measure the physiognomy of a flora. These may be divided into 6 categories: margin characteristics, size, apical characteristics, basal characteristics, length:width ratio, and shape. Within each category the character states are linked in the sense that they describe the same aspects of the leaves physiognomy. The calculation of the character state scoring system is described briefly below. For a full description [see Wolfe, 1993, pages-21–28]

Each species is assigned a score for each character state of between zero and one. If no

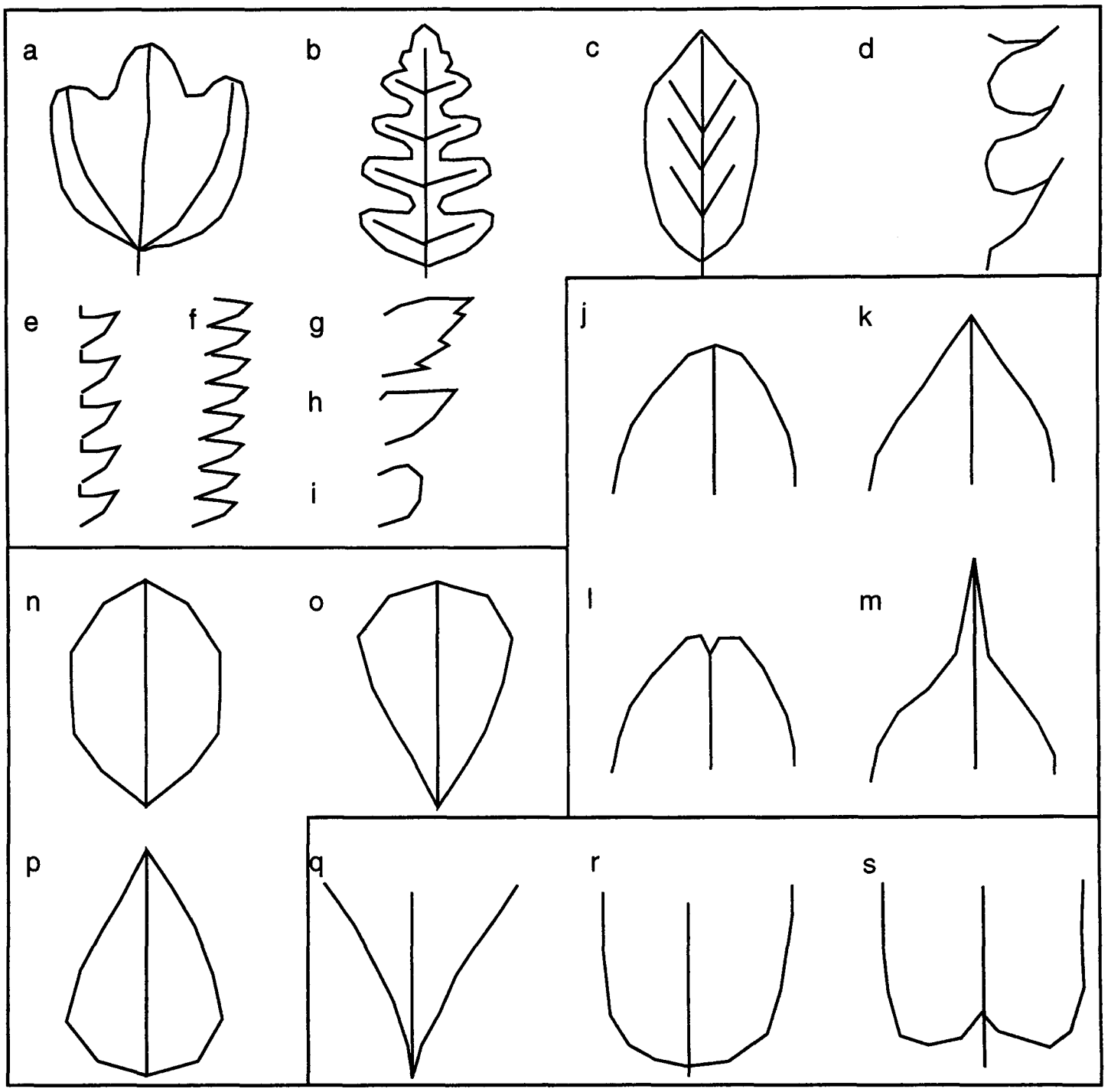


Figure 2.1: Character states: The margin may be lobed, a] or b]. In addition it may be entire, c] or have teeth. Wolfe (1993) classifies spinose teeth, d] to be entire. Those species with teeth may be further classified according to whether they have regular teeth e], close teeth f] or compound teeth g]. All teeth are classified as either acute h] or round i]. The apex may be described as round j], acute k], emarginate l] or attenuate m] and the overall shape as elliptical n], obovate o], i.e. the broadest part in the top third of the lamina, or ovate p], i.e. the broadest part in the basal third of the lamina. The base is classified as either acute q], round r] or cordate i.e. the lamina extends below the attachment to the petiole s]. Other character states not illustrated here relate to size (7 character states: leptophyll 1 and 2, microphyll 1 2 and 3, and mesophyll 1 and 2) and length:width ratio (5 character states L:W<1,L:W 1-2, L:W 2-3,L:W 3-4, L:W>4).

leaves within a species exhibit that character state it receives a score of zero whereas if all leaves exhibit it, a score of one is assigned. In general if more than one character state within a category is exhibited within a species, the maximum score of 1 is divided equally amongst those character states represented. The scores for each character state for an entire flora are calculated as a percentage sum of the species scores. Consequently all the scores within a category sum to 100. The exceptions to this rule are the apex and margin categories. Three out of four of the apex character states sum to 100. These are apex–acute, apex–attenuate and apex–round. The fourth: apex–emarginate has been defined by Wolfe to be independent of the other three and receives a score of one if it is present at all, however infrequently. In the case of the margin category, of the seven character states included within it, only three: percent no–teeth, teeth–round and teeth–acute are mutually exclusive and sum to 100. The scores for teeth–regular, teeth–close and teeth–compound are clearly limited by the number of species displaying the teeth character state. Consequently their upper limit is defined by the no–teeth score subtracted from 100. The lobed character state is independent of the teeth character states and scores either 0, 0.5 or 1 depending on whether it is uniformly present, occasionally present or entirely absent.

2.2.2 The existing data set

The CLAMP data are entirely from the northern hemisphere. They are drawn primarily from North American sites with only 13 from Japan, Puerto Rico and Panama. The raw data matrix was originally presented with 29 different physiognomic variables although recent works have expanded the data set up to 31 by dividing both the largest and the smallest size categories into two [Wolfe, 1995; Herman & Spicer, 1996].

The data set is plainly multidimensional. This data matrix however, has a certain amount of redundancy because a proportion of the variation described by any physiognomic characteristic across sample space is duplicated to a certain extent by other physiognomic characteristics. Using a process called ordination the original data can be reduced down to the major sources of variation within them, by eliminating duplication and redundancy (see Figure 2.2). Using this type of approach, the bulk of the variation within the multidimensional data can then be represented graphically on plots in just two or three independent dimensions. There are several techniques available to conduct this process [Mardia *et al.*, 1979; Kent & Coker, 1992]. These can either be direct, when the data is redescribed in relation to environmental factors, or indirect, when the ordination is independent of any preconceived ideas about the nature of the controlling environmental factors involved and the major axes of variation within the data are sought.

2.2.3 The CLAMP analysis

In his analysis of the CLAMP data set, Wolfe [1993] used correspondence analysis (CA) [Hill, 1973, 1974] also known as reciprocal averaging to reduce parsimoniously the dimensionality of

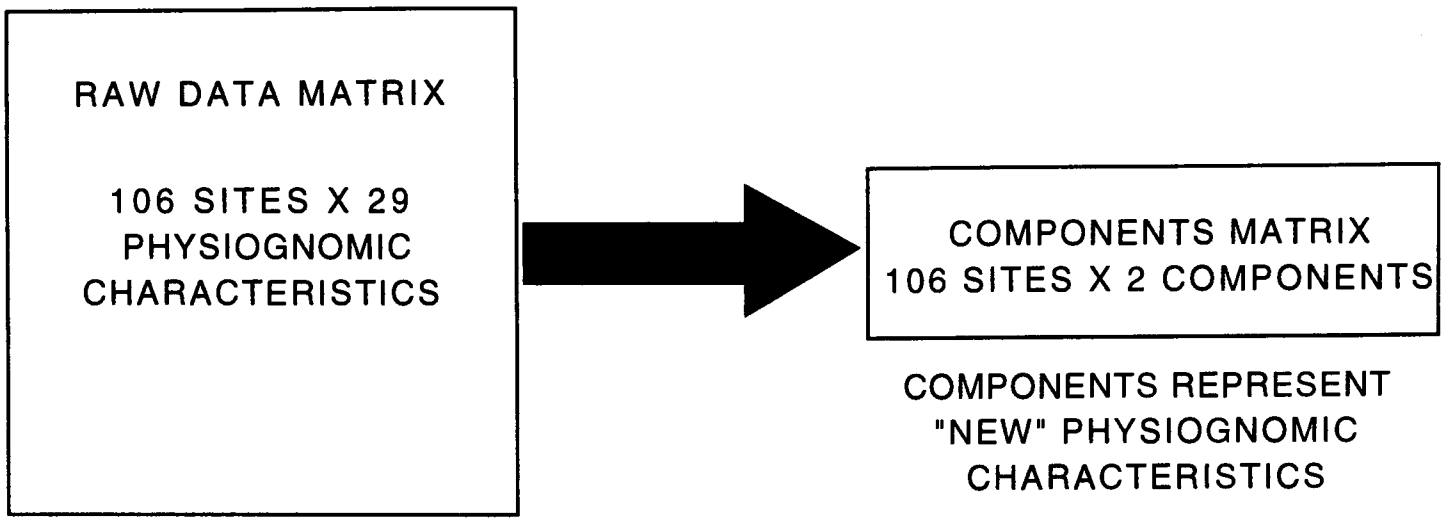


Figure 2.2: The use of ordination to reduce the dimensionality of a multivariate data set is done by selecting the directions within the space that describe the most variation

the data. CA supposes that each physiognomic character state, i, has a preference, let us call it r_i, associated with its environmental conditions (which do not need to be specified). Then the score, S_j, of a particular site, j, with observed character states x_{ij} would be

$$S_j \propto \sum_i \frac{x_{ij} r_i}{X_{\bullet j}} \tag{2.1}$$

Where

$$X_{\bullet j} = \sum_i x_{ij} \tag{2.2}$$

[pages 237-239 Mardia *et al.*, 1979]

If the preferences, r_i, were known these relations would yield a set of scores that could be used to place the sites in order. Equally, if the scores for each site were known, then the preferences could be determined:

$$r_i \propto \sum_j \frac{x_{ij} s_j}{X_{i\bullet}} \tag{2.3}$$

Where

$$X_{i\bullet} = \sum_j x_{ij} \tag{2.4}$$

In practice neither scores nor preferences are known. CA solves for both simultaneously, (Hill, 1973, Mardia *et al.*, 1979, page 237-239) generating preferences and scores directly from the data.

Often when CA is used, scores and/or preferences are the object of the analysis. Wolfe [1993] however, took advantage of the property that CA yields a set of orthogonal axes that describe the data space. These axes were considered preferable to orthogonal axes derived from more well–known techniques such as principal component analysis (PCA), because they are derived with no assumptions about the distribution of data, and with only the minimal hypothesis that the physiognomic character states must exhibit some dependence on environment. This dependence is however, supposed to be linear and to apply to the whole of the observed space of character states (see Equations 2.1–2.4). The axes are chosen in order of descending percentage variance explained. To some extent CA has been supplanted by canonical correspondence analysis, [ter Braak, 1986] a direct gradient analysis in which the principal axes are combinations

of the environmental variables supplied. Wolfe [1993] shows that the resulting sample plot is highly similar to the CA sample plot and it is for this reason that I have chosen to discuss the methodology in its original simpler form.

For the CLAMP data set, the first five axes alone account for 86.6% of the variance, and approximately 70% of physiognomic variation can be represented on a 2–D plot using the first two axes. Of these two axes, the first, which describes 47.6% of the variation is strongly related to temperature. The second is related to water stress. Consequently the two–dimensional plot can be divided into four quadrants representing warm and wet; warm and dry; cold and dry; and cold and wet (see figure 2.3). It is in this two–dimensional space that Wolfe develops his predictive tool for climate estimation. Sites are projected onto a line that ranks them in terms of the environmental variable in question. In the case of mean annual temperature (MAT) for example, the vector chosen for this purpose is the no–teeth vector which is sub-parallel to axis one. The MAT at a fossil site is estimated by projecting the fossil site onto the vector in axis one–axis two space and fitting a third order polynomial curve (see Figure 2.4). The resulting MAT estimates are satisfactory except at low temperatures (see Figure 2.5a). Wolfe [1993] identifies several sets of outliers that do not follow the general rule. The largest of these is the subalpine floras, defined as floras collected at sites where the warm month mean temperature is less than 16°C and the cold month mean temperature is less than 3°C. These sites plot consistently too warm when projected onto the no–teeth vector. 19 out of 20 of them form a coherent group within sample space, positioned below sites adjacent in the 2D plot, on the third axis selected by correspondence analysis ([see Wolfe, 1993, Fig. 30]. Other non-subalpine sites are not found within the bounds of this group. Another group identified by Wolfe, that does not fit the model are the dry microthermal sites. In all Wolfe removes 26 outliers. The fit is much better for the remaining 80 samples (see Figure 2.5b).

Other workers have also attempted a multiple character approach based on the data collected by Wolfe. Gregory & Chase [1992] used a multiple regression analysis to develop a predictive equation for MAT. This approach makes the assumption that the physiognomic variables are linearly independent. Many of the variables however are interdependent, consequently the estimate of regression coefficient will be imprecise [see Mardia *et al.*, 1979, pg. 157]. For this reason I believe Wolfe's use of CA to be more rigorous.

Both of these analyses of Wolfe's data [Wolfe, 1993; Gregory & Chase, 1992] have the characteristic that a global relation is sought between the physiognomic character states of the leaves and the environmental conditions in which they grew. Even given the limited extent of Wolfe's data set this approach appears to be flawed with two subsets of data (the subalpine and the dry microthermal outliers [Wolfe, 1993]) that do not conform with the global model he describes. These subsets are recognisable not only by their climate but also by the position in physiognomic space that they plot.

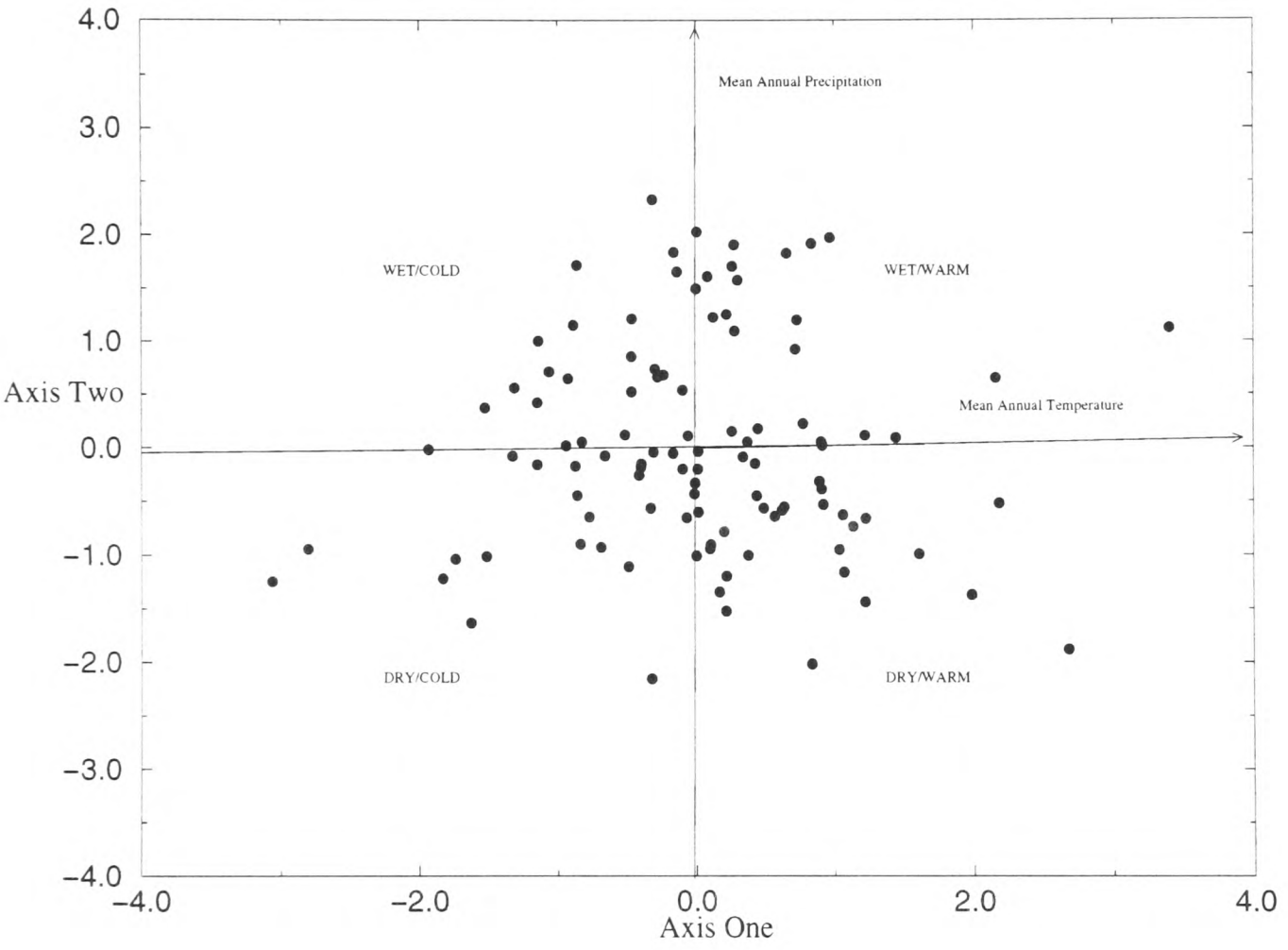


Figure 2.3: The vectors that best rank the data in terms of Mean Annual Temperature and Mean Annual Precipitation in axis one–axis two space (after Correspondence analysis). Consequently this plane can be divided into 4 quadrants: warm and wet, warm and dry, cold and wet, and cold and dry.

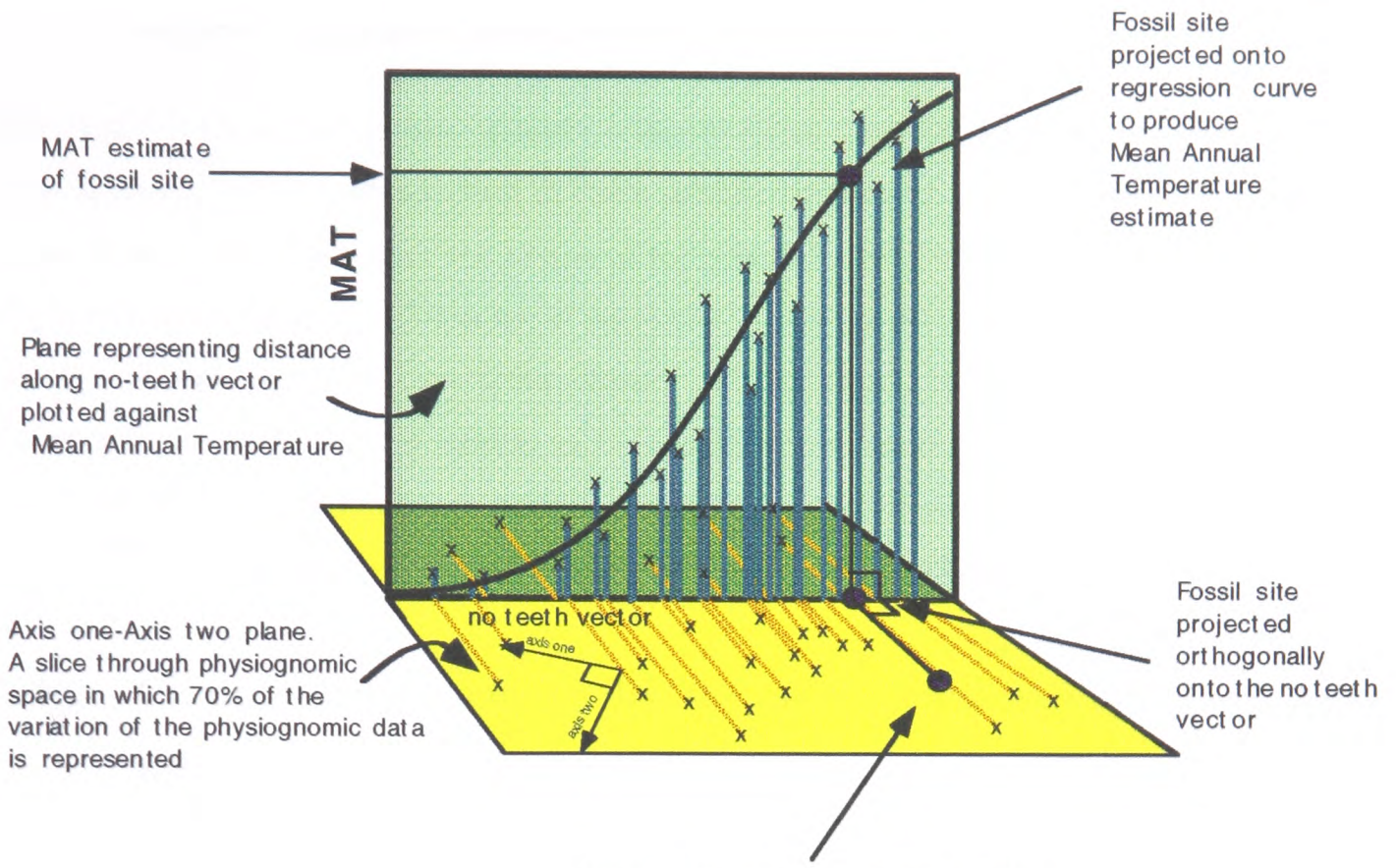


Figure 2.4: Cartoon showing the methodology proposed by Wolfe (1993) to estimate climatic parameters (in this case MAT) of a fossil site from its position in axis one–axis two space. (x = modern sites)

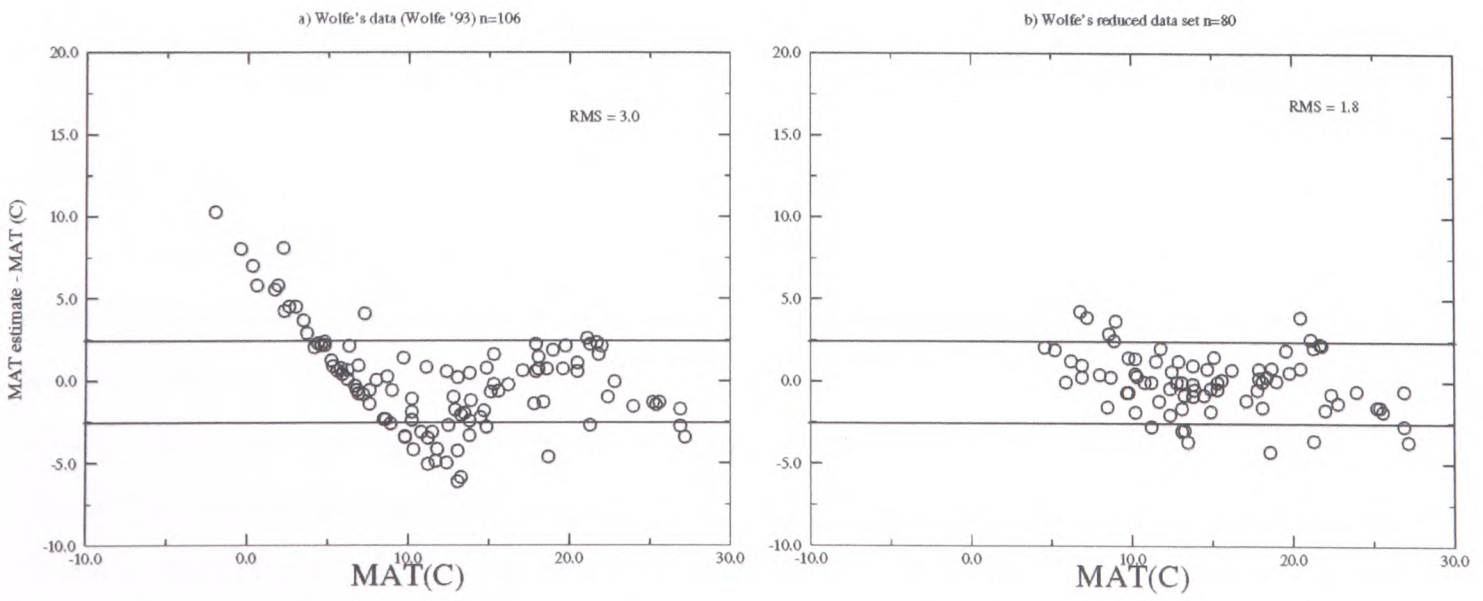


Figure 2.5: Estimate of MAT of all modern northern hemisphere sites using Wolfe's methodology

2.3 Data collection

2.3.1 The Suitability of New Zealand and Australia for the collection of new CLAMP physiognomic samples

The study of the physiognomy of newly collected floras from the southern hemisphere, mainly New Zealand, and the introduction of these sites to the present CLAMP data set allows us to increase our understanding of the nature of the relationship between physiognomy and climate. These southern hemisphere floras are of particular interest because of their Gondwanan heritage, which is in contrast to the Laurentian ancestry of the majority of the present CLAMP sites (see figure 2.6). In addition they enable us to sample new areas of climate space, and potentially new areas of physiognomic space, testing the assumptions that a) the physiognomic response to climate is independent of taxa, and b) that it is consistent throughout physiognomic space.

2.3.2 Climate range covered by the newly collected southern hemisphere sites

New Zealand climate

In terms of area, New Zealand is not a large country. Its three main islands lie entirely within the zone of mid—latitude westerlies. It is surrounded by ocean, and this position ensures that approaching air masses are moisture laden. Despite these facts, it exhibits a wide range of climates. Its three main islands are elongate in a north-east south-west direction and span 1500 km of latitude, between 34° and 47°S. This large latitudinal spread results in a broad range of temperature. Mean annual temperature (MAT) at sea level, ranges from 15.9°C in the north (met station A53123, 35°39′S), to 9.5°C in the south (meteorological station I68913 46°25′S). This is further enhanced by the country's topography, with MATs as low as 3.7°C recorded in the high altitude regions of the Southern Alps (meteorological station H31162, 43°08′S 171°41′E). The east coast of South Island which is on the leeward side of the Southern Alps in prevailing weather conditions, is subject to hot dry föhn winds generated when the moisture laden prevailing westerlies pass over this topographic barrier (see Figure 2.7).

This large axial range of mountains account also, for the huge diversity observed in mean annual precipitation (MAP) (see Figure 2.8). It forms an unbroken barrier, of 750 km, the full length of the South island, to the mean west–south-westerly airflow off the Tasman Sea. For this reason, the west coast of South Island is subject to extremely high orogenic rainfall, exceeding 10,000 mm on the westernmost ranges [Wardle, 1991], as these moisture laden winds are forced up over the Southern Alps. The rate of precipitation here can also be very high; 120 mm/24 hours is not uncommon. Conversely, the rain shadow on the leeward side of this large mountain range means MAPs on the east coast of South Island of between 500 and 750 mm per annum. This rain is brought mostly by occasional southern fronts. Intermontane basins that lie in rain

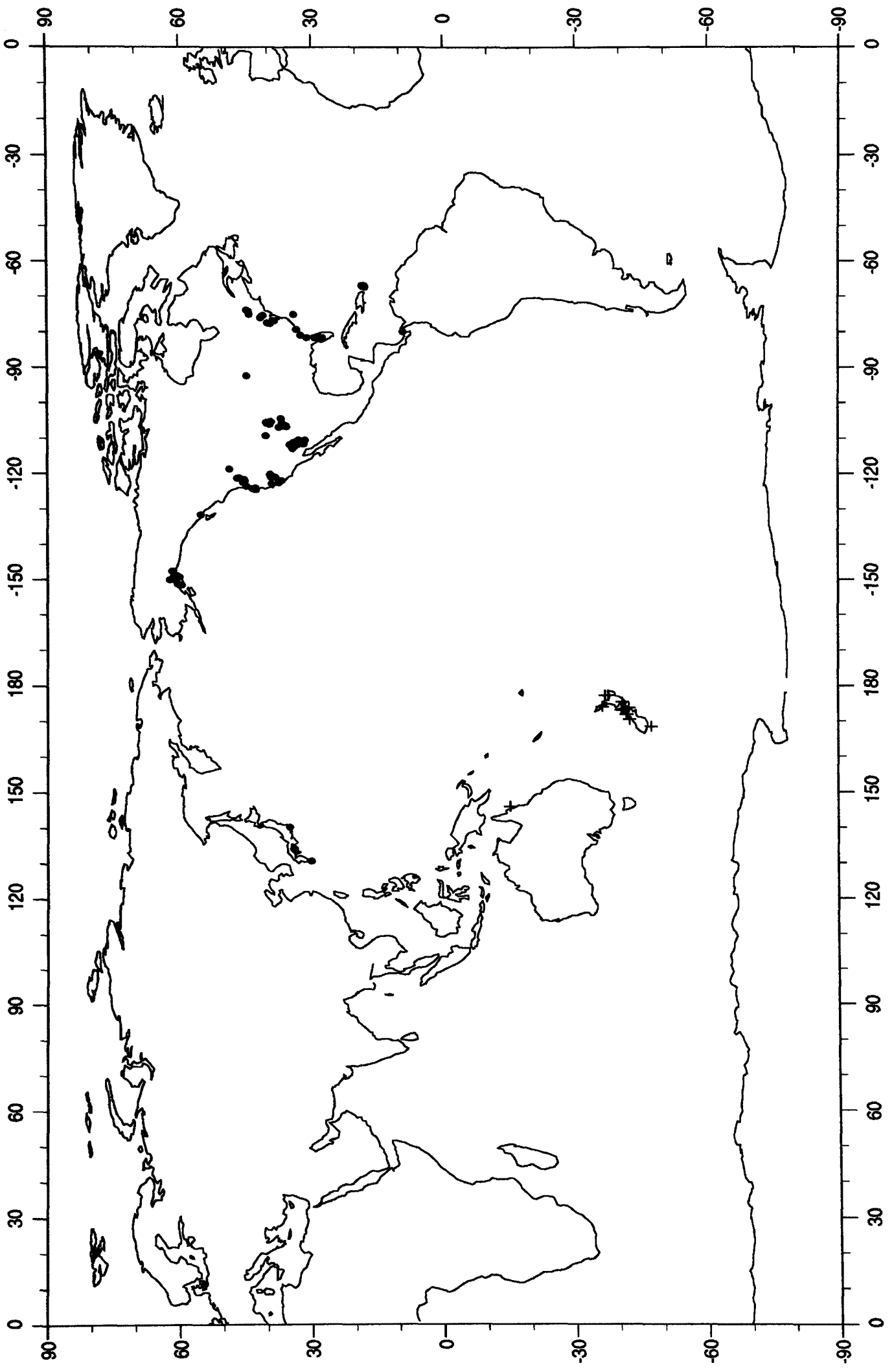
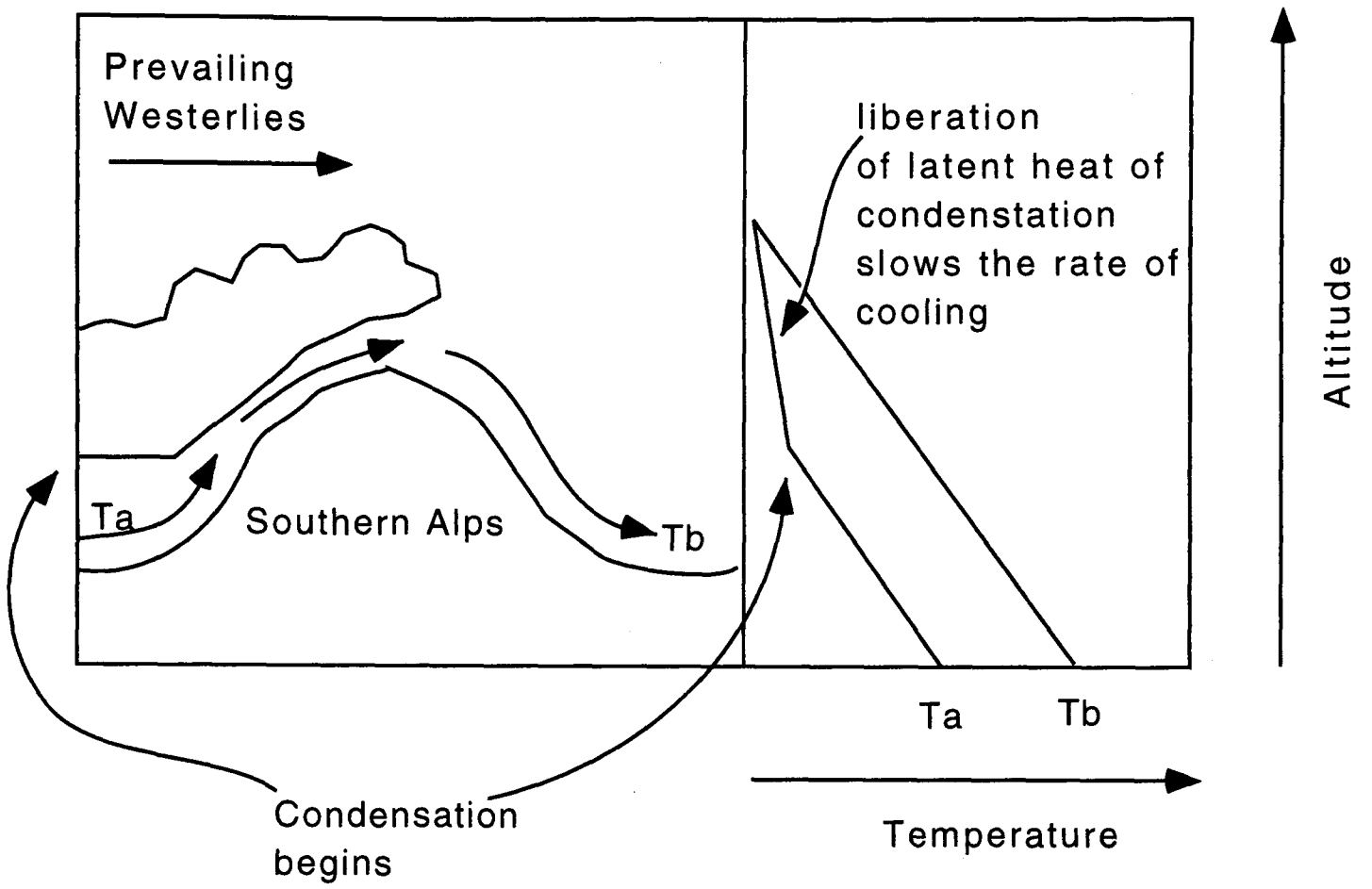


Figure 2.6: Map showing relative position of original CLAMP data (circle) with their Laurentian heritage to the newly collected southern hemisphere sites (cross) of Gondwanan origin



Ta = temperature at the windward foot of the Southern Alps
Tb = temperature at the leaward foot of the Southern Alps

Figure 2.7: The föhn winds on the east coast of South Island are formed as warm air passes over the Southern Alps. As it rises over this topographic barrier into an environment of lower pressure, it expands. This process is coupled with a decrease in temperature due to the conservation of energy. As the air cools, water begins to condense and latent heat is liberated. The overall rate of cooling of the air packet is decreased. When the air flows downwards on the leeside of the mountain it is compressed and heated. Because of the latent heat of condensation, it reaches a higher temperature than it had before it hit the topographic barrier: he resulting air flow is dry and warm.

shadows from both east and west can record MAP as low as 350 mm.

In the east, conditions become very dry when there is a sustained period of anti-cyclones and dry north westerlies. These practically rainless periods can last for two or more months. In the west dry periods can last for up to a month and are caused by a prolonged period of easterly weather.

A less prominent and less continuous mountain range continues on North Island producing a similar pattern of orographic rain and rain shadow, although these climatic patterns are less strongly differentiated. Its lower latitudes mean generally higher MATs than South Island.

Its diverse climate makes New Zealand an excellent place to collect floras and study the link between their physiognomy and the climate in which they grow.

Australian site climate

The climatic range of the southern hemisphere CLAMP samples collected in this study, was increased by collecting an additional sample from the tropical rain forest of northern Queensland near Cairns. Both Australian samples were collected from 16° 45°S, altitude 340 metres above sea level. The proximity to the ocean and the low latitude of this site results in a very warm and wet climate. With a MAT of 25° C and a MAP of 2000mm, it can be thought of as a northerly (warmer) extension to the range of samples collected in New Zealand .

2.3.3 The New Zealand vegetation and its evolutionary history

To understand the relationship between physiognomy and climate in New Zealand, we should first have a sound grasp of the evolutionary history of its floras. The modern flora is the product of many interacting factors over geological time. These fall into two categories. The first is environmental factors: these control both the development and disappearance of habitats resulting in evolutionary pressures on plants. It is important to note that plants suited to certain habitats may evolve, and later become extinct if that habitat disappears, such that later, when the habitat redevelops there are no pre–adapted species to radiate into it. The second is phylogenetic, and controls what plants are available to radiate and diversify into new environments. The tectonic history of New Zealand has affected both of these; firstly in the form of climate change, caused by change in the latitude and altitude of the land mass, and secondly by changing the proximity of adjacent land masses, which are a potential sources for locally new species.

The Cenozoic tectonic history of New Zealand and its relevance to the evolution of the New Zealand flora

The Cenozoic tectonic and environmental histories of New Zealand will be discussed here, where relevant to the modern flora of New Zealand. This information is also summarised in Figure 2.9.

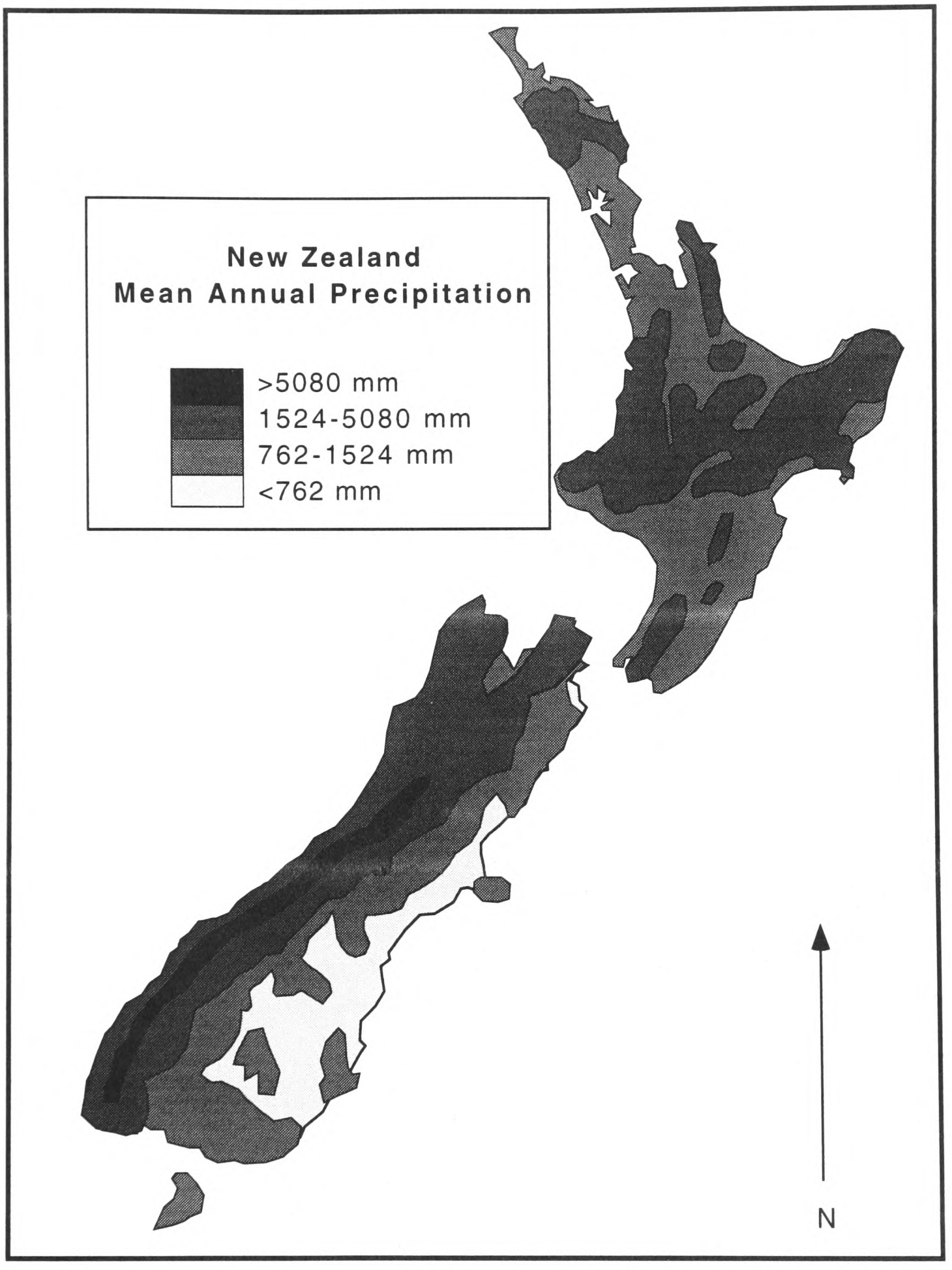


Figure 2.8: Map showing Mean Annual Precipitation on the three main islands of New Zealand

These effects will then be discussed in the light of foliar physiognomic adaptation to environment.

The ancestry of the present day forests of New Zealand lies firmly in Gondwanaland, with Late Cretaceous forest floras in New Zealand scarcely differing from those of southern Australia, [Stevens, 1977; Wardle, 1991] and showing strong similarities with floras from contemporary Antarctica [Cranwell, 1959] and the southern tip of South Africa [Axelrod & Raven, 1978] . Angiosperm were present in New Zealand and Australia by the Cenomanian, approximately 100 Ma before present [Couper, 1960; Dettmann & Playford, 1969].

The break up of Gondwanaland included the separation of New Zealand from Australia, which occurred in the Late Cretaceous (80-60 Ma). By this time the angiosperms were already very diverse [Ingrouille, 1992]. Since then, New Zealand has remained a geographically isolated archipelago. It moved north from its high latitude position of the Late Cretaceous until the Miocene when it was at its most equatorial, 33- 53°S, slightly north of its present day latitude.

New Zealand's isolation has limited the diversity of the source flora available to radiate into new environments. Workers in this field agree however, that the archipelago has never been entirely floristically isolated [Wardle, 1978; Raven, 1972; Wardle, 1991]. Indeed Close *et al.* [1978] showed that the transfer of viable biological material, including seeds, between Australia and New Zealand is not uncommon today.

The extent of New Zealand's isolation is reflected by a high proportion of endemic species [Cockayne, 1928; Hooker, 1853] in the modern flora. As many as 85% of seed plant species are endemic [Millener, 1960]. In addition, New Zealand has a surprising floristic poverty despite its sub–tropical luxuriance. There are 2000 species of native vascular plants compared with 6000 in Japan, its northern hemisphere latitudinal equivalent [Mildenhall, 1980]. A lack of generic diversity is another characteristic of the New Zealand flora. This is especially noticeable in those genera which grow in exclusively low altitude habitats. These have an average of 1.3 species/genera, where the world average is 12.5 [Mildenhall, 1980]. It should be noted that there are a few large genera eg *Hebe* and *Olearia* which have radiated principally into subalpine and alpine habits [Raven, 1972]. This will be discussed below in the light of the uplift of the Southern Alps.

By the end of the Cretaceous New Zealand was a land of low relief. This lack of upland regions continued until the uplift of the Southern Alps beginning 8 Ma ago [Tippett & Kamp, 1993]. Despite a distinct cooling at the end of the Eocene [Devereux, 1967] which resulted in the extinction of some tropical taxa [Mildenhall, 1980], New Zealand did not have a microthermal climate until the middle Pliocene [Mildenhall, 1978] when this uplift was well under way. In fact, since the Late Cretaceous, New Zealand has remained mainly within the cool to warm temperate region [Mildenhall, 1980]. No tropical fossil assemblages have yet been recognised even in the Miocene, when New Zealand reached it lowest latitude (see Figure 2.9).

In the Middle Eocene, Australia and Antarctica began to separate with the activation of the Indian Antarctic rise This led to the initiation of circum–polar oceanic currents by the

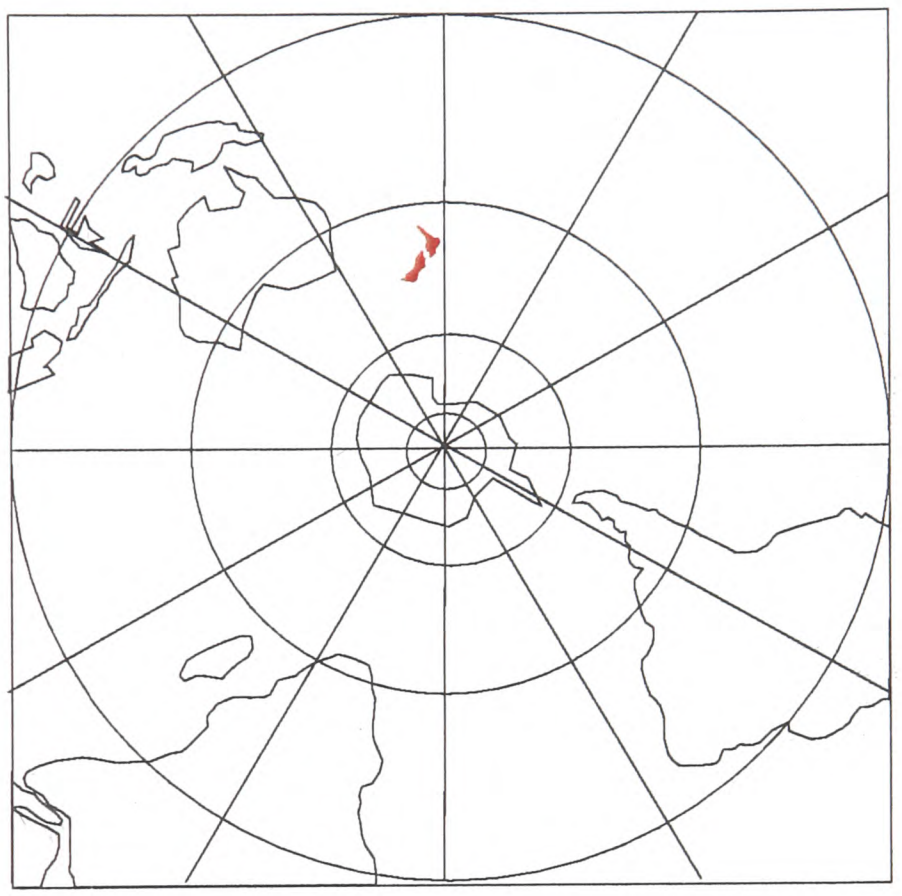


Figure 2.9: Cartoon showing the important events controlling the evolution of the New Zealand flora including the tectonic and climatic history of New Zealand and its geographic position throughout the Cenozoic

Flowering plants present in New Zealand by the Cenomanian (100 MA)

Break up of Gondwanaland New Zealand becomes an isolated archipelago

Distinct cooling at the end of the Eocene

Instigation of circumpolar current

New Zealand at its most equatorial

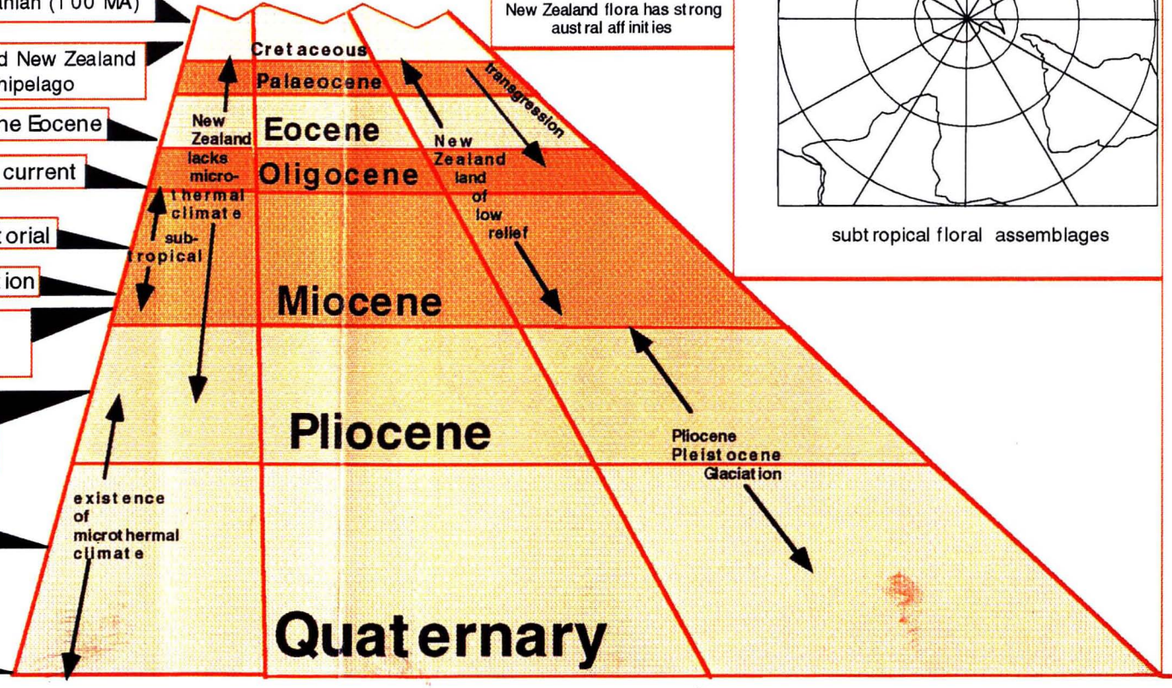
Late Miocene climate deterioration

Initiation of uplift of the Southern Alps

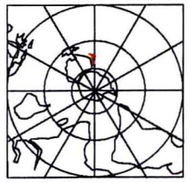
Development of subalpine zone

Subalpine assemblages found on North Island

Arrival of Man

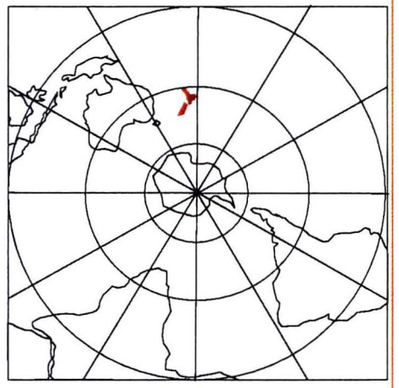


Late Cretaceous



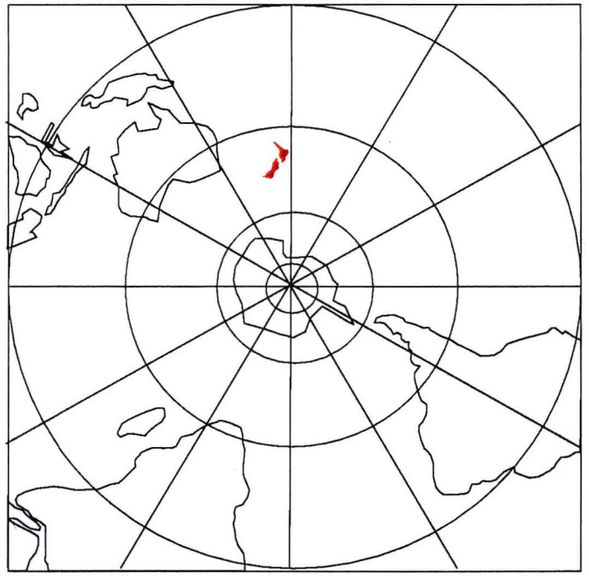
New Zealand flora has strong austral affinities

Miocene



subtropical floral assemblages

Present



modern New Zealand flora has a large number of endemic species and a lack of generic diversity, apart from some upland genera.

end of the Oligocene [Kennett *et al.*, 1975]. It is thought that the resulting increase in westerlies is responsible for an increase in new mainly temperate plant taxa in the late Oligocene–Early Miocene [Couper, 1960] and the disappearance of some warm temperate plants [Mildenhall, 1980].

The origin of the high altitude flora of New Zealand

The physiognomic adaptation of the modern New Zealand vegetation to the microthermal climate, given both the limited time period for the radiation into this niche, and the limited nature of the source vegetation, is of great interest. If a palaeobotanical tool is to be applied to fossil floras to obtain climate information, we must be confident that plants are capable of adapting to new environments in a geologically short period of time. The time taken for 'adaptation' will affect the temporal resolution of any palaeobotanical climate estimates. It is therefore vital that the origin of the upland floras is understood, so that we know the extent to which species now living in the uplands have had to evolve to suit that habitat.

The high altitude plants that exist in New Zealand today have several sources. It has been suggested [Wardle, 1991] that some cold–tolerant plants survived the middle Tertiary warmth in habitats such as peneplains, with soils too leached to support continuous forest. In addition to these, some non–endemic genera undoubtedly reached New Zealand through late transoceanic immigration. The restricted ranges of a few genera on the West coast,[McGlone, 1985] suggests some are very recent new arrivals. [Wardle, 1991] states that the bulk of New Zealand's shrubby and herbaceous upland flora, has evolved in response to the new environments of the Quaternary era. These include: i) Genera cosmopolitan in cool regions of the world, but with a secondary centre of evolution in New Zealand ii) Genera concentrated in other southern lands, but with distinctive species clusters in New Zealand, iii) Genera with species in the New Zealand lowlands, that have radiated into mountain environments as these became available and iv) Small genera of high altitude that are satellites of larger genera.

So, whilst some species currently inhabiting the upland regions of New Zealand were already tolerant to a microthermal climate before it started to develop on these islands, most appear to have evolved their cold tolerance since that time, i.e. since the mid Pliocene [Mildenhall, 1978] approximately 3Ma before present.

In terms of getting good climatic signals from foliar physiognomy of microthermal floras, New Zealand, with its recent uplift and limited genetic pool is, in many ways, a worst case scenario. In summary this is because of the relative newness of its microthermal climate and the limited genetic pool for radiation into this niche, along with the evolutionary remoteness of the New Zealand flora to the existing northern hemisphere data set. If we are able to obtain meaningful climate information from the physiognomy of upland floras in New Zealand, it bodes well for the use of palaeobotany for climate estimation of fossil floras.

2.3.4 Australian site vegetation

On the eastern coast of Australia there are several forest types. Luxuriant rain forest is found on coastal lands, coastal highlands and parts of the Great Dividing Ranges, but rarely penetrates beyond 150 km inland. It is not continuous, and is interrupted by large tracts of forest of a more open and dry type. Due to logistical constraints CLAMP samples were taken from one site only, in tropical rain forest. It is noted here that a valuable addition to this work would be the collection of CLAMP samples from the open eucalyptus and acacia forests neglected in this study.

Australia's rain forests consist of dense vegetation comprising trees shrubs and herbaceous plants. The rain forest of northern Queensland is extremely diverse, and generally contains no dominant species. There are numerous epiphytes the commonest of which are ferns, orchids (monocotyledon) and lichens. By far the greater proportion of trees found in the rain forest are confined to Australia. Of the few that are found beyond, most are located in Papua, Pacific Islands, India and South East Asia [Francis, 1985]. In terms of diversity these forests are an ideal place to investigate leaf physiognomy and its adaptation to climate.

2.3.5 The selection of sites for data collection

One of the main reasons for collecting in the southern hemisphere was to investigate the physiognomy of floras that are biogeographically and evolutionarily remote from the sites in the existing CLAMP data set. Man's activities upset natural ecosystems, and therefore have great potential for polluting the climatic signal obtained from modern floras. In order to avoid this problem, it was the aim of this work to sample native floras that have undergone minimal disturbance. To do this successfully, it was essential to have a full understanding of the numerous ways in which man has affected his environment, and to be able to spot the tell tale clues left behind by his activities.

Anthropological influences on the New Zealand and Australian flora and selection of least disturbed sample areas

Man's influence on the native floras of Australia and New Zealand has taken many forms. Perhaps the most obvious of these is the clear felling of large areas of rain forest for lumber and farming. This is illustrated on Figure 2.10, where the depletion of native forest in New Zealand is shown after the arrival of the Polynesians in AD 700, and the Europeans in AD 1800. If this were the only form of disturbance of the native ecosystem, it would be a trivial task to avoid sampling in such areas. Unfortunately other forms of disturbance are more subtle and consequently less easy to spot.

Logging, i.e. the removal of selected large trees from the forest for lumber, is one of these. Generally in New Zealand it is the great emergent gymnosperm that are targeted for removal, eg the rimu (*Dacrydium cupressinum*), and so the effects on woody dicotyledons are

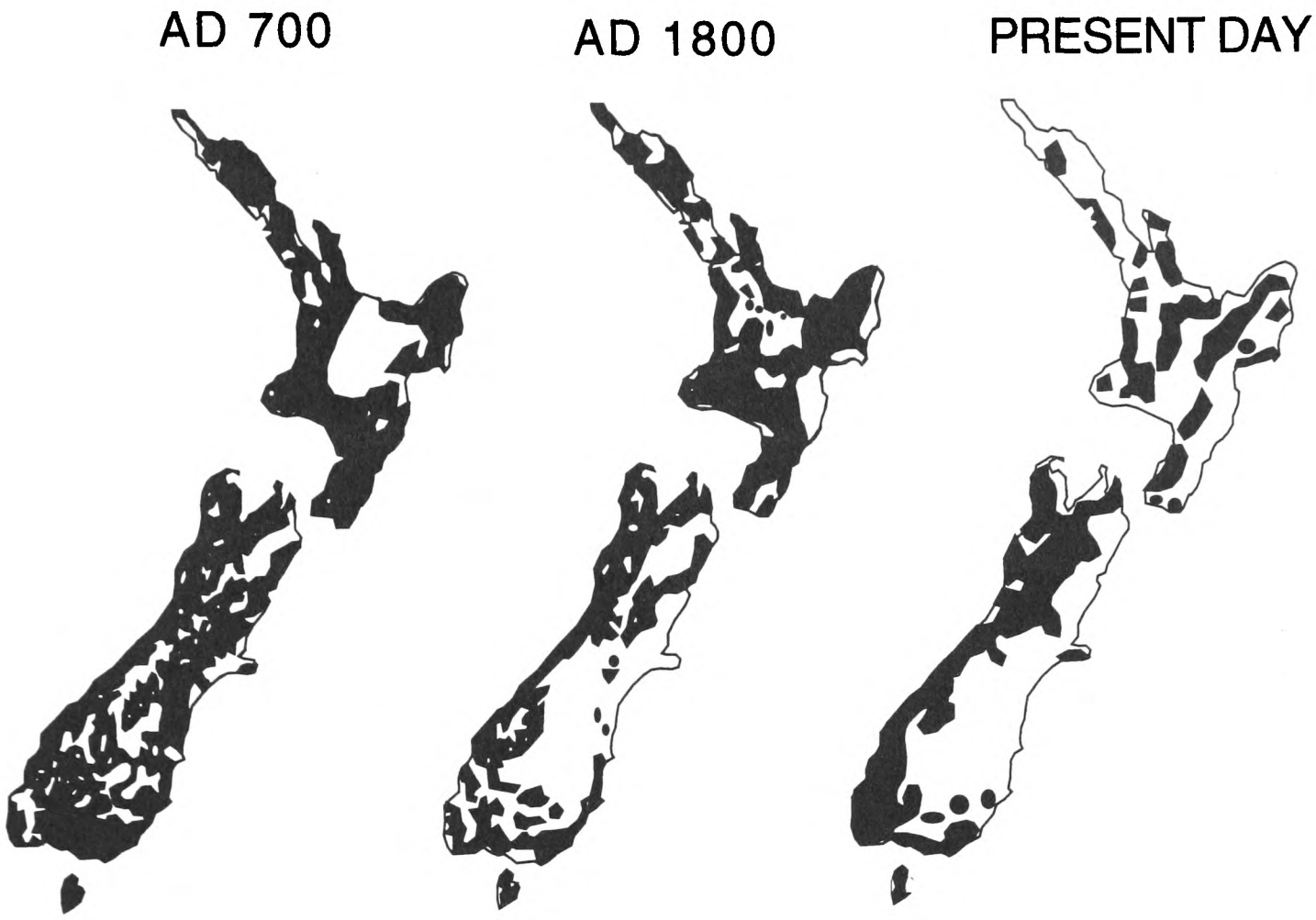


Figure 2.10: Depletion of New Zealand's forests since the arrival of the Polynesians

indirect. The removal of canopy and emergent trees disturbs the ecosystem below, the extent to which depends largely on the severity of the disturbance. Baxter & Norton [1989] show that most floristic changes occurred immediately after logging, and that subsequent changes were largely structural. They conclude that logged areas are likely to return to a condition similar to that prior to logging if left undisturbed. It is uncertain how long after logging ceases this would take; Baxter & Norton [1989] suggest 100-150 years. For this reason I endeavoured to avoid heavily logged areas as much as possible. This was done by selecting areas of forest where large emergent trees protruding above the canopy were still in place.

The effect of the introduction of exotic flora and fauna: Exotic species of flora and fauna, introduced both intentionally and accidentally by man since his arrival on these islands 1300 years ago, have had a huge effect on the floras of New Zealand. Gorse, for example was introduced originally as a hedging plant, but now grows wild across much of New Zealand. It would be quite simple to avoid collecting non native species of plant, but this would still not be entirely satisfactory because introduced species will affect the balance of the ecosystem in which they grow. It is for this reason that as far as is possible sites where the flora is composed entirely of native species were preferable. Areas where introduced species were visible were avoided during the selection of sites, and advice was taken from local botanists (John Ogden, University of Auckland and David Norton, University of Christchurch). This approach was successful to a great extent with only one exotic species being found at any of the selected sites. This was in the Peraki Saddle Reserve on the East Coast of South Island. A total of 28 native species were

also collected here (see Appendix B). The site was not discarded from the data set because the level of disturbance was not considered to be great. The single exotic species however, was not included in the analysis.

The exotic fauna introduced to New Zealand since the arrival of man on the islands, is having a devastating effect on the native flora and fauna. Perhaps the most destructive introduction was the Australian opossum. Not only does it spread TB amongst cattle, and prey on the eggs and young of many endangered native species such as the kiwi, it browses trees in an intensive way that kills many native species, not adapted to this form of feeding. This is the single most difficult form of disturbance within New Zealand's forests to avoid. It is estimated that 20 million opossum are born in New Zealand every year, and they are prevalent across all of the main islands. The Department of Conservation has cleared some smaller islands of exotic mammalian species to create a safe haven for some of the endangered native species of bird, and are currently trapping in some areas of mainland forest where endangered species survive. Samples were collected in the forest of Ulva Island, just off Stewart Island, which has been cleared of introduced mammals, and Okarito on the west coast where trapping is ongoing. Apart from this it was not possible to avoid areas which are at least partially disturbed by introduced fauna.

The resemblance of some dicotyledon species to monocotyledon

Whilst initially all woody dicotyledon found were collected, some were later excluded from the analysis because of the strong resemblance of the foliar physiognomy to that of monocotyledon. All species from the genus *Dracophyllum*, a member of the Epacridaceae family, have leaves with reed like blades and parallel venation (see figure 2.11) and so were not included in the data set. This was done because on the basis of the leaves alone (the state in which they are likely to occur in the fossil record) they would certainly be identified as monocotyledon and therefore not included in any analysis of woody dicotyledon foliar physiognomy.

Meteorological data

The main constraints on site selection are outlined above. In addition native flora samples were always collected as close to meteorological stations as possible in order to have good climate data to tie in with the physiognomic measurements. The number of stations from which precipitation data were available (2259 [NZMS, 1983a]) far exceeds the number from which temperature normals may be obtained (323 [NZMS, 1983b]). Regression equations developed by [Norton, 1985] were used to estimate temperature normals when data was unavailable. These equations use latitude, altitude and distance from coast to form estimates. Norton shows that the standard error of the estimates $\sim 0.5°C$. The pattern with which rain fall varies locally is extremely complicated [Salinger, 1980]. For this reason I did not extrapolate between meteorological stations to calculate rainfall for collection sites, preferring instead simply to use the data from the nearest meteorological station. Because of the large number of stations that collect precipitational data in New Zealand this station was rarely more than a few miles from the collection site. The

Figure 2.11: *Dracophyllum traversii*

climate data used in conjunction with the physiognomic data, along with its source, is shown in Table 2.1.

Collection of different forest types at same locality

At several localities more than one sample of vegetation was collected. The purpose of this exercise was to ascertain the amount of 'noise' that we should expect in a climatic signal due to non–climatic environmental factors. There were four different localities where this was done: three on the South Island of New Zealand and one in Queensland, Australia (see Figure 2.12). The diversity at the Australian site (Flaggy Creek) was so great that it was possible to collect both an entirely riparian sample and an entirely non–riparian sample. Some plants collected in the riparian sample were not exclusively riparian in their habit and so were duplicated in the non–riparian sample. Because of the high rainfall at this locality, which means water stress is not great even at non streamside sites, it is expected that the two climate signals will be very similar. The collection of these two samples allows us to test this hypothesis.

In Kaikoura on the east coast of South Island, New Zealand, three separate samples were collected within 22 kilometres of one another and at similar altitude (the difference between the highest and lowest is 170m). The precipitational and temperature regimes at these sites are very similar (see Table 2.1) but the vegetation is not identical. The first of these samples (Blue Duck Reserve) grows on limestone, the second (Puhi-puhi), grows on a river terrace and the third (Mount Fyffe) grows on greywacke. Whilst the edaphic controls on the vegetation represented in a fossil leaf deposit are not quantified, it is hoped that this experiment will allow us to begin

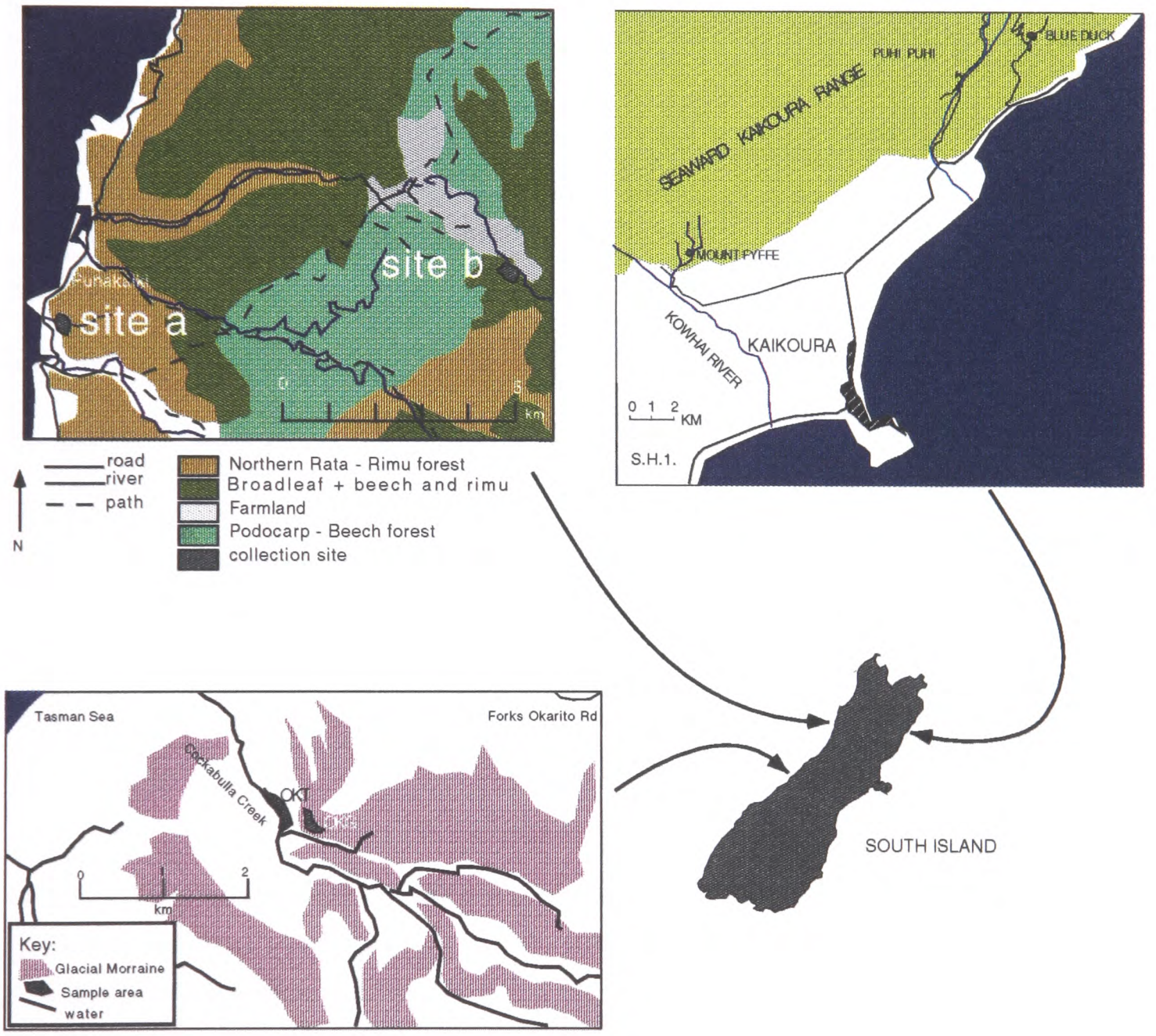


Figure 2.12: Localities where more than one CLAMP sample was collected from adjacent areas

	LOCATION			TEMPERATURE		PRECIPITATION		
	alt(m)	lat	long	MAT	source	MAP	MGSP	source
Alex Knob1	1160-1285	43°25′	17°08′	5.7	Norton	495	84	F30311
Alex Knob2	1020-1070	43°25′	17°08′	6.6	Norton	495	84	F30311
Alex Knob3	810-860	43°25′	17°08′	7.7	Norton	495	176	F30311
Alex Knob4	600-650	43°24′	17°08′	8.7	Norton	495	225	F30311
Alex Knob5	300-350	43°24′	17°08′	10.3	Norton	495	312	F30311
Okarito1	10	43°16	170°09′	11.6	Norton	116	266	F30233
Okarito2	100	43°16	170°09′	11.4	Norton	116	266	F30233
Otira Gorge1	940-950	45°54′	171°34′	5.9	Norton	465	59	H21952
Otira Gorge2	840	45°54′	171°34′	6.5	Norton	465	93	H21952
Otira Gorge3	700	45°53′	171°34′	7.2	Norton	465	124	H21952
Otira Gorge4	550	42°50′	171°34′	9.3	Norton	491	198	F21851
Otira Gorge5	400	42°46′	171°34′	10.1	Norton	491	239	F21851
Otira Gorge6	120-160	42°35′	171°34′	11.5	Norton	457	122	F21641
Link Track1	1165-1120	3831	175°36′	8.2	Norton	184	50	C85551
Link Track2	1050-1065	38°31′	175°36′	8.6	Norton	184	50	C85551
Link Track3	950-1050	38°32′	175°36′	8.8	Norton	184	65	C85551
Link Track4	800-850	38°32′	175°36′	9.8	Norton	184	83	C85551
Lady Lake	120	42°35′	171°34′	11.7	Norton	457	122	F21641
Tongariro1	1390-1410	39°19′	175°31′	6.6	Norton	291	80	C95251
Tongariro2	1160-1180	39°21′	175°30′	7.8	Norton	291	80	C95251
Tongariro3	980	39°22′	175°29	8.6	Norton	166	62	E95341
Tongariro4	680-700	39°24′	175°26′	10.1	Norton	166	73	E95341
PunakaikiA	30	42°08′	171°79′	12.3	Norton	249	190	F21131
PunakaikiB	100	42°07′	171°26′	11.9	Norton	249	143	F21131
Lake Mary	8	44°03′	168°44′	11.5	Norton	249	281	F38961
Ulva Island	0-60	46°56′	168°09′	9.5	I68913	134	81	I68912
Kaikoura1 BDR	260	42°14′	173°47′	12.0	Norton	91	50	G23182
Kaikoura2 PP	160	42°16′	173°44′	12.0	Norton	159	94	G23271
Kaikoura3 MF	270	42°21′	173°33′	11.0	Norton	159	64	G23341
Chateau	1040	39°12′	175°31′	7.4	C95251		80	C95251
Tronson Kauri Park	200	35°43′	173°39′	14.4	A53651	160	160	A53771
Banks Peninsula	300-400	43°49′	172°52′	12.0	H32791	98	42	H32791
Flaggy Creek	340	16°45′	145°35	25.0	Cairns	184	200	Cairns

Table 2.1: environmental data for southern hemisphere CLAMP samples. This data was obtained either using either the nearest Meteorological station (see code) or the regressions equations of Norton, 1985

to quantify the amount of noise, and the potential error that such factors might introduce. A similar exercise was carried out on the west coast of South Island in Okarito where samples were collected from a glacial moraine and from an adjacent (within $\frac{1}{4}$ km) river terrace. In Punakaiki samples from two different forest types were collected from within 10 km of one another at similar altitudes and climatic regimes. Their physiognomic and climate signals will be compared.

Collection of altitudinal transects

The potential uses for a palaeobotanical methodology to extract palaeoaltitudinal information from the fossil record leads me to investigate the change in physiognomy with altitude locally. New Zealand's rugged topography is well suited to examining the local change in physiognomy with increasing altitude, without the signal becoming polluted by large changes in latitude and/or continentality. In addition it is of great interest to include high altitude floras in this new data set because of the relatively recent evolution of that habitat (since the mid–Pliocene [Mildenhall,

1978]). Four altudinal transects were conducted: two on North Island and two on South Island. In each case the samples were collected along one incline. In the case of the Otira Gorge, this was along the base of a valley that winds through the Southern Alps (see Figure 2.13). Of the four transects conducted, the sites on this transect have the most horizontal separation, with ~25 kilometres between the lowest and highest samples. The other sites were collected from hill sides: Alex Knob in the western foothills of the Southern Alps (see Figure 2.14), and Tongariro Park and Link Track from volcanos in North Island (see Figures 2.15 2.16). In each case the highest and lowest samples are separated by less than 10 kilometres horizontally.

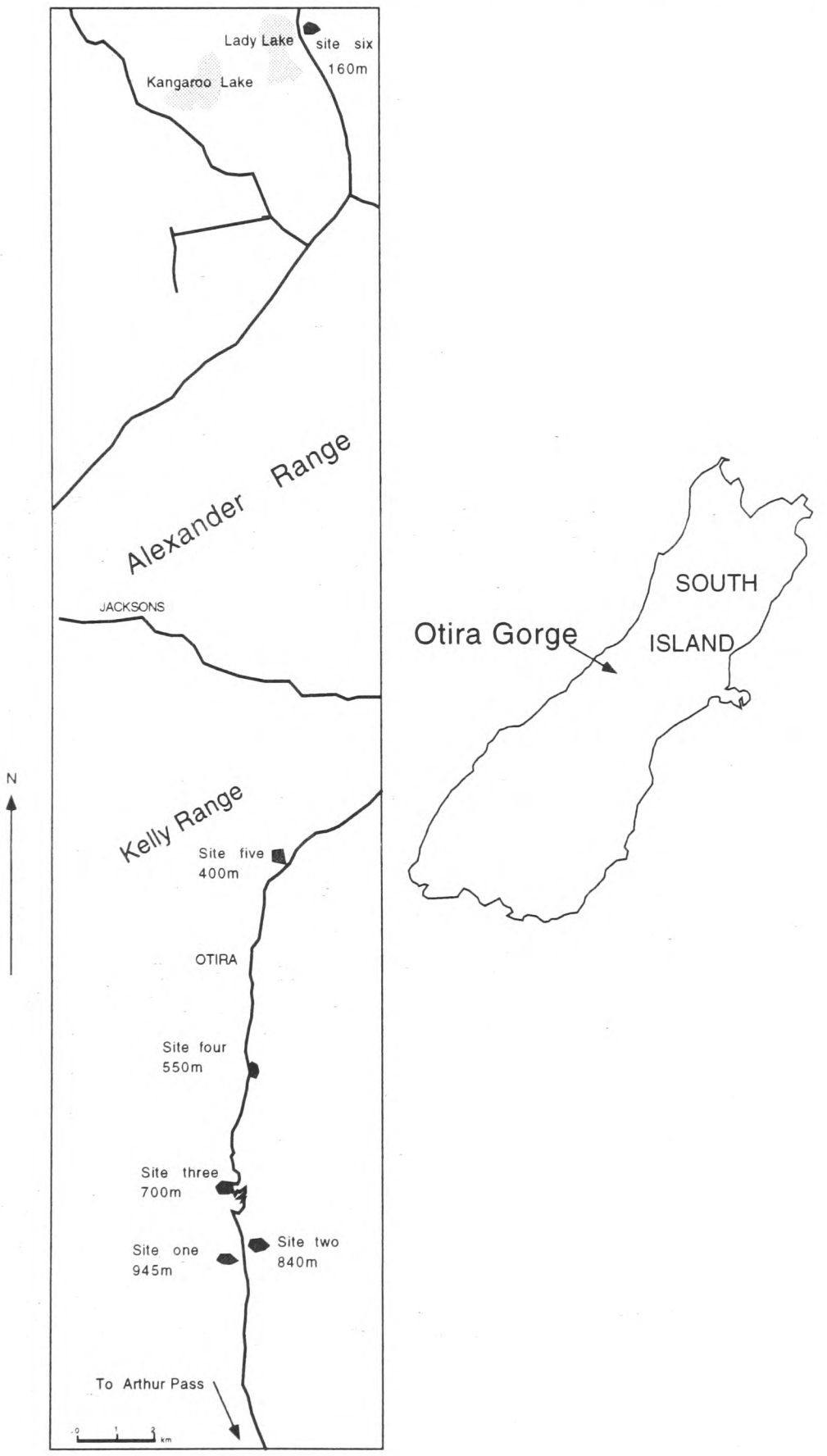


Figure 2.13: Location of samples taken in the Otira Gorge altitudinal transect

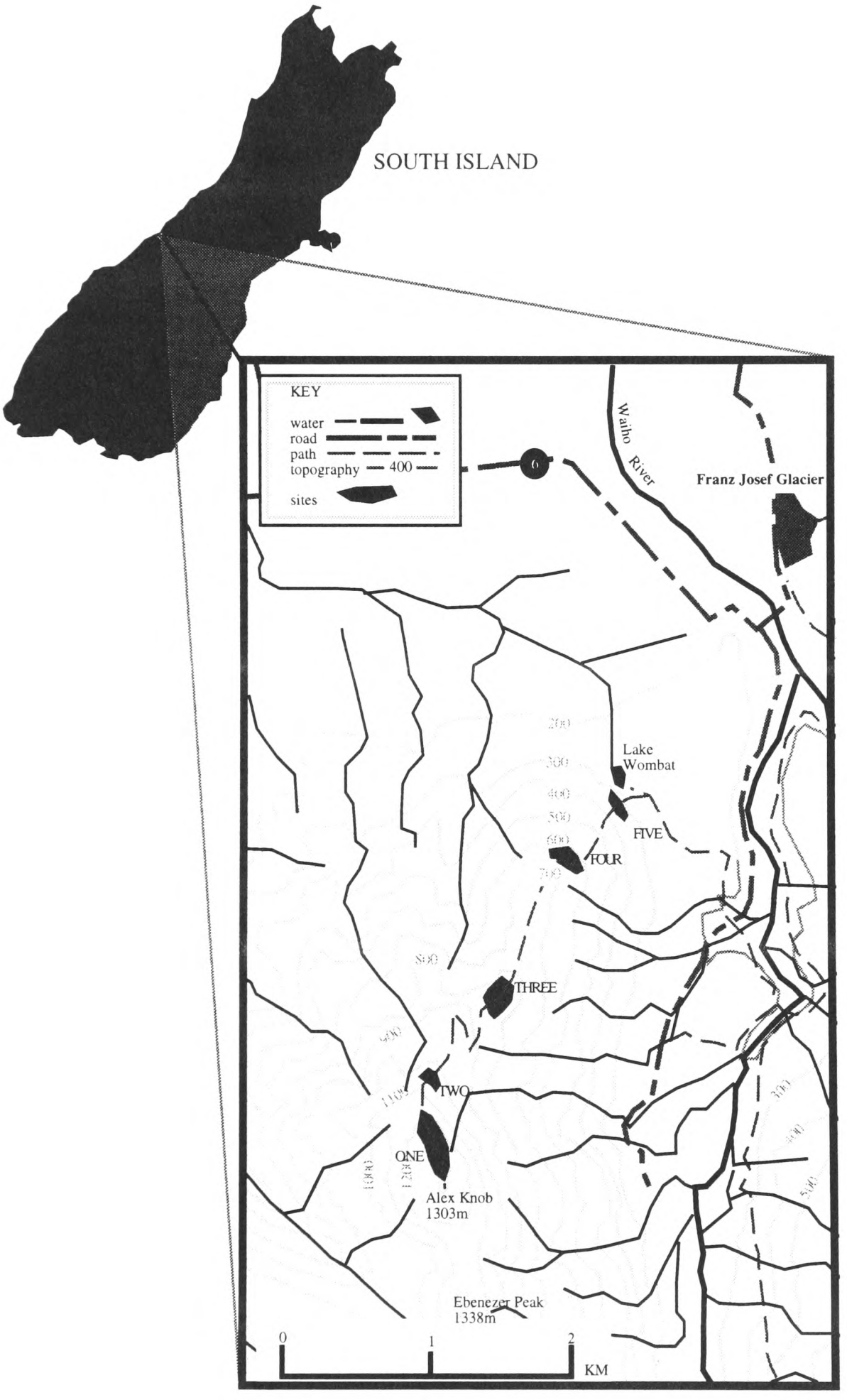


Figure 2.14: Location of samples taken in the Alex Knob altitudinal transect

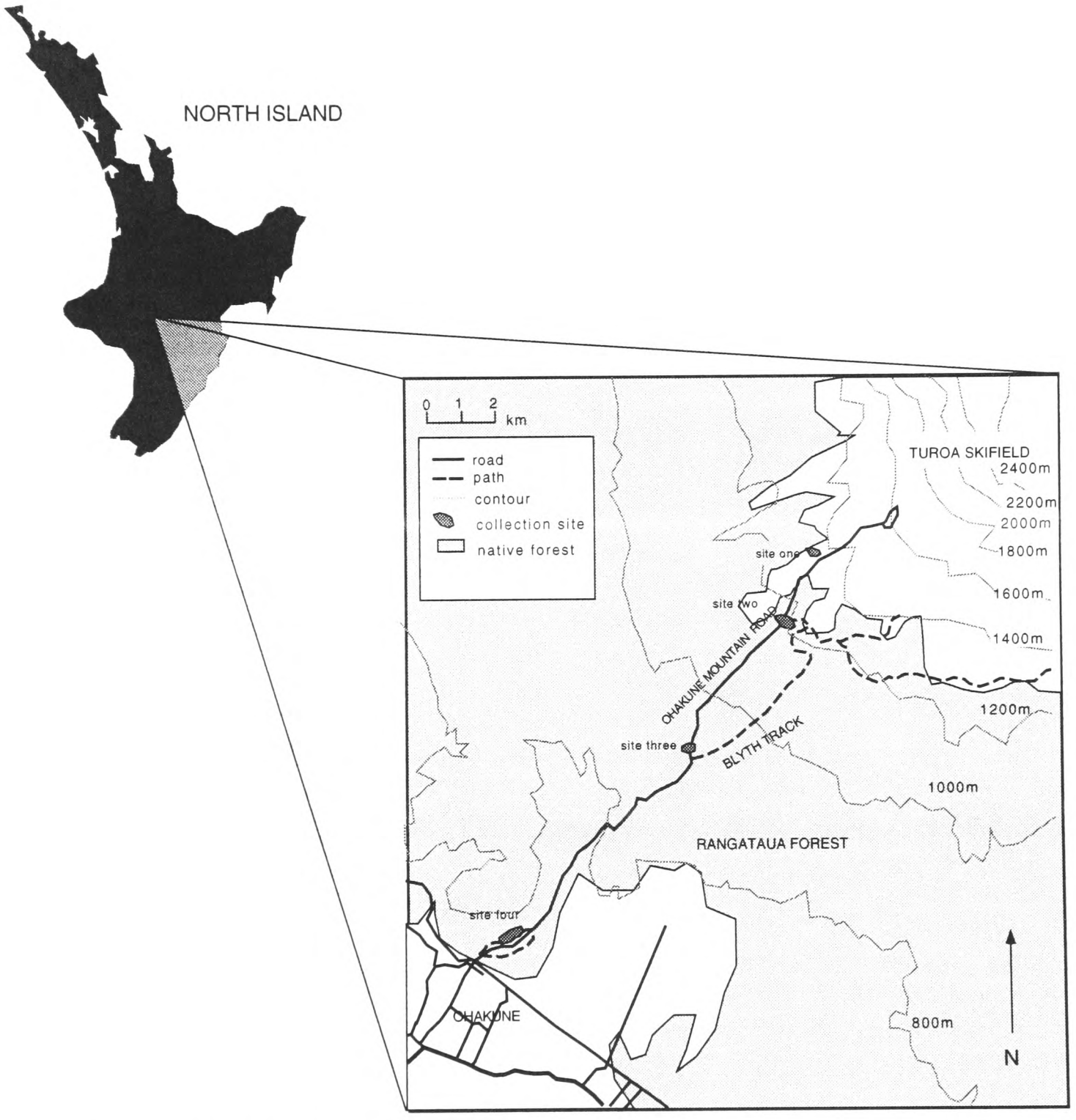


Figure 2.15: Location of samples taken in the Tongariro Park altitudinal transect

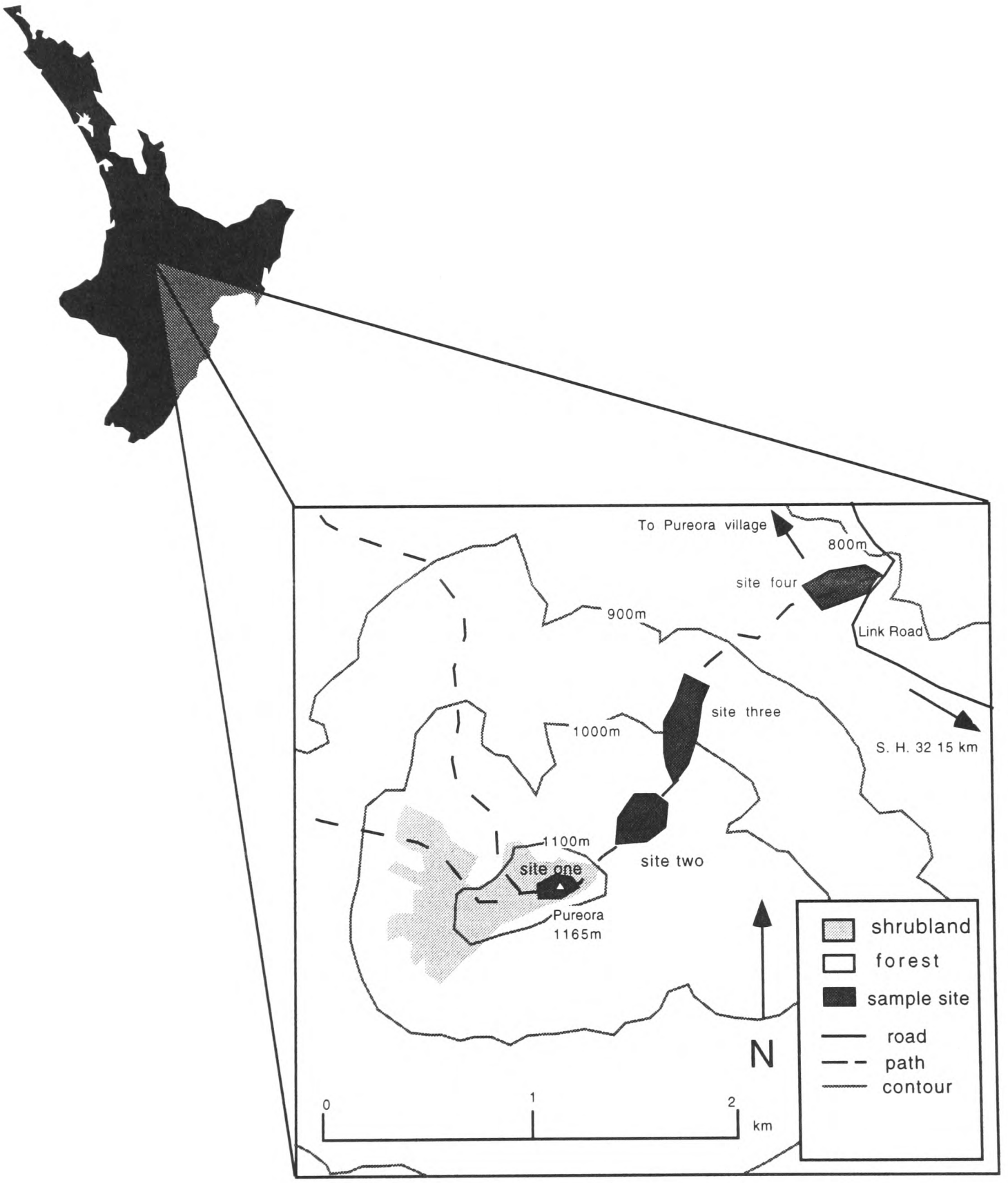


Figure 2.16:
Location of samples taken in the Link Track altitudinal transect

2.3.6 Sampling Strategy

The sampling strategy of Wolfe [1993] page 5, was followed as closely as possible. Samples were collected from a limited geographic area that might be comparable to an area that furnished an assemblage of fossil leaves i.e. less than 5 hectares. The full range of physiognomy for each species was collected using a combination of leaf litter and samples collected using a catapult and climbing. Wolfe [1993] recommends that at least 20 taxa should be collected from each site. As many species as could be found in the area were collected, but, as discussed above in Section 2.3.3 the New Zealand vegetation is floristically poor and so some collections made had fewer species. In the altitudinal transects, it was not always possible to sample riparian vegetation at each site especially at the higher altitude sites. It is noted however that in New Zealand where it is available, the taxonomic content of riparian vegetation does not differ greatly from that of the non–riparian vegetation, the main differences being in terms of the abundance which is not measured in the CLAMP methodology. *Fuchsia excorticata* for example is commonly found along stream banks. Whilst it is less common in the non riparian vegetation it is not absent, often being located where some disturbance has occurred, for example where a canopy tree has been lost. Because the CLAMP data set does not incorporate species abundances, it is considered acceptable to incorporate these altitudinal samples into the CLAMP data set. The sites where samples were collected are listed in Table 2.2.

Whilst Wolfe's [Wolfe, 1993] analysis of physiognomy is designed to be independent of taxonomy, wherever possible samples were identified to a specific level. This was not always possible, especially in the more diverse genera, such as *Coprosma* and *Hebe*, because flowers and fruit, which would allow specific names to be assigned were not generally available at the time of year that the collections were made. Aspects of plant morphology, available in a herbarium sample of foliage, such as venation on the laminae, arrangement of leaves on the stem, length of the petiole and the presence or absence of stipules, allowed the distinction of taxa, if not their identification to a specific level. It was possible therefore to ensure that the physiognomic samples were successfully divided into separate taxa.

It is noted that some species included in these collections have noticeably different leaf forms growing in the same area and sometimes even on the same plant. In some species such as *Penantia corymbosa* and *Pseudopanax crassifolius* (see Appendix A plate 8–f and plate 11–o) the juvenile plant has leaves that are so different from the adult leaves, that if preserved in the fossil record where leaves are usually preserved in isolation from other plant parts, they would not be grouped as the same species. Another species *Parsonsia heterophyllus* has leaves with very different physiognomy growing on the same plant (see Appendix A plate 8–c) . These leaves, if studied in isolation could be grouped into several different morphotypes. In this study, whilst acknowledging that if found in the fossil record they would be split, I have chosen to treat these very different morphotypes as one species and scored them accordingly. The reason for this choice, is that whilst some species obviously have two distinct morphotypes, others have more of a continuum between end members, such that to divide into morphotypes would be subjective,

both in terms of how many divisions are made, and where. In the New Zealand samples collected here, the proportion of such species within a flora is generally very low. The difference between splitting and not splitting these species therefore is minimal in terms of the CLAMP scores. The localities of the floras collected in this study are summarised in Table 2.2.

SAMPLE SITE	long	lat	alt(m)	notes
QUEENSLAND, AUSTRALIA				
Flaggy Creek, Kuranda State Forest a)	145°35′E	16°45′S	340	non–riparian vegetation.
Flaggy Creek, Kuranda State Forest b)	145°35′E	16°45′S	340	riparian vegetation.
NORTH ISLAND, NEW ZEALAND				
Tronson Kauri Park	173°39′E	35°43′S	230	
Pureora State Forest Park	175°36′E	38°31′S	800–1120	altitudinal transect, 4 sites
Ohakune Mountain Road	175°29E	39°21′S	680–1410	altitudinal transect, 4 sites
Whakapapa	175°31′E	39°12′S	1040	
SOUTH ISLAND, NEW ZEALAND				
Punakaiki A	171°26′E	42°07′S	18	Broadleaf, beech and rimu forest
Punakaiki B	171°79′E	42°7.5′S	60	Northern Rata Rimu Forest
Blue Duck Reserve	173°35′E	42°21′S	280-350	limestone bedrock
Puhi Puhi Reserve	173°44′E	42°16.5′S	180	river terrace
Mount Fyffe	173°47′E	42°21′S	220-300	greywacke bedrock
Otira Gorge	175°34′	42°35–54′	120–950	altitudinal transect, 6 sites
Lady Lake	42°35′E	171°34′S	120	next to taphonomic samples
Okarito a)	170°09′E	43°17′S	120	River terrace
Okarito b)	170°09′E	43°17′S	50	Glacial moraine
Alex Knob	170°08′E	43°25′S	300–1285	altitudinal transect, 5 sites
Banks Peninsula	172°52′E	43°49′S	280-380	
Lake Mary	168°38′E	43°59′S	8	
ULVA ISLAND, NEW ZEALAND				
Ulva Island	46°55′E	168°08′S	2-72	

Table 2.2: Location of sample sites for the collection of new CLAMP data

2.4 Sites

2.4.1 The position of southern hemisphere sites relative to northern hemisphere sites after ordination

When all sites, both the newly collected southern hemisphere site and the northern hemisphere sites collected by Wolfe [1993], are transformed together using correspondence analysis (CA), the southern hemisphere sites plot together in a cluster. In axis one–axis two space, this cluster plots within the space defined by the northern hemisphere sites. They plot in a half of physiognomic space associated with the warm and dry sites of the northern hemisphere (see Figure 2.17). Their position in this plane, which forms the basis for Wolfe's climate estimation, is incongruous with their climate when compared with the position of the northern hemisphere sites. On the third axis defined using CA the southern hemisphere sites lie apart from the northern hemisphere sites in a part of physiognomic space not occupied by northern hemisphere samples (see Figure 2.18). This is similar to the outliers defined by Wolfe [1993] which may also be differentiated from other sites on the basis of their axis three scores. Indeed when Wolfe's methodology is used to form

MAT estimates for the entire combined data set, the results are poor (see Figure 2.19a) with root–mean–square errors of 4.8°C. If the southern hemisphere sites are treated separately and the same procedure followed, the results are greatly improved (see Figure 2.19b) with a RMS error of 2.1°C, comparable to that for Wolfe's reduced data set.

2.4.2 A comparison between the raw data from the southern and northern hemispheres

It is clear that the New Zealand and Australian samples plot in a different part of physiognomic space from the northern hemisphere samples collected by Wolfe [1993]. It is clear also that they would be regarded as outliers in the context of Wolfe's reduced data set, because of their position in axis one–axis two space (see Figures 2.17) relative to the climate in which they grew and because of their separation from the northern hemisphere sites on the third axis (see Figure 2.18). As seen above, this results in very large errors in the MAT estimates obtained using Wolfe's methodology if the data are not split. The physiognomic response of the woody dicotyledon clade is not as simple as is implied by Wolfe's 2–D model. Whilst his model for climate change across physiognomic space is adequate to describe his reduced data set, it cannot accommodate either the outliers he removes from his original data or the new data presented here. The sites that do not conform to the model do not lie in the same regions of physiognomic space as the reduced data set. Three CA axes must be inspected to discern this difference in position.

To understand more about the differences between the two data sets it is useful to return to the raw 29 dimensional matrices. An important aspect of the data is its internal structure. By this I mean the relationship between the physiognomic variables. We might ask the question whether two physiognomic variables are similarly correlated (or uncorrelated) in the two data sets. As discussed above in section 2.2, the 29 physiognomic variables all covary with one another to a greater or lesser extent. This can be quantified using the product moment correlation coefficient (PMCC)

$$C_{i,j} = \frac{\frac{1}{N}\sum_{r=1}^{N}(x_{ri} - \bar{x_i})(x_{rj} - \bar{x_j})}{\sigma x_i \sigma x_j} \tag{2.5}$$

where $C_{i,j}$ is the product moment correlation coefficient between variables i and j, N is the number of sites, x_{ri} is the value of x for variable r at site i, $\bar{x_i}$ is the mean value of x for the variable i, and σx_i is the variance of x for variable i.

Physiognomic variables with a PMCC of $+1$ or -1 are totally correlated, whilst those with a PMCC of 0 vary independently of one another. A PMCC can be calculated between each of the 29 variables giving a symetrical matrix that describes the internal structure of the data set. The difference between the two PMCC matrices is therefore a measure of the difference between the structure of the raw data itself. Figure 2.20 is a graphical representation of the difference between these two matrices. Correlation coefficients have not been calculated between variables within physiognomic categories because results are spurious when calculated

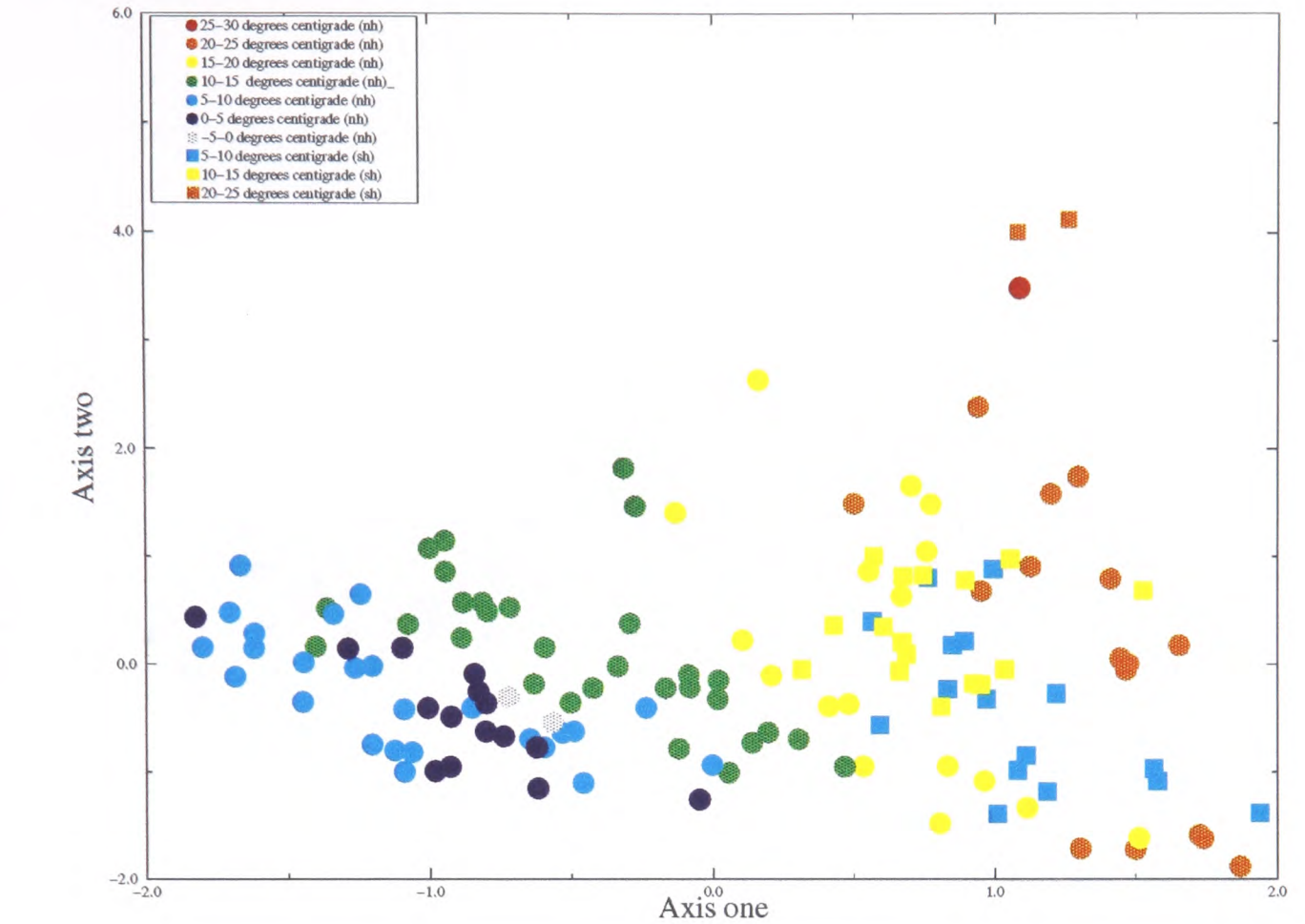


Figure 2.17: Position of all sites in axis one–axis two space after correspondence analysis, showing Mean Annual Temperature (upper graph) and Mean Annual Precipitation (lower graph). Squares represent southern hemisphere (sh) sites and circles, northern hemisphere (nh) sites.

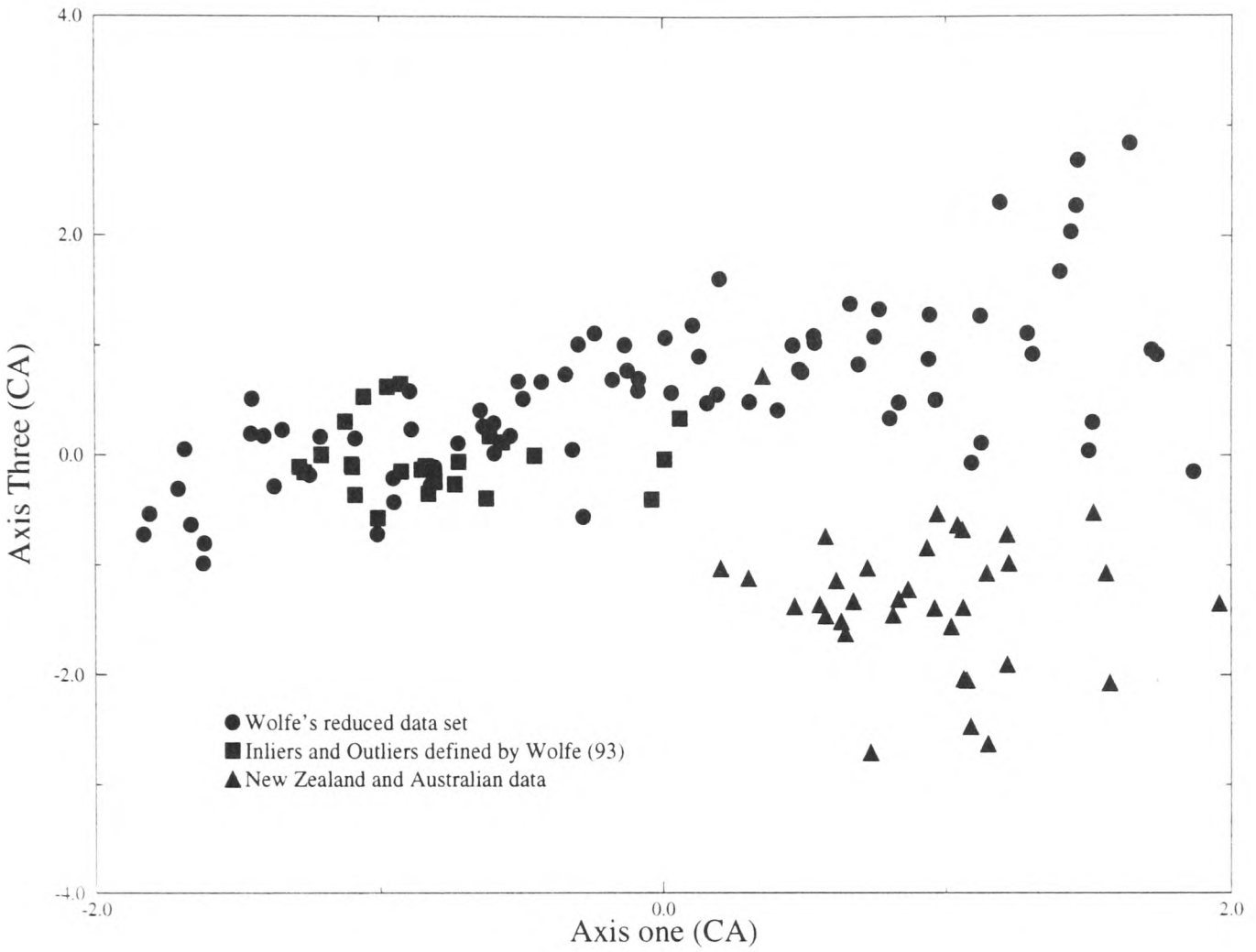


Figure 2.18: Position of New Zealand and Australian sites in correspondence analysis axis one–axis three space relative to Wolfe's (Wolfe, 1993) full northern hemisphere dataset

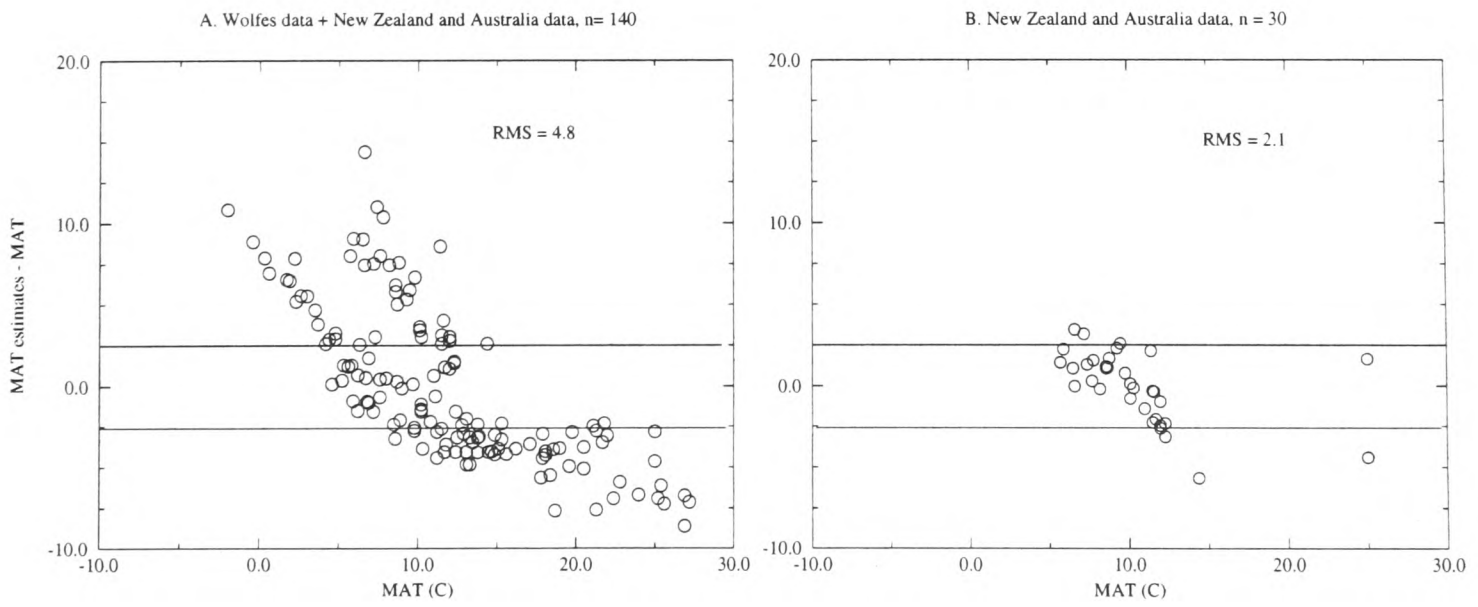


Figure 2.19: Estimate of MAT, using Wolfe's methodology for a. the combined northern hemisphere and southern hemisphere data set and b. the southern hemisphere dataset alone.

for compositional variables (for further explanation see Section 3.2.2). The results allow us to see that marginal character states and those representing the aspect ratio of the leaf, consistently differ in their PMCC values between the northern hemisphere and southern hemisphere data sets. This is significant given the strong correlation between marginal characteristics and Mean Annual Temperature. Physiognomic space itself is significantly distorted as one moves through sample space between the two data sets. This result suggests that the relationship between climate and physiognomy will not be the same throughout physiognomic space. All analyses of the CLAMP data set conducted thus far [Wolfe, 1993; Gregory & Chase, 1992; Forest *et al.*, 1995] have sought a global relation between the physiognomy of leaves and the environmental conditions in which they grow. The additional data presented here suggests that such a relation is not robust over a wide range of a) climate conditions experienced by plants both now and in the past, or b) physiognomic responses to climate conditions.

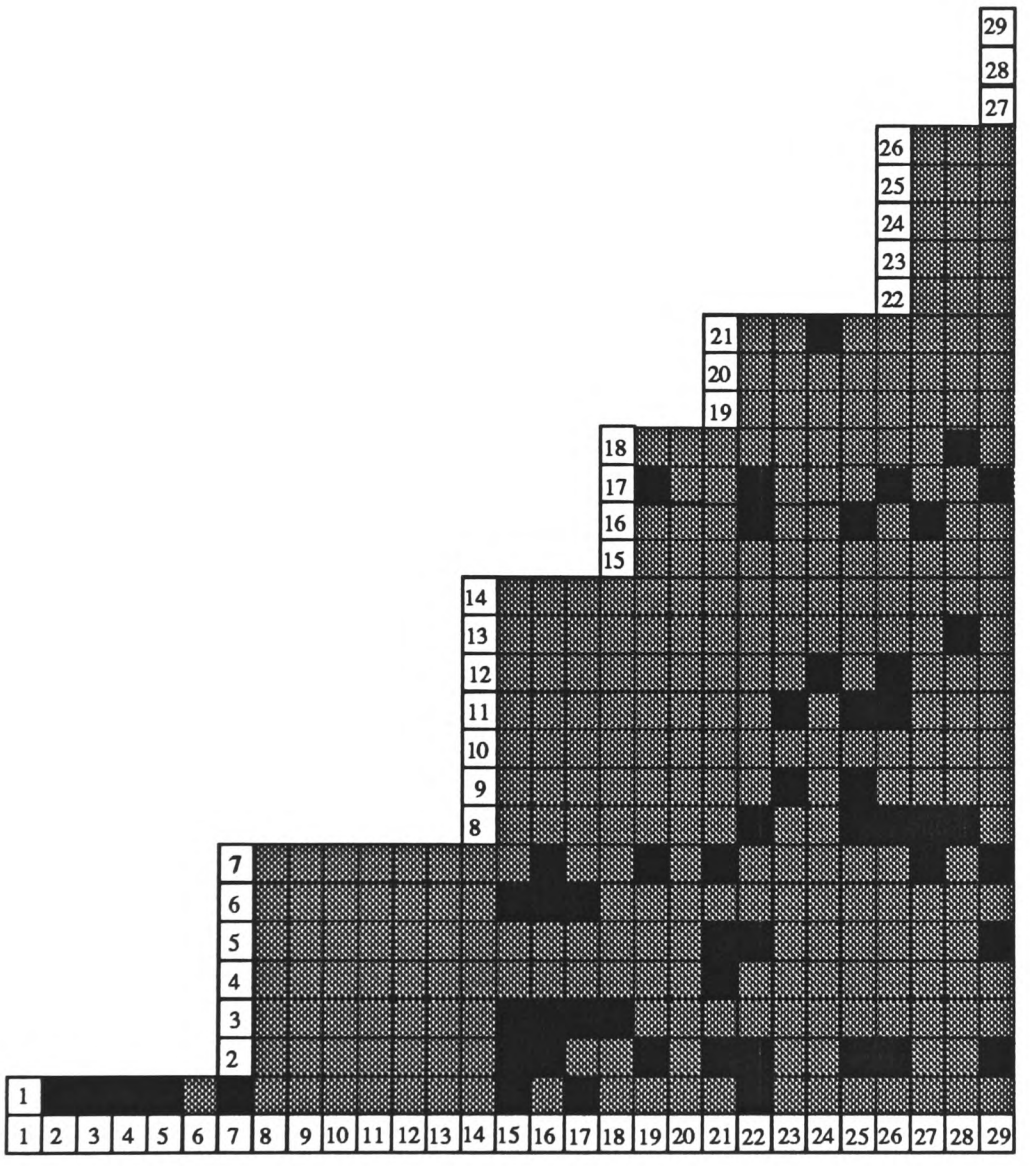


Figure 2.20: Illustration of difference between product moment correlation coefficients of southern hemisphere and northern hemisphere data set. When the PMCC values for the two datasets are different by greater than 0.4 the square on the diagram corresponding to those two variables is coloured black. A stippled shading indicates PMCC's that lie within the range $\pm$ 0.4 of each other. 1-7 = margin character states, 8-14 = size character states, 15-18, = apex character states, 19-21 = base character states, 22-26 = length:width character states and 27-29 = shape character states

This result does not negate the use of palaeobotany as a climatic tool, but forces us to investigate the data in a different way. Samples that do not fit in with Wolfes reduced data set, i.e. the subalpine and dry microthermal outliers identified in Wolfe [1993] and the southern hemisphere samples presented here, plot in regions of physiognomic space distinct from that

occupied by the reduced data set. This suggests that any predictive methodology to estimate climate from physiognomy must involve looking at where in physiognomic space the fossil site plots in relation to the modern data set, and the use of regional relations between climate and physiognomy as predictive tools.

2.4.3 Physiognomic variation at one location

The physiognomic variation described by the first four CA axes at the four localities where multiple samples were taken: Punakaiki, Okarito, Kaikoura and Flaggy Creek, is displayed in Figures 2.21 and 2.22. At Kaikoura, where three samples were taken, the axis one and four scores show the most variation, ~0.6 and 0.8 respectively on a scale where the combined data set varies between -2 and 2 on axis 1 and between -2 to 4 on axis 2. Axes two and three scores differ by less than 0.3. The two Flaggy Creek samples taken from riparian and non–riparian vegetation are located at the periphery of data space. They plot very close to one another, with individual axes scores not differing by more than 0.3. In contrast the Okarito site scores on the first four axes differ by as much as 0.6 (on axis 2) with the exception of axis three score which are almost identical. At Punakaiki where two forest types are compared, the axes two and three scores differ between the two samples whilst the axis one and four scores are almost identical.

The significance of these results can only be discussed in the light of a methodology for climate estimate. The flaws in the methodology developed by Wolfe have been outlined above. It is consequently inappropriate to use Wolfes methodology for climate estimation based on the position of southern hemisphere samples in physiognomic space. For this reason, a discussion of the local variation in physiognomy and any deductions that can be made about noise in the climatic signal is postponed until the development of a more suitable approach for climate estimation has been discussed. In Chapter 3 a new methodology is developed; these results will be re-examined at the end of that chapter.

2.4.4 Physiognomic changes with altitude

Vegetation clearly changes with altitude in terms of stature and structure of the forest. The canopy becomes lower and the complexity of the tiering within the forest is reduced as altitude increases. At a certain altitude trees cease to exist altogether. Above this point the subalpine vegetation consists of low shrubbery and herbaceous plants. At still higher altitudes the shrubland and herbfield disappears with only lichens surviving on bare rock faces. In the woody dicotyledon aspect of the New Zealand flora, there are distinct changes in taxonomy with altitude, with the genera *Hebe, Gaulthieria* and *Olearia* beginning to dominate at higher altitudes. Because of the changing environment with increasing altitude, most notably changes in temperature variables, one would also expect a foliar physiognomic response to increasing altitude. Changes were apparent in the altitudinal transects conducted in this study, and these are described below and summarised in Figures 2.23 2.24, 2.25 and 2.26.

In terms of the individual physiognomic character states responses to altitude the

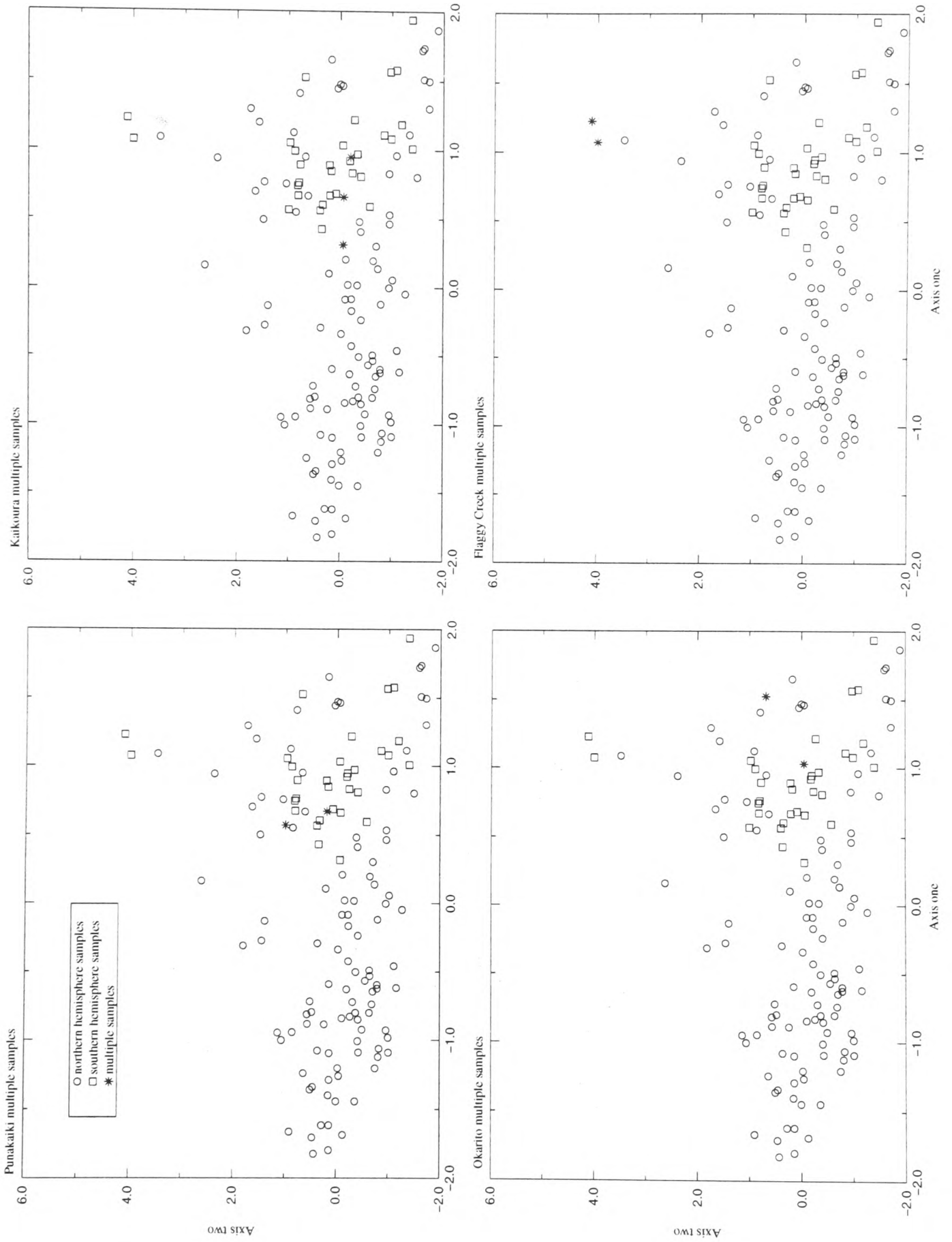


Figure 2.21: Position of samples from localities where multiple samples were taken in axis one–axis two space after correspondence analysis

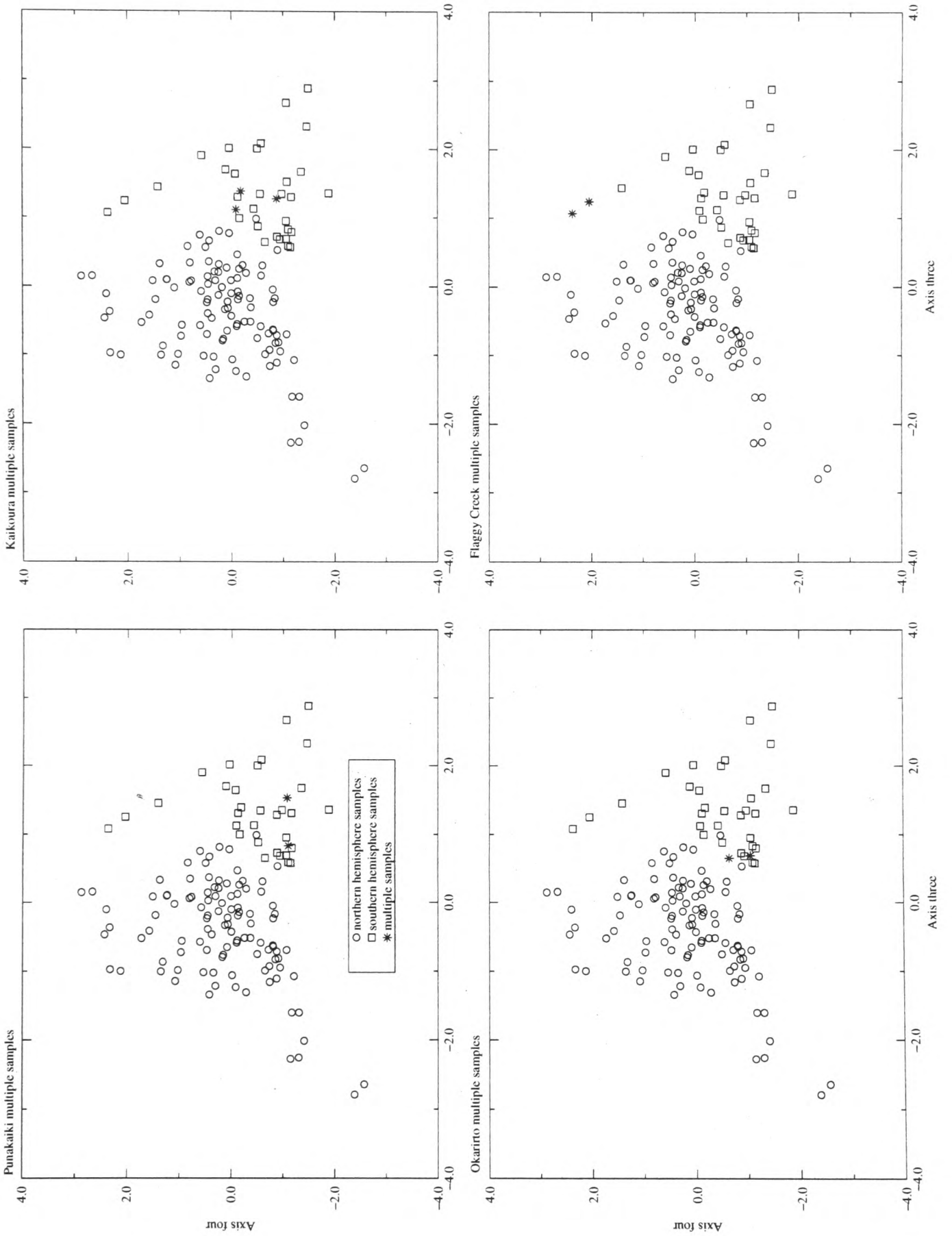


Figure 2.22: Position of samples from localities where multiple samples were taken in axis three–axis four space after correspondence analysis

Tongariro

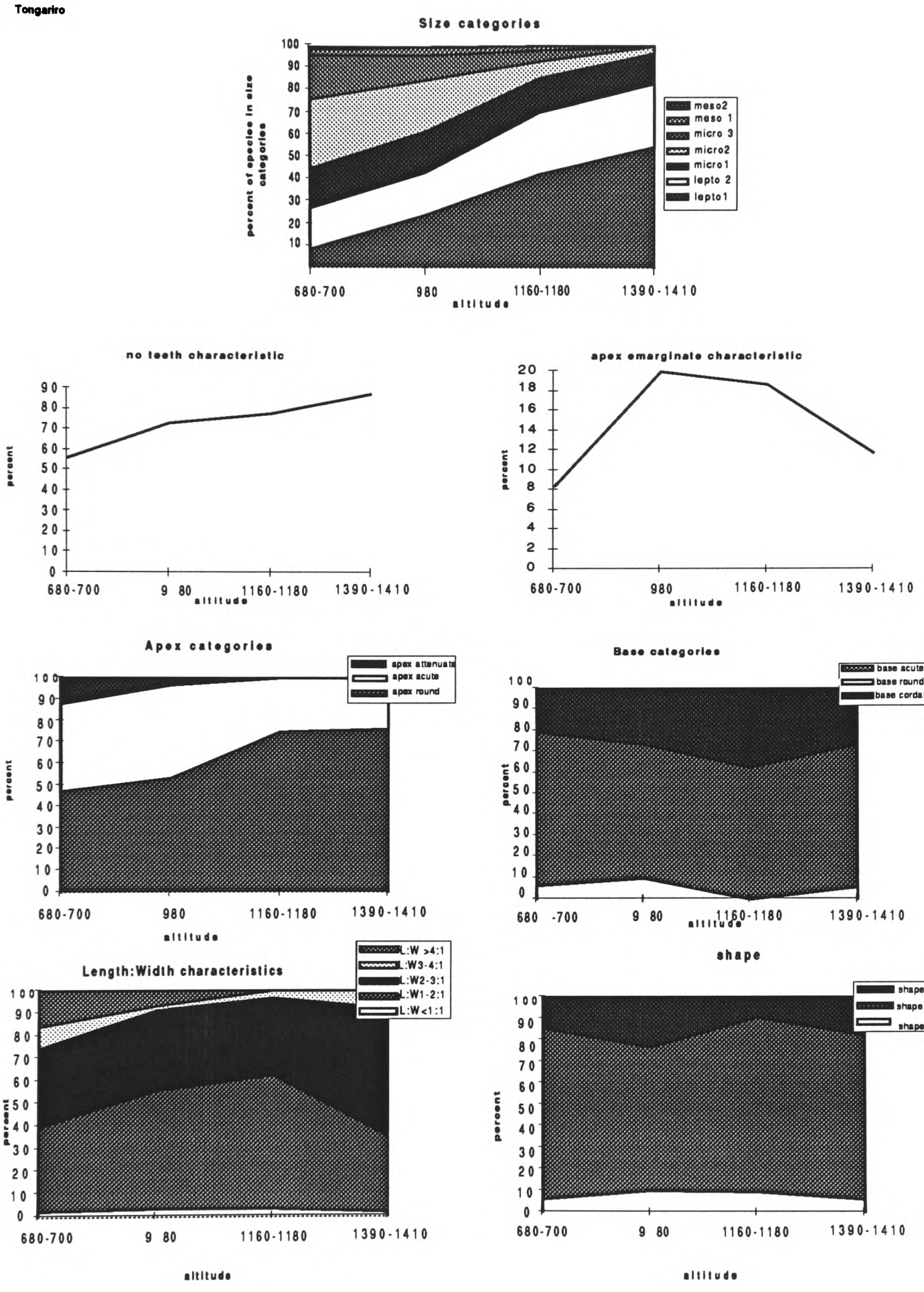


Figure 2.23: Response of physiognomic categories to increase in altitude in the Tongariro altitudinal transect

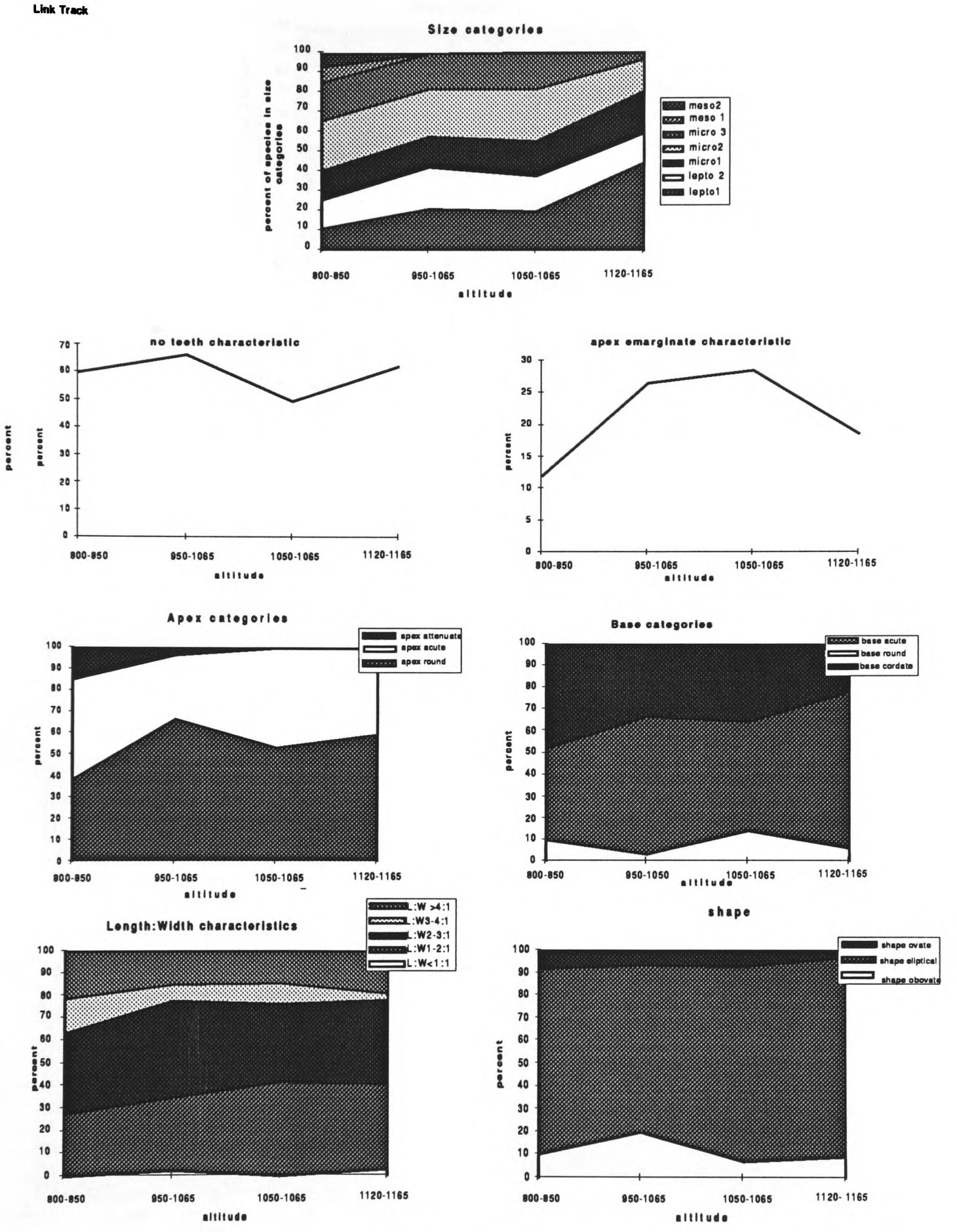
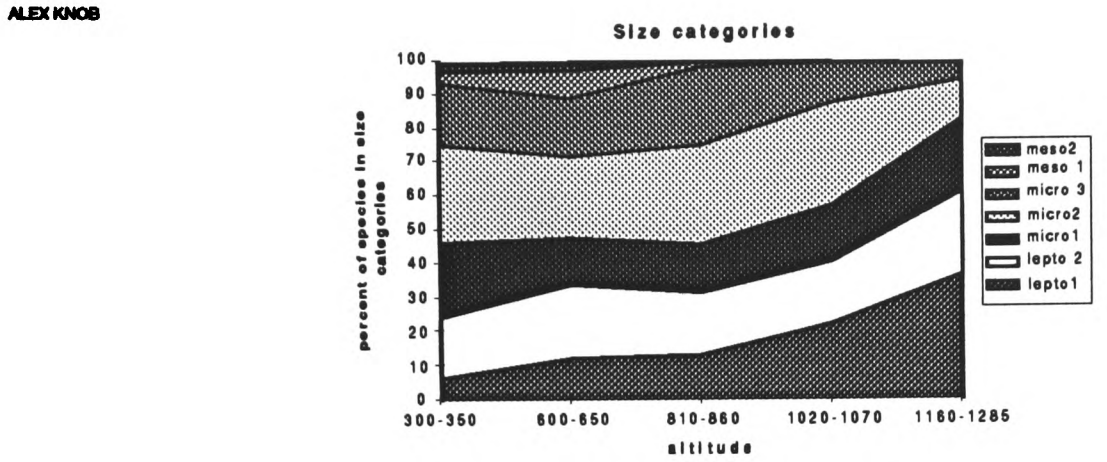
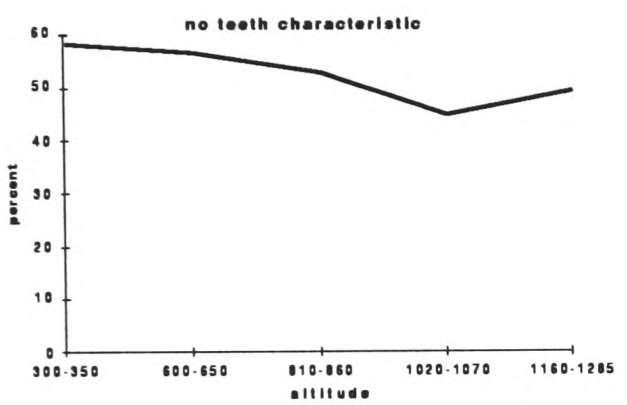
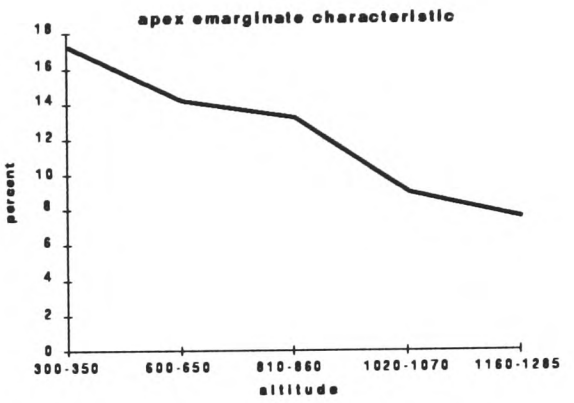
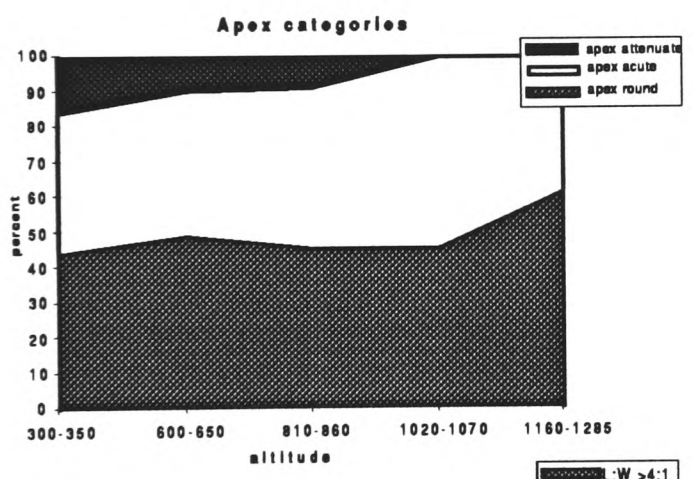


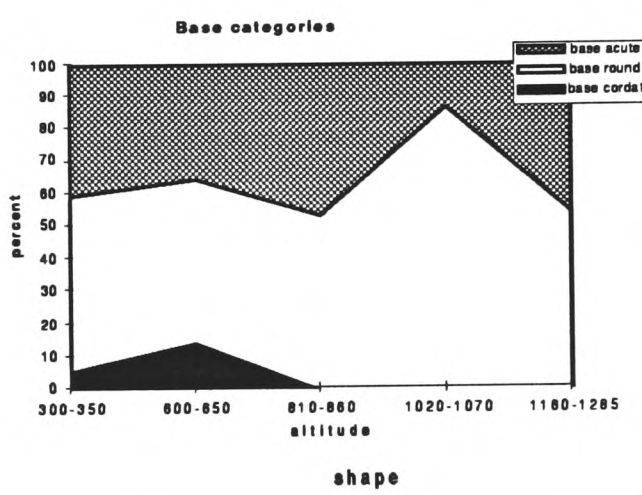
Figure 2.24: Response of physiognomic categories to increase in altitude in the Link Track altitudinal transect

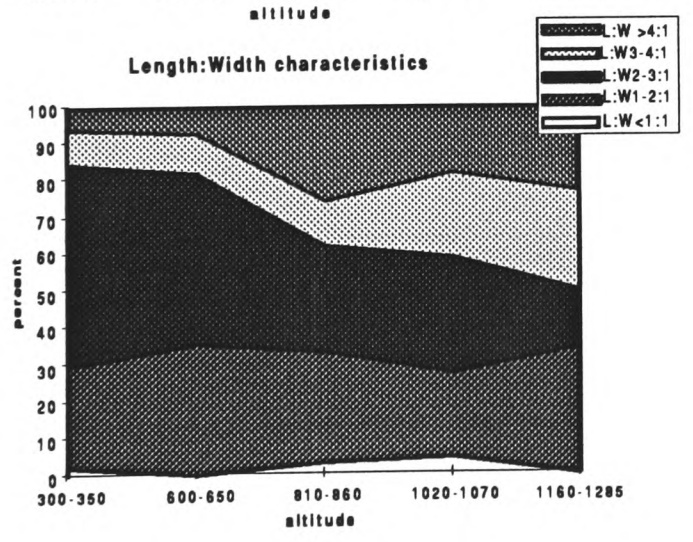












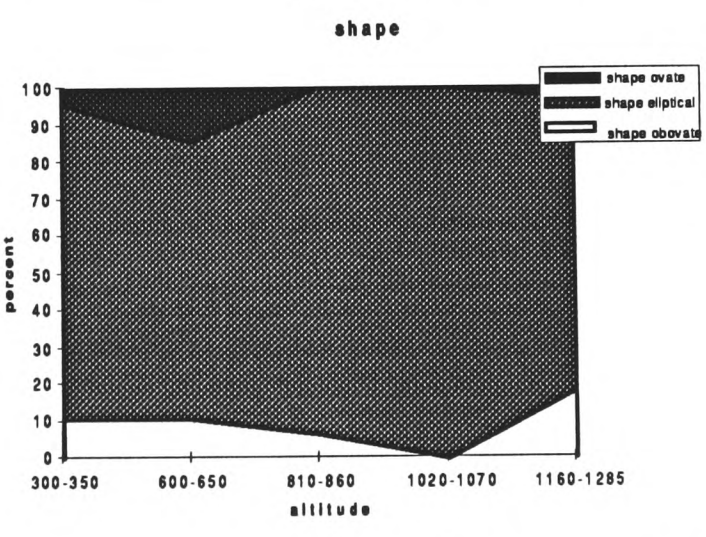


Figure 2.25: Responses of physiognomic categories to increase in altitude in the Alex Knob altitudinal transect

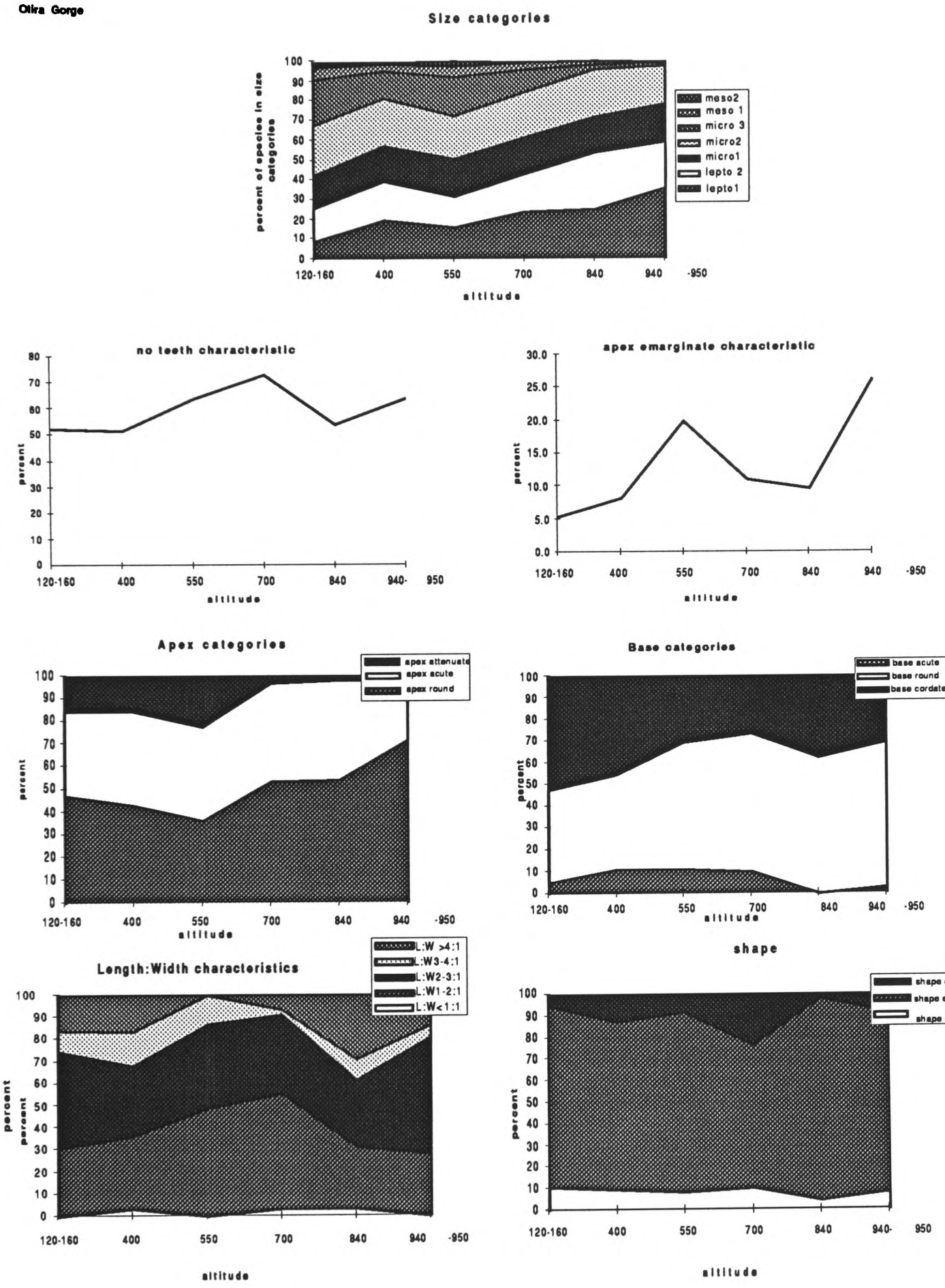


Figure 2.26: Responses of physiognomic categories to increase in altitude in the Otira gorge physiognomic transect

strongest trends were apparent in the size character states. With increasing altitude the leptophyll 1 characteristic became dominant. In the low altitude forests collected leptophyll 1 generally scored less than 10%. This score is increased to 35-50% in the high altitude shrublands collected above the tree–line. This change is not abrupt at the tree–line, but changes gradually with altitude. In tandem with this variation, the proportion of the larger leaf sizes (mesophyll 1 and 2) decrease with altitude, and both are entirely absent from the subalpine samples at each transect. The microphyll character states are all present at all sites. Microphyll 1 shows little variation with altitude although microphyll 2 and 3 percentages are reduced at the higher altitude sites at Tongariro, and microphyll 3 pinches out in the higher regions of all the transects.

Given the strong relationship between MAT and leaf margin [Raunkiaer, 1934] one might expect to see strong trends in the no–teeth character state with changing altitude. This is not the case: only Tongariro displays a continuous decrease in the no teeth character state moving along the transect. This trend is coupled with decreasing altitude which is counter to the theory that percent no teeth increases with decreasing MAT. At all of the three other transects no obvious relationship exists between the no–teeth vector and altitude. This can be explained by the increased water stress at high altitude that occurs, not because of a lack of precipitation, but because in the more frequently sub–zero temperatures the water is often 'tied up' as ice and unavailable to the plant. The high altitude species response is to have smaller leaves (see above). A side effect of this is that on the smaller leaves, physiognomic characteristics such as teeth are not expressed because of the scale of the leaf.

At high altitudes apex attenuate is absent in three out of four of the transects and severely reduced in the fourth. Again this may be because on small leaves it is impossible for this characteristic to be exhibited.

No other obvious trends with altitude exist in the remaining physiognomic character states. This is not surprising since, as I have already stressed, a species response to climate is complex and multivariate. To view the overall response of species to altitude in a few dimensions CA is used. The positions of the altitudinal transect samples in CA axes one to four is shown in Figures 2.27 and 2.28. In axis one–axis two space the high altitude sites (numbered one in Figures 2.27 and 2.28) have the highest positive axis one score and the highest negative axis two score of any of the samples in their transect. With decreasing altitude the axis two scores become more positive and the axis one scores oscillate towards lower positive values. In axis three–axis four space the physiognomic response to increasing altitude is complicated. The locus of physiognomic response in this plane coils around on itself with increasing altitude such that the lowest altitude samples plot almost adjacent to the very highest samples collected.

As with the multiple samples taken at individual localities, it is considered unwise to discuss these results further at this stage. The means of analysis of the data set and the methodology for extracting climate information from it, is discussed in Chapter 3. The results from these altitudinal transects will be discussed further in the light of the methodology proposed in that chapter.

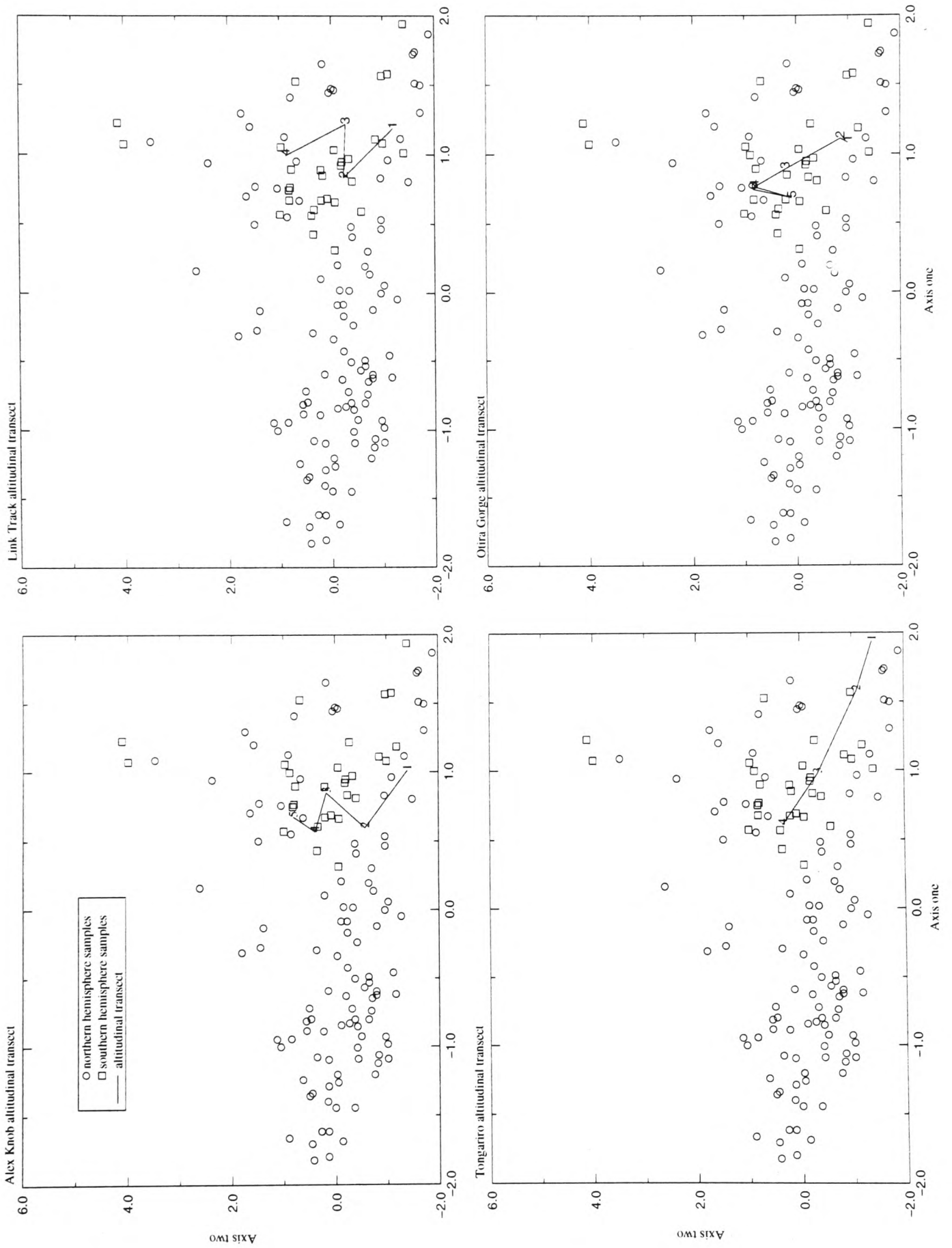


Figure 2.27: Position of samples from altitudinal transects in axis one–axis two space after correspondence analysis

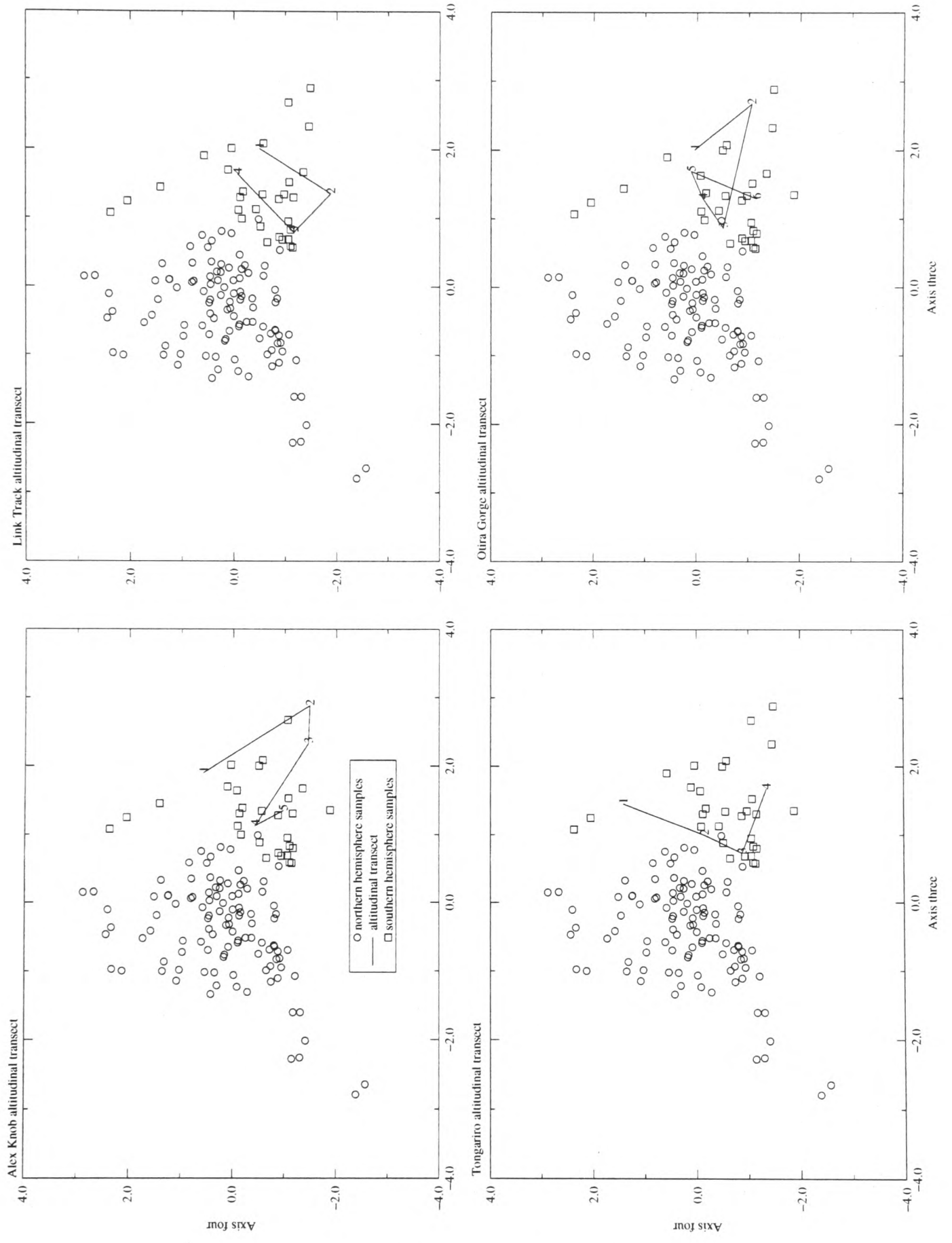


Figure 2.28: Position of samples from altitudinal transects in axis three–axis four space after corre spondence analysis

Chapter 3

Resemblance analysis: an improvement of the CLAMP methodology

3.1 Introduction

As discussed in Chapter 2, there are several properties of the CLAMP data set that force us to question the premises behind analytical methodologies employed in modelling the relationship between climate and physiognomy. These in turn force us to doubt the applicability of the resultant models over the full range of physiognomic and climate space.

The first of these, an assumption made in all analyses of the CLAMP data set conducted thus far [Wolfe, 1993; Gregory & Chase, 1992; Forest *et al.*, 1995; Wolfe, 1995; Herman & Spicer, 1996] is that a global relationship exists between physiognomy and climate. The nature of the relationship between climate and physiognomy varies across physiognomic space, as illustrated by the outliers in the modern data. Wolfe's [Wolfe, 1993] methodology deals with this awkwardly because a global relationship is sought, and to obtain good fits, outliers must be excluded. This weakness shared by other techniques applied to date, eg multiple regression [Gregory & Chase, 1992] and canonical correspondence analysis [Herman & Spicer, 1996] has motivated me to look at the data in a more localised manner.

A second premise that must be challenged is that enough information is contained within the first two axes of correspondence analysis (CA) to form valid and accurate climate estimates. Again this appears to be flawed. The subsets that do not conform to the global model proposed [Wolfe, 1993] can be distinguished on the basis of their axis–three position in physiognomic space, as can the southern hemisphere sites collected in this study. This suggests that axis three contains important information that cannot be discarded if accurate climate estimates are to be formed. Whilst the two dimensional ordination diagram produced by CA represents approximately 70% of the variation within the data set, it is not sufficient to distinguish between subsets within the data that display very different physiognomic responses to climate.

3.1.1 The non–global response

The non–global response is not surprising given that there are thresholds within both climate and physiognomic space, on either side of which, different controls apply. To illustrate this concept I will use both an environmental and a constructional example.

The first concerns the effects of temperature parameters on the precipitation *perceived* by plants. In a warm or warm–temperate climate, where the daytime temperature rarely or never drops below freezing, the precipitation perceived by plants is equivalent to the actual precipitation. If, on the other hand, the daytime temperature drops regularly below 0°C water freezes and therefore is in an unusable form for the plant. Consequently the availability of water to the plant is less than actual precipitation. This effective aridity is reflected in the physiognomy of the plant. In Wolfe [1993] it is found that the 'growing season precipitation' i.e. the precipitation that falls during months where the mean temperature exceeds 10°C is a more important control on foliar physiognomy than mean annual precipitation. This quantity is, however, limited in its use for palaeoclimatic interpretations because it refers to an unknown proportion of the total precipitation for the year. Wolfe [1993] reports that when actual mean growing season precipitation (MGSP) exceeds 145cm, estimates for this variable using the CLAMP methodology are extremely poor. This is thought to be because, above this threshold, water stress is no longer a factor that limits physiognomy. 145cm of precipitation therefore delineates a boundary in climatic space on either side of which the models of physiognomic response to climate must differ.

In the same way certain trends in physiognomic response to environment may reach a threshold beyond which constructional limitations affect the physiognomic response. The obvious example of this is when small leaf size restricts the exhibition of marginal characteristics. In addition, responses such as increasing size are limited by the constructional constraints of the biomaterials used. As a consequence physiognomic response to climate *cannot* be uniform across physiognomic space.

3.2 The use of Resemblance Functions

I have chosen to inspect the relationship between physiognomy and climate at a local level using only physiognomically similar sites to form climatic estimates. The natural way to look at similarity between physiognomic characteristics was to use the correlation matrix (see section 2.4.2). The most natural measure of similarity for sites, and also the most rigorous [see Orlóci, 1975], is a measure of distance using a metric. The chosen function must therefore satisfy the metric space axioms:

If A=B then d(A, B)=0

If A$\neq$B then d(A, B)>0

d(A, B) = d(B, A)

d(A, B) $\leq$ d(A, C) + d(C, B)

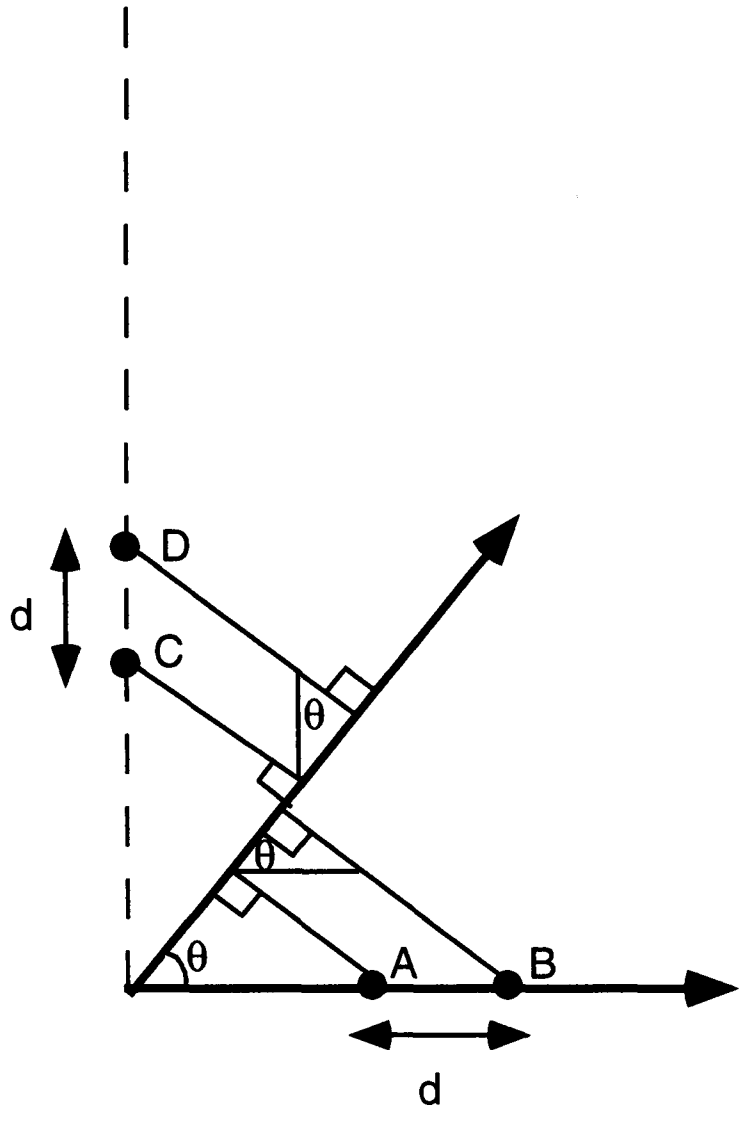


Figure 3.1: If two axes are correlated, they can be represented as non orthogonal axes in orthogonal space where the angle θ between them is related to their correlation coefficient S by $S = cos\theta$. In non orthogonal space vectors of identical length will be weighted differently depending on their orientation. The length $D(AB)$of vector AB measured in non–orthogonal space which is parallel to one of the correlated axes is $[D(AB)]^2 = d^2 + [dcos\theta]^2$ This value is greater than d. In contrast the length $D(CD)$ of the vector CD which is perpendicular to one of the correlated axes is $D[CD] = dsin\theta$

where d(A,B) is the distance between two points, A and B. The first step in resemblance analysis is to define the metric. The Euclidean distance in untransformed space would fulfill these axioms, but because of the correlation between axes, certain directions within the data space would be more heavily weighted than others (see Figure 3.1). This problem is overcome if the distribution of the data is described using orthogonal axes. As with the first part of Wolfe's indirect analysis, I chose to transform the data so that it was described relative to uncorrelated axes. There are several ordination techniques and transformations available to carry out this task.

3.2.1 The Mahalanobis transformation

One of the most important measures of proximity and therefore similarity between sites in non–orthogonal multivariate space is the Mahalanobis distance, D_{rs}. This is the Euclidean distance between sites after the Mahalanobis transformation [see Mardia *et al.*, 1979, pages 14 and 17].

$$D^2_{rs} = (x_r - x_s)'S^{-1}(x_r - X_s). \tag{3.1}$$

where x_r and x_s are the two objects, and S is the covariance matrix. The Mahalanobis transformation uses the covariance structure of the raw data matrix to transform the data such that

the correlation between variables is eliminated and the variance standardised. For this reason it is commonly used in cluster analysis [Mardia *et al.*, 1979] where the distance between objects is used to split them into homogeneous classes. It therefore might appear to be ideal for our purposes of identifying nearest neighbours in physiognomic space.

The Mahalanobis transformation however, in contrast with ordinations such as principal component analysis (PCA), correspondence analysis (CA) and canonical correspondence analysis (CCA), does not parsimoniously summarise the data in fewer dimensions (see figure 2.2). Later in the analysis, once the nearest neighbours have been selected, I will use these objects to form estimates of climate using regression. The more dimensions (axes) that are used, the less confident one can be about the fit of a regression, given a constant number of data points. This is because the goodness of fit of a model increases with increasing numbers of degrees of freedom ν [Press *et al.*, 1992; Davis, 1986].

$$\nu = N - M \tag{3.2}$$

where N is the number of points and M is the number of adjustable parameters in the equation i.e. the number of dimensions used. I have chosen to use as my metric the Euclidean distance between sites after an ordination rather than the Mahalanobis transformation so that the dimensionality is reduced and fewer parameters can legitimately be used in the regression part of the analysis.

3.2.2 Ordination techniques

In his analysis Wolfe [Wolfe, 1993] chose to use CA (see page 14, equations 2.1–2.4) because it makes the least restrictive assumptions about the distribution of the data. It does however assume a linear relationship between environmental variables and physiognomy. This assumption is not made in the more commonly used ordination, PCA, but that approach also has a drawback, in that assumptions are made about the distribution of the data [Kent & Coker, 1992].

PCA [Mardia *et al.*, 1979] was developed by Hotelling [1933] after its origin by Pearson [1901]. It seeks the standardised linear combinations of the original variables which have the largest variance, in order to parsimoniously summarise the data. A linear combination is simply, $l \cdot \mathbf{x}$ where l is a vector of weights whose components are l_i and x is the vector representing the object in terms of the original variables. A standardised linear combination is where $\Sigma l_i^2 = 1$. PCA is an orthogonal transformation which transforms any set of variables into a set of new variables which are uncorrelated. In order to do perform this task the covariance structure of the data matrix is used [see Mardia *et al.*, 1979, Chapter 8]. Its application to the CLAMP data set is therefore problematic because the CLAMP data set is partially compositional, i.e. within character state categories such as size, L:W and base, the variables are constrained to sum to 100%. The correlation coefficients between such variables are not valid because they are not independent of one another. This is illustrated if we consider a hypothetical category which contains only two variables, they will show a perfect, but spurious correlation [Aitchison, 1986]. Consequently the covariance structure for the CLAMP data set used in the PCA ordination will be partially spurious. Whilst it is theoretically more problematic than CA I have nonetheless

chosen to use PCA alongside and in comparison with CA in my investigations of the CLAMP data set using resemblance analysis.

In addition to these two ordinations there are several adaptations of CA intended to improve its performance. These are detrended correspondence analysis (DCA) [Hill & Gauch, 1980] and canonical correspondence analysis (CCA) [ter Braak, 1987-1992, 1986, 1987].

DCA was designed to overcome two problems associated with CA; the arch affect and the axis compression affect. Wolfe dismissed it because in the modification involves more restrictive assumptions about the distribution of the data. Hill and Gauch themselves [Hill & Gauch, 1980] pointed out that DCA is an *ad hoc* adjustment of CA which "does not enhance our understanding of the data". Indeed Wartenberg *et al.* [1987] and Minchin [1987] stated that it may result in the loss of some information. For this reason along with the fact that the arch affect does not appear to be a problem in Wolfe's analysis I have chosen to disregard this ordination method.

Canonical Correspondence analysis has also been used to analyse the CLAMP data set [Herman & Spicer, 1996]. This is a constrained ordination similar to CA but where environmental variables are used to dictate the selection of the principal axes. It is a direct ordination where the descriptive and interpretative aspects of the analysis are not kept separate. Because it has been shown that environmental variables do not have a globally applicable relationship with climate (see Chapter 2) I have chosen to disregard this method in favour of the simpler indirect ordinations.

3.2.3 The choice of metric

In summary the measure of proximity chosen is simply the Euclidean distance calculated in the data space, transformed either by CA or by PCA. These transformations were executed using the FORTRAN program CANOCO developed by ter Braak [1987-1992].

The CLAMP data set, x_{np}, with n sites and p variables, is transformed using either of these transformations to give a matrix, X_{np}. The Euclidean distance is given by

$$E_{jk} = \sqrt{\sum_{h=1}^{D}(X_{hj} - X_{hk})^2} \tag{3.3}$$

where E_{jk} is the Euclidean distance between sites j and k, $X_{hj} - X_{hk}$ is the distance between sites j and k along dimension h, and $D(\leq p)$ is the number of dimensions that contain useful information (see below).

The resemblance structure defined by the Euclidean distance (Equation 3.3) was used to select nearest neighbour sites for each of the modern sites in turn. The MATs of these nearest neighbours were then used to estimate the MAT at the chosen site, by assuming that a linear relation exists *locally* between MAT and position in the data space. For each of N nearest neighbours, the MAT of the nearest neighbours is related to the MAT of the chosen site, T_0, by:

$$T_c = T_0 + a_1x_1 + a_2x_2 \ldots\ldots a_ix_i \tag{3.4}$$

where x_i is the distance of that site from the site under analysis, along the i^{th} axis. The coefficients a_i and T_0 were found by general least squares fitting [Press *et al.*, 1992] to the N observations. The estimated MAT at the chosen site is then compared with the MAT for the site known from meteorological stations. In this way an estimate of the reliability of this method for estimating MAT at fossil sites is formed. A flow diagram summarising the methodology is shown in Figure 3.2.

There are two factors in this analysis that can be varied. First both CA and PCA yield orthogonal axes ordered by the amount of variance the axes account for. The first 6 axes in PCA account for 90% of the variance and in CA the first 5 account for 86.6%. Accordingly, there is little merit in using all 29 dimensions in transformed space and there may indeed be dangers if the variance associated with the higher dimensions carries no information about climatic parameters. The second factor is the number of nearest neighbours to use in the calculation, which cannot be specified *a priori*.

Accordingly experiments were carried out in which both the number of dimensions and the number of nearest neighbours were varied (see figure 3.2). The minimum number of dimensions to be chosen was 2 because Wolfe [1993] shows the first 2 axes to be strongly correlated with climatic variables. We have seen (above) that variation in axis 3 is associated with poor estimates of MAT from CLAMP (see Figures 2.5 and 2.19) and so the difference between estimates made with and without this third axis using our nearest–neighbour technique is of particular interest. The number of nearest neighbours used must be greater than or equal to the number of dimensions used.

3.3 Using the nearest neighbour approach on the northern hemisphere data

The RMS misfit (for all 106 sites) was chosen as a measure of goodness of fit between observed MAT and MAT estimated from the leaf physiognomy, using the method above. For each choice of axes (CA/PC), the quality of fit is almost independent of the number of nearest neighbours for $D \leq 3$. However, the RMS misfit is greater for D>3, though the quality of fit improves markedly as the number of nearest neighbours is increased to about 20, but varies little if further nearest neighbours are introduced (Figure 3.3, Table 3.1). The differences between estimates made using axes derived from CA and those from PCA are small, but for each choice of number D of significant dimensions the misfit is smaller for CA than for PCA with the exception of D=4, where they are very close (Table 3.1).

The number of dimensions that produces the lowest misfit for CA is clearly 3, whereas for PCA the difference between using 3, 4 and 5 dimensions is much less marked (see Figure 3.3, Table 3.1) This observation is consistent with the different approaches of the two methods. Each orders axes in terms of variance accounted for, but CA chooses axes under the hypothesis that variance reflects environmental preferences (Equations 2.1–2.4, page 15), whereas PCA makes

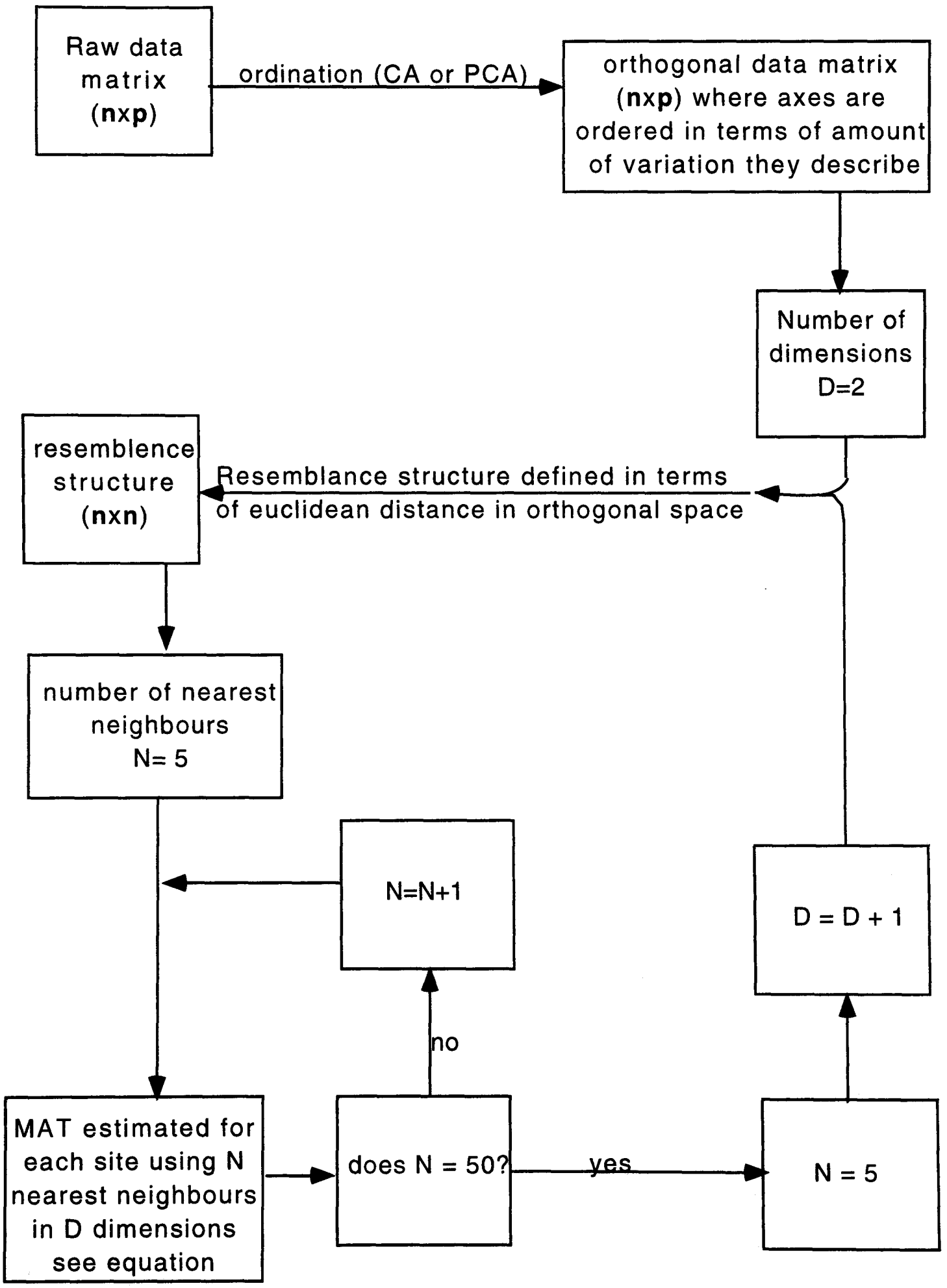


Figure 3.2: Flow–diagram showing procedure for nearest neighbour experiment

transformation used	PCA					CA				
no. of dimensions used	2	3	4	5	6	2	3	4	5	6
nearest neighbours										
10	2.52	2.41	3.09	3.21	3.79	2.19	2.22	2.62	3.18	4.10
11	2.59	2.43	2.91	3.23	3.73	2.20	2.21	2.69	2.91	3.10
12	2.63	2.34	2.78	3.02	3.50	2.21	2.14	2.62	2.77	3.01
13	2.62	2.46	2.61	2.88	2.97	2.21	2.18	2.57	2.64	2.74
14	2.63	2.49	2.42	2.59	2.94	2.23	2.13	2.56	2.68	2.57
15	2.63	2.39	2.47	2.57	2.70	2.22	2.15	2.51	2.53	2.50
16	2.63	2.40	2.42	2.51	2.85	2.26	2.13	2.44	2.52	2.52
17	2.64	2.35	2.44	2.40	3.06	2.25	2.13	2.47	2.55	2.54
18	2.65	2.30	2.41	2.33	2.72	2.25	2.10	2.45	2.48	2.52
19	2.64	2.26	2.43	2.32	2.65	2.27	2.07	2.45	2.48	2.52
20	2.63	2.35	2.41	2.42	2.56	2.28	2.07	2.45	2.41	2.36
21	2.61	2.31	2.46	2.35	2.51	2.25	2.09	2.41	2.39	2.31
22	2.62	2.34	2.42	2.40	2.60	2.23	2.07	2.38	2.33	2.30
23	2.63	2.32	2.37	2.42	2.53	2.28	2.09	2.39	2.32	2.46
24	2.64	2.37	2.35	2.44	2.44	2.31	2.10	2.36	2.30	2.46
25	2.65	2.32	2.30	2.44	2.34	2.31	2.10	2.32	2.23	2.50
26	2.66	2.32	2.32	2.46	2.35	2.33	2.11	2.29	2.25	2.40
27	2.69	2.32	2.31	2.44	2.37	2.31	2.10	2.29	2.23	2.38
28	2.67	2.32	2.36	2.36	2.36	2.32	2.14	2.32	2.28	2.41
29	2.66	2.36	2.36	2.33	2.33	2.33	2.16	2.33	2.29	2.38
30	2.70	2.38	2.38	2.27	2.33	2.35	2.16	2.32	2.27	2.38

Table 3.1: RMS values calculated for MAT estimates made using the nearest neighbour approach described above for the Wolfe (1993) data set. The data is first transformed using either correspondence analysis or principal component analysis. The number of nearest neighbours and the number of dimensions used are varied.

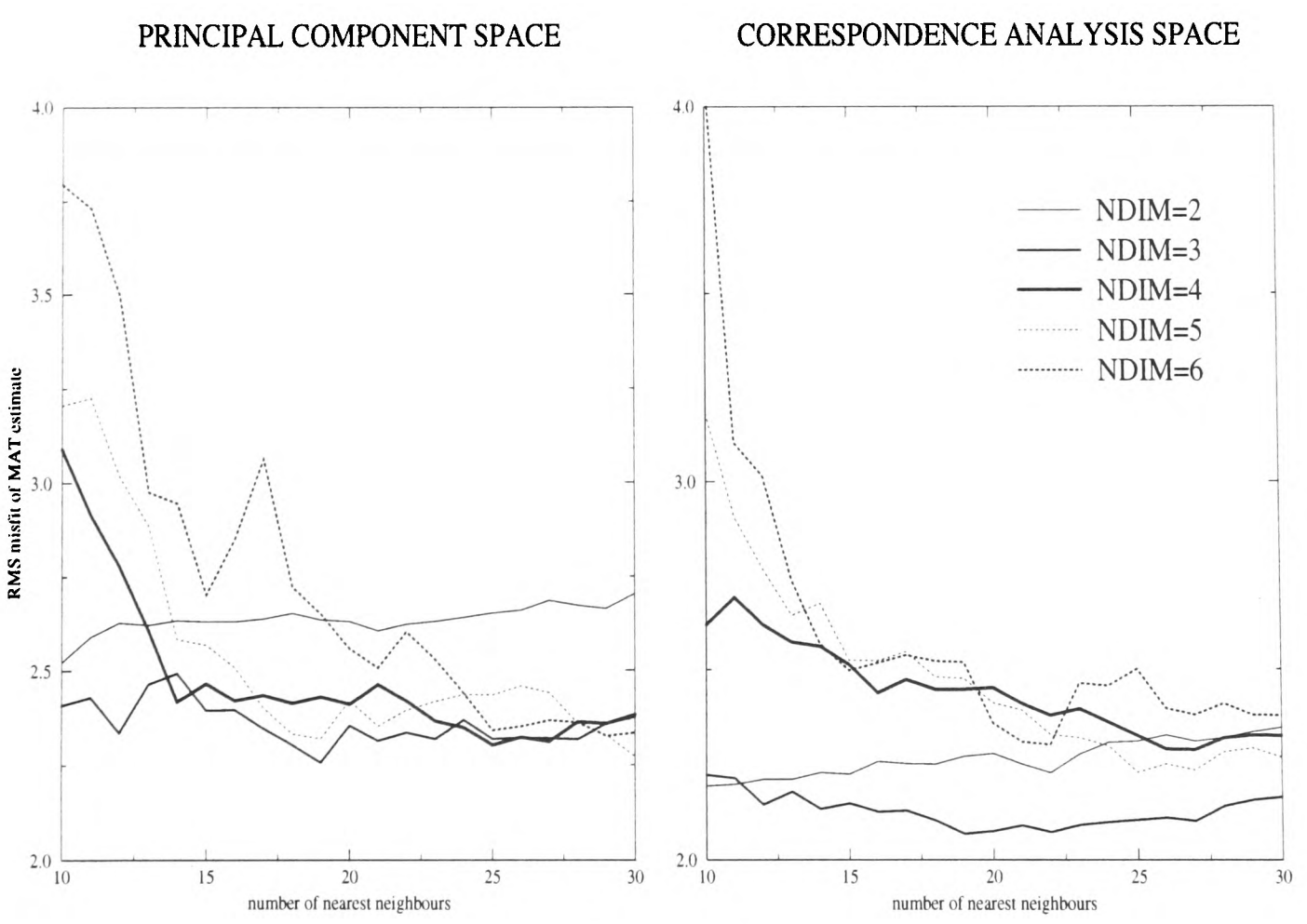


Figure 3.3: Graphical representation of Table 1. RMS misfit for MAT estimation for a range in Number of nearest neighbours using the full CLAMP data set (Wolfe, 1993), varying also D (number of dimensions used in the calculation) and the transformation used to redescribe the data in terms of orthogonal axes (either CA or PCA).

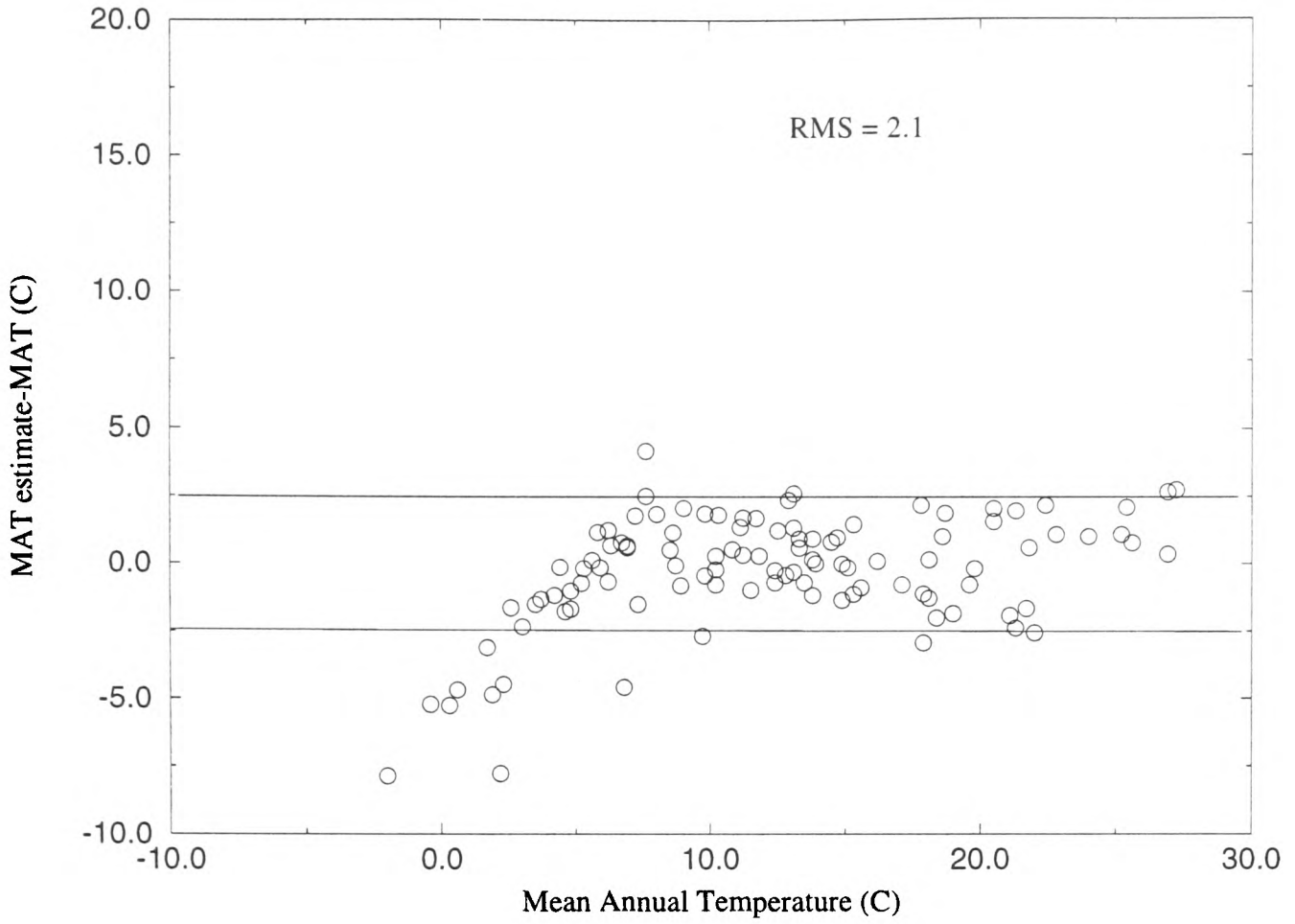


Figure 3.4: Error in MAT estimates produced from CLAMP data set (Wolfe,1993) when 19 nearest neighbours are selected for each calculation. Transformation used is correspondence analysis, Number of dimensions used (D) is 3

no such assumption. If most of the variance is indeed associated with environmental preferences, but a significant proportion is not, one should expect the two methods to be roughly equivalent, but with each PCA axis containing less environmental information than the corresponding CA axis. Consequently more PCA axes are needed to obtain the same environmental information. Equally, because the PCA axes contain, relative to corresponding CA axes, more variance that is not correlated with environment, one should expect misfits to be greater for PCA than CA. In addition the principal components generated by PCA are based on a covariance structure for the data which is partially spurious (see Section 3.2.2). This may also partly explain its poorer performance than CA.

Rather than dwelling on the differences between PCA and CA, I prefer to emphasize the similarity between the results obtained using the two ordinations. The RMS misfit for $N \geq 30$ is $\sim$ 2.5-2.0°C for the best value of D in each case. I suggest that this illustrates the robustness of the method.

The misfits for all 106 sites, in the best case where CA is used to transform the data (3 dimensions and 19 nearest neighbours) are shown in Figure 3.4. The RMS misfit for MAT estimates using this approach is 2.1°C compared with 3.0°C for the full data set using the CLAMP methodology. With the nearest–neighbour approach the tail at low temperatures is much reduced. The contrast between the distinctive 'v' form of Figure 2.5a and the nearly linear form of Figure 3.4, indicates the influence of the assumption of a *global* linear response, which is present in the former and absent in the latter.

3.4 Using the nearest neighbour approach on the combined data set

The power of the CLAMP methodology to estimate MAT of the southern hemisphere sites collected in this study has already been shown to be poor in Chapter 2, with a root mean square (RMS) misfit of 4.8°C (see Figure 2.19). This is significantly worse than the fit to Wolfe's original data alone and is due not only to the poor estimates made for all southern hemisphere sites, but also to poorer fittings of Wolfe's original data set. The fit of the polynomial appears to be a compromise solution between these two data sets and fits neither well. When the New Zealand data are treated as a subset the RMS misfit is reduced to 2.1°C (see Figure 2.19b). There is however, a discernible slope to the misfit, revealing a tendency to underestimate the higher temperatures and overestimate the lower ones. This corroborates our suspicion that using only the first two axes of CA space overlooks important information contained on subsequent axes. The new nearest neighbour approach was used to form estimates of climate and the results are presented below.

Using the Euclidean distance (Equation 3.3), and the combined data set, I again calculated the nearest neighbours to each of the sites in turn. Using CA to transform the data and setting $N = 19$, and $D = 3$, estimates were made of the MAT at each site. The results are displayed in Figure 3.5. The RMS misfit of these estimates is 2.3°C. This is compared with a RMS misfit of 4.8°C for MAT estimated using the CLAMP methodology (see Figure 2.19) and 2.1°C using the nearest neighbour approach on the CLAMP data set only (see Figure 3.4).

The estimates I have obtained were from the full data set, without any necessity to place the sites into subsets by inspection. Whilst the methodology does in effect split the sites into subsets, this is on a mathematical, not a subjective, basis. It is consequently repeatable and therefore a more satisfactory way of looking at the data. An additional advantage of the nearest neighbour approach is that the calculation of resemblance structure of the data reveals the proximity of each site to its neighbours. Because of the variation of the relation between physiognomy and climate through physiognomic space, it is essential to know the proximity of neighbours when analysing a fossil site. Estimates from those fossil sites that are isolated in physiognomic space cannot be treated with the same degree of confidence as those that plot within the space defined by modern sites. As with all empirical models, there is a real danger in extrapolating beyond the extent of the collected data.

3.5 Estimation of other environmental parameters

3.5.1 Precipitation

Wolfe [1993] shows that when northern hemisphere sites are projected onto the axis 2 vector, their rank generally approximates precipitation but with a high standard error. This error is particularly large for microthermal samples where the plants are not growing all year round.

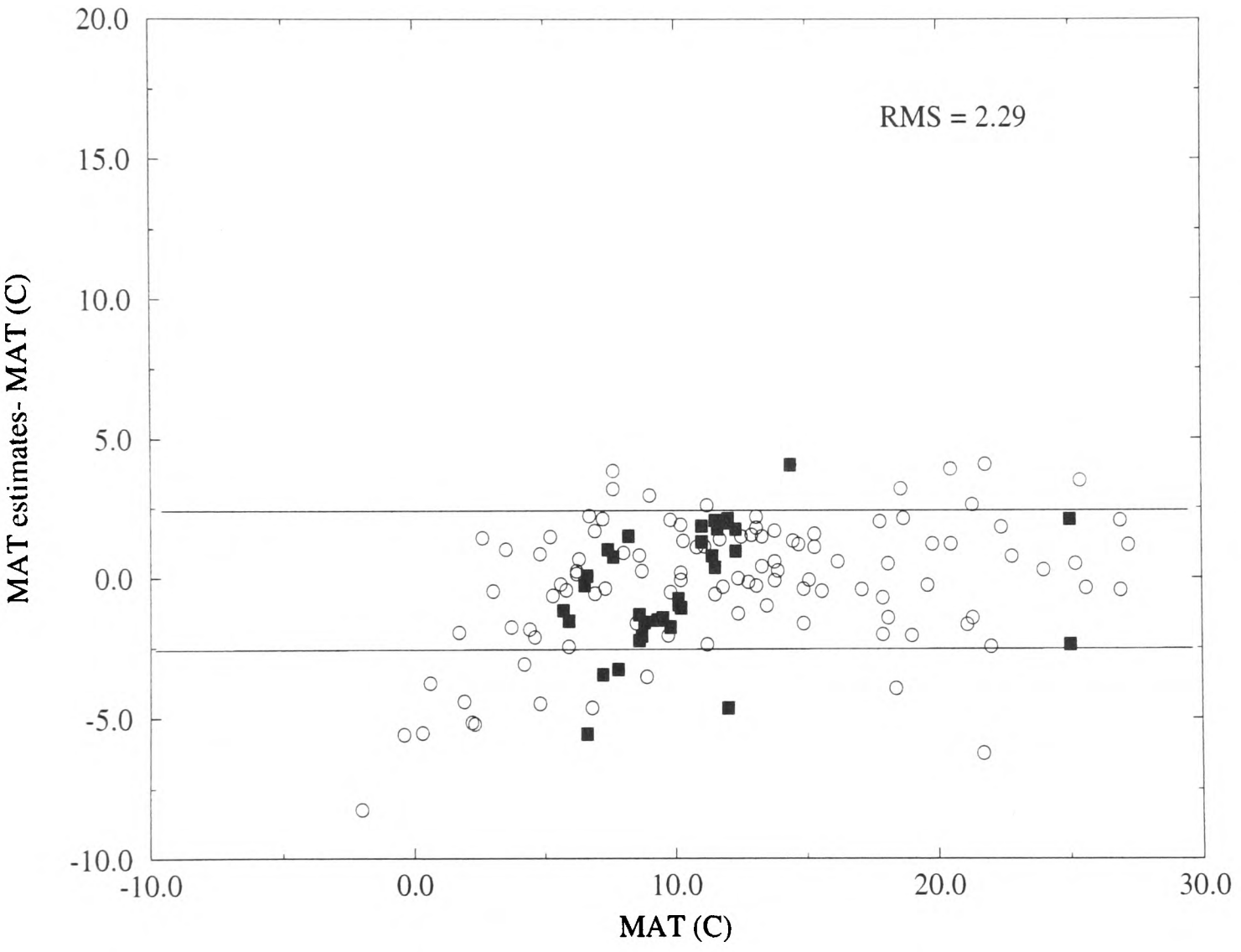


Figure 3.5: Error in MAT estimates for the combined CLAMP data set (northern hemisphere data (Wolfe,1993) plus Southern Hemisphere data presented here) using nearest neighbour method. Transformation used is correspondence analysis, D=3, N=19. filled square = southern hemisphere sample, unfilled circle = northern hemisphere samples

Wolfe relates this to the fact that high precipitation outside the growing season for the plant is not particularly significant to the vegetation and therefore not related to the physiognomy. Wolfe finds that the mean growing season precipitation (MGSP) defined as the mean precipitation that falls in the months when the MAT exceeds 10°C, shows a stronger relationship with physiognomy. As with the MAT analysis he needs to divide the data set on the basis of climate to accommodate for the change in response across climate space. The two subsets comprise: in subset one, those samples from megathermal and mesothermal climates and in subset two, those from microthermal climates. The latter shows a poor correlation with MGSP when projected onto the CA axis 2. The megathermal/mesothermal samples produce better estimates, however the scatter is much greater at higher levels of precipitation (see discussion in section 3.1.1).

In general then, CLAMP is less successful at estimating precipitation variables than it is at estimating MAT. In the following discussion I investigate whether the nearest neighbour approach offers any improvements for the estimation of rainfall. As with initial MAT experiments, not only the ordination used, but also the number of dimensions and the number of nearest neighbours, were varied. Figure 3.6 shows that attempts to estimate MGSP using the nearest neighbour approach are far more successful than attempts to estimate MAP with RMS values for MGSP approximately half those for MAP. In both the estimation of MAP and MGSP, whether PCA or CA is used, the effect of increasing the number of dimensions from 2 to 8 is small. There is also little variation in the power of the technique when the number of nearest neighbours is increased above ~15. One of the reasons for this may be that estimates for samples with high precipitation are consistently bad whatever method is used. This is because of the insensitivity of plants to precipitation above and beyond the point when water stress is no longer a controlling factor. The best results for each of the precipitation variables in combination with each of the ordinations are displayed in Figures 3.7–3.10 A clear pattern is exhibited in all the results of decreasing accuracy with increasing rainfall. This is especially well pronounced in the MGSP experiments. Here MGSP below 100cm are extremely well estimated with an RMS of 27.4cm and 35.8cm for the CA and PCA analyses respectively. Above ~100cm the accuracy of the estimates decreases. The RMS for all sites up to 200 cm MGSP is 30.13 for the CA transformation and 41.7cm for the PCA transformation. After this point there is a linear increase in error with increasing rainfall. This pattern is very similar to that displayed when the CLAMP methodology [Wolfe, 1993] is used to estimate precipitation variables. The nearest neighbour approach offers little improvement over the CLAMP methodology in terms of accuracy although as discussed before it is theoretically preferred because the data is split on a mathematical rather than subjective basis.

The agreement between the two very different methodologies strongly suggests that the limitations of using physiognomy to estimate rainfall, especially in wet regions, are real, and not attributable to the means of extracting this information. This is for two reasons. First, water is a controlling factor on physiognomy only when it is not plentiful and secondly, water is not 'seen' by a plant when it is in its solid state, i.e. below 0°C or when the plant itself is not growing.

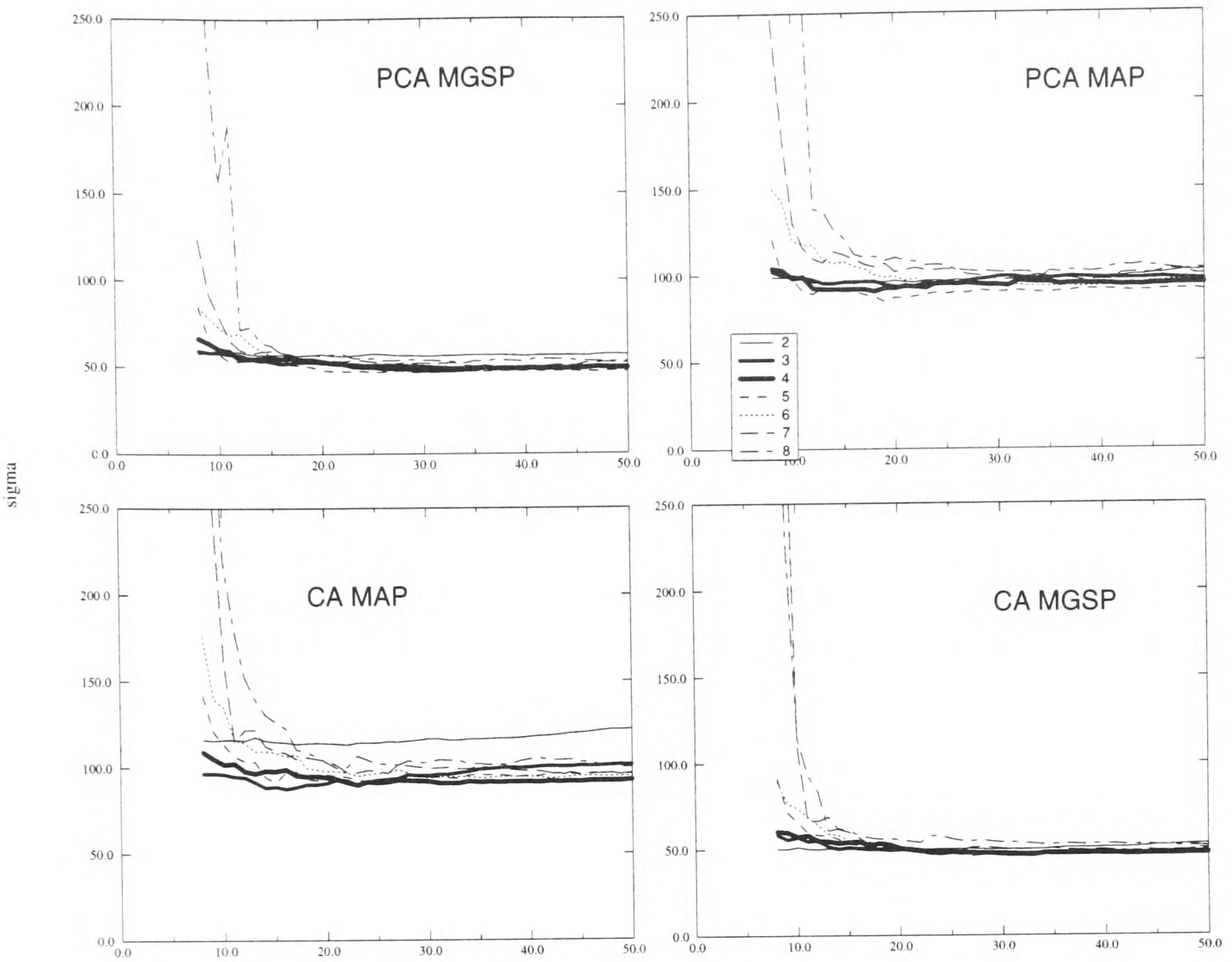


Figure 3.6: Values for sigma for estimates of MAP and MGSP varying the transformation used (either CA or PCA), D the number of dimensions used and N the number of nearest neighbours used in the calculation

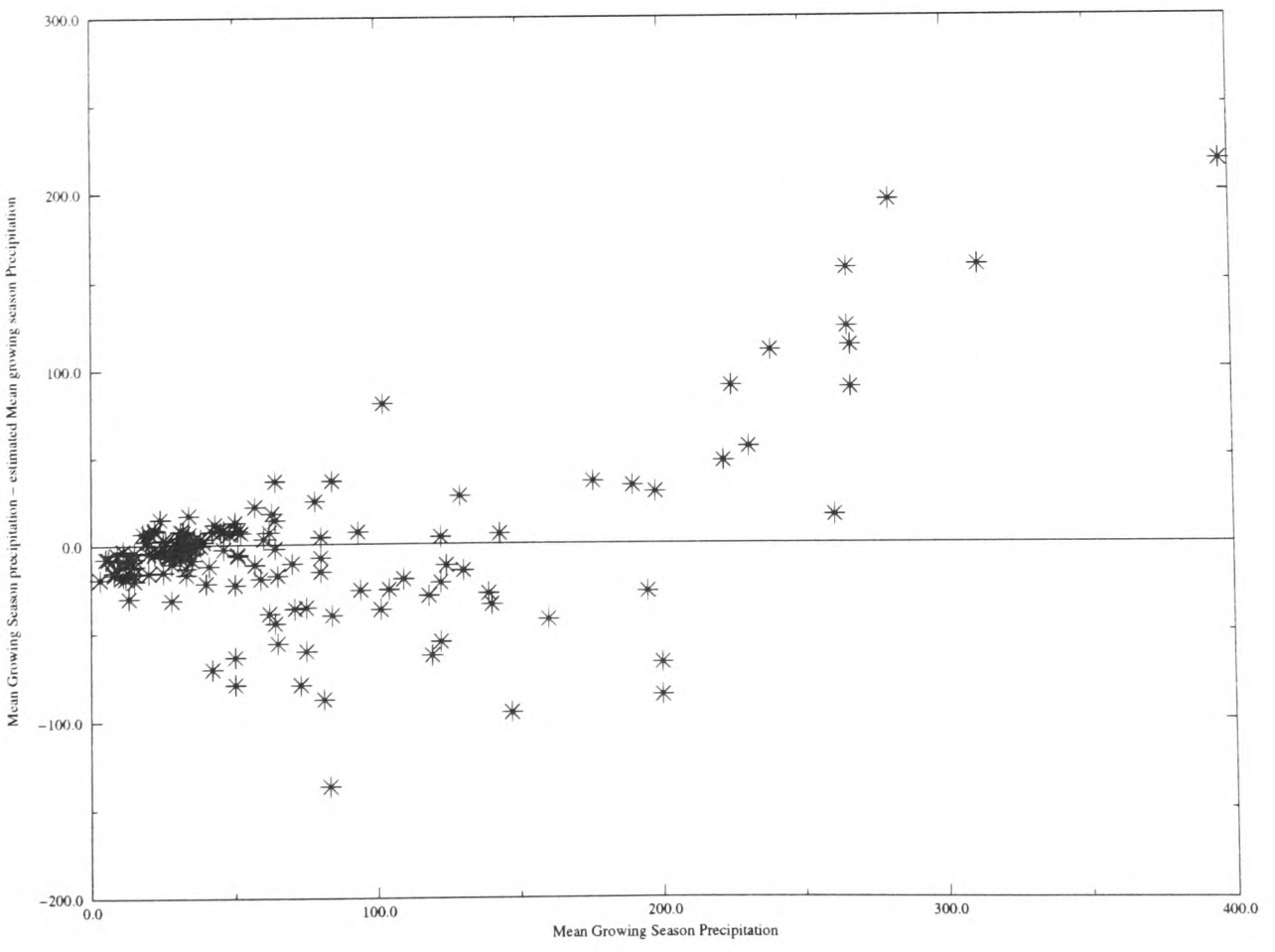


Figure 3.7: Errors in MGSP estimation when calculated using 4 correspondence analysis axes and 26 nearest neighbours

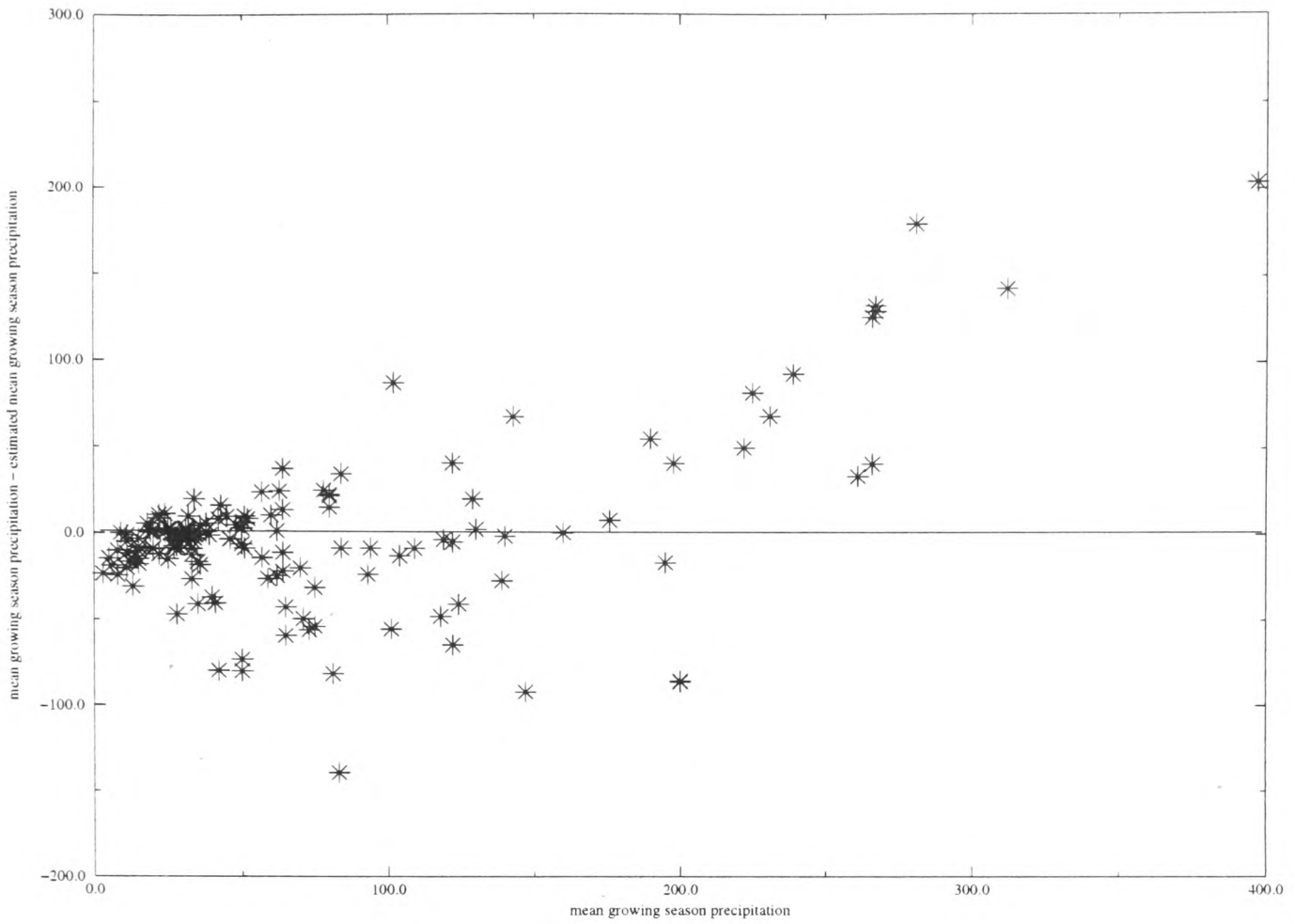


Figure 3.8: Errors in MGSP when estimated using 5 principal component axes, and 31 nearest neighbours

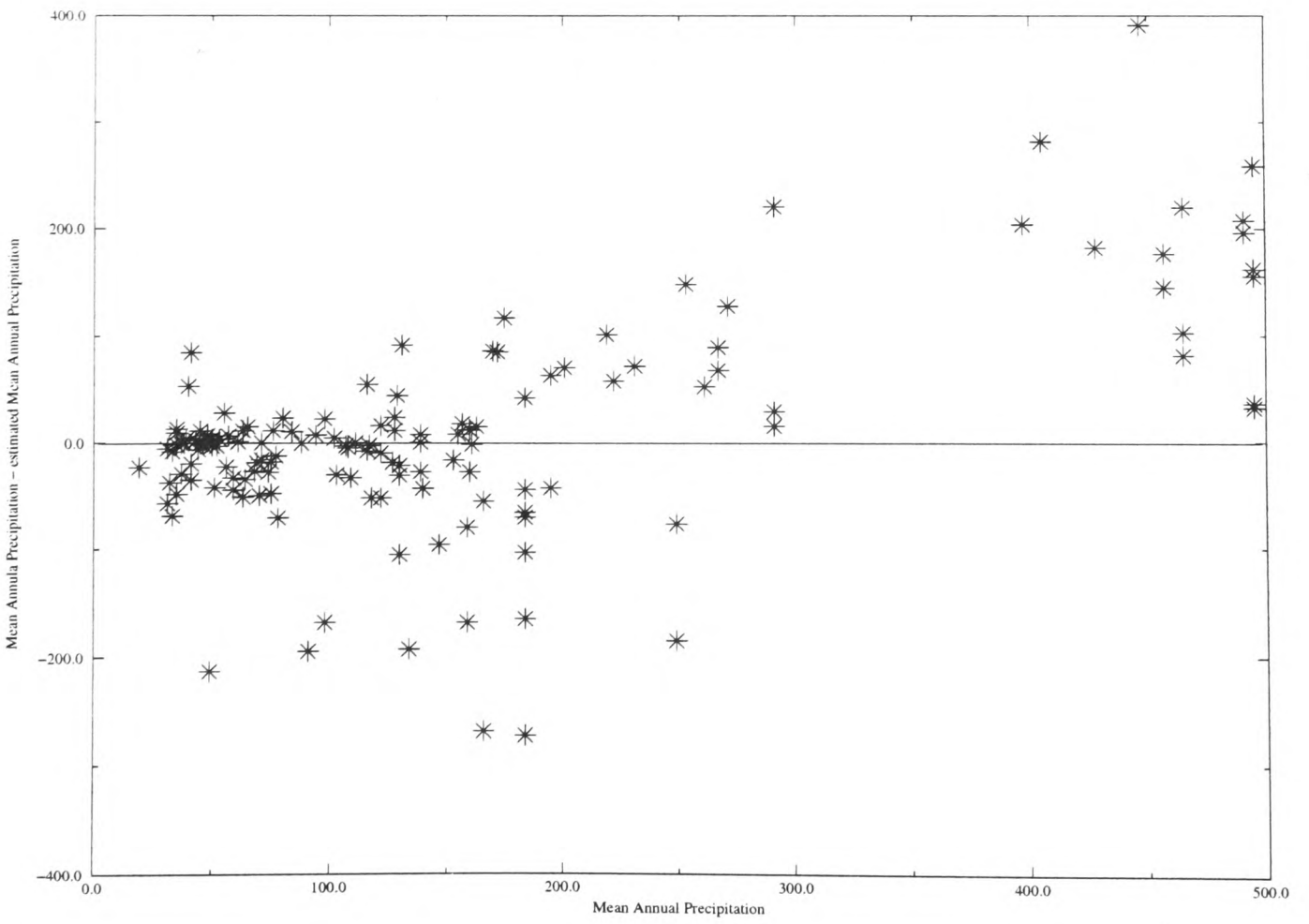


Figure 3.9: Errors in mean annual precipitation when estimated using 3 correspondence analysis axes, and 9 nearest neighbours

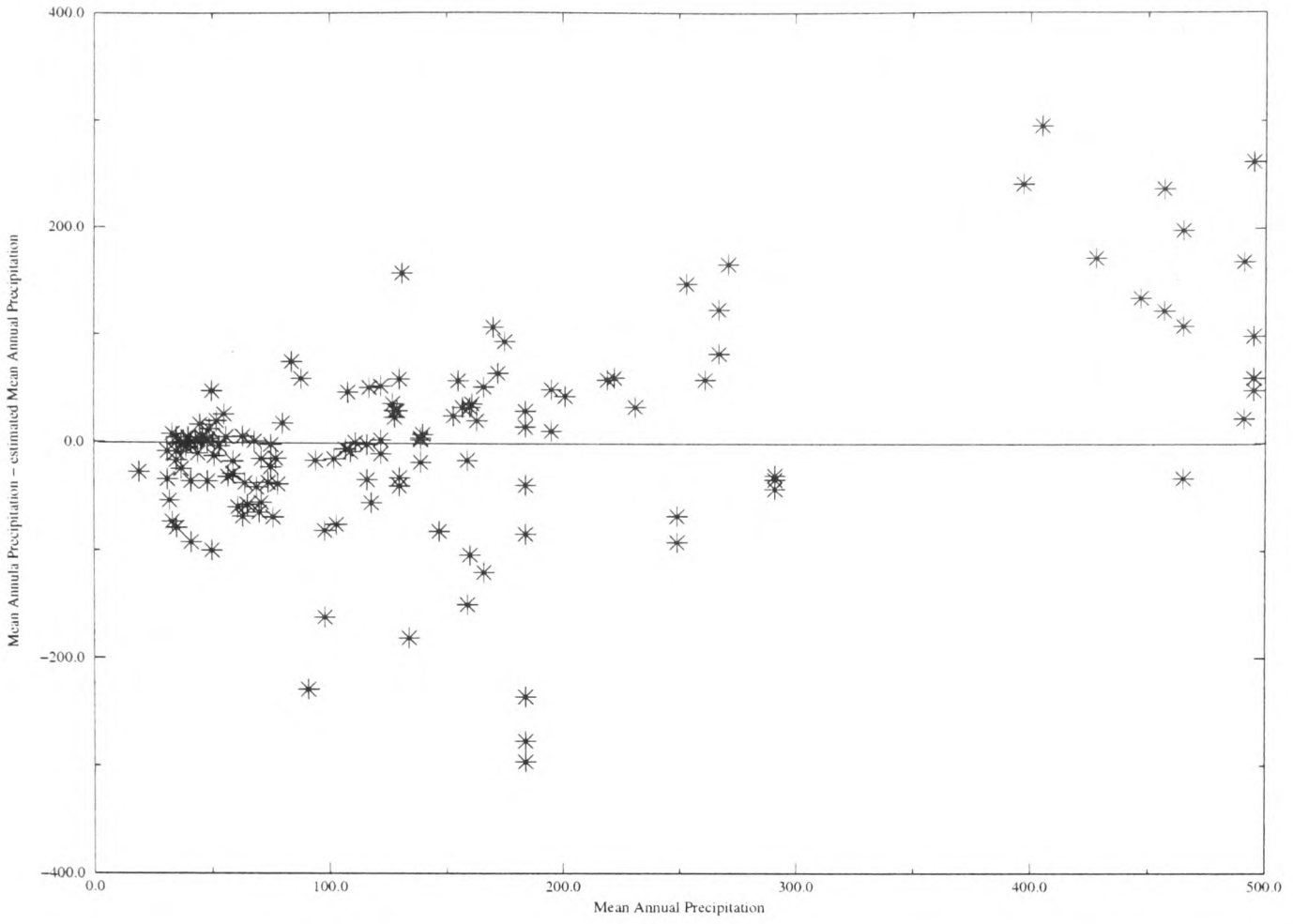


Figure 3.10: Errors in mean annual precipitation when estimated using 5 Principal Components axes, and 12 nearest neighbours

3.5.2 Moist enthalpy

In recent work, Forest *et al.* [1995]; Forest [1996], show the potential for estimating palaeoelevations from moist enthalpy of the atmosphere (H). It is argued that the use of this quantity for palaeoaltitude estimates is an improvement on the use of MAT, because its basis is not an empirical temperature/altitude relationship, but the conservation of energy. Moist static energy per unit mass, h is the total specific energy content of air excluding kinetic energy which is very small ($\ll 1$) compared to other terms [Peixoto & Oort, 1992]. It is the sum of the moist enthalpy (H) and the gravitational potential energy of the air per unit mass, and is written:

$$h = c_p' T + L_v q + gZ = H + gZ \tag{3.5}$$

where c_p' is the specific heat capacity at constant pressure of moist air, T is temperature (in K) L_v is the latent heat of vaporisation of water, q is specific humidity i.e. the ratio of air's partial density of water vapour to the total density of moist air, g is gravitational acceleration and Z is altitude.

Forest *et al.* [1995]; Forest [1996] show that to a good approximation, h is conserved along lines of latitude and is zonally symetrical in meteorological terms. It follows from Equation 3.5 that if one assumes h to be zonally symmetric along the earth's surface, the altitude of a locality may be calculated from an estimate of the moist enthalpy there, H_{site}, and an estimate, H_{sl}, of enthalpy at sea level at the same latitude using,

$$Z = \frac{H_{sl} - H_{site}}{g} \tag{3.6}$$

where Z is the altitude and g is the gravitational acceleration. Forest *et al.* [1995] use the data set of Wolfe [1993] to investigate the potential for using foliar physiognomy to estimate values of moist enthalpy using a multiple regression. I investigate the potential for using the nearest neighbour approach to estimate moist enthalpy from leaf physiognomy. Moist enthalpy data are available for all 92 North American sites in the CLAMP data set, (*Forest, personal communication*). Moist enthalpy values were also calculated for the New Zealand sites collected by *Stranks (in press)* using Equation 3.5 to calculate enthalpy at the nearest meteorological station and Equation 3.6 to extrapolate to the sample collection site.

The results show similarities with the MAT estimates. As before, the best results come when the data is transformed using CA rather than PCA (see Figure 3.11). Using CA the lowest misfits are produced when two and three dimensions are used. When the data are transformed using PCA, there is little to chose between using 3, 4, 5 and 6 dimensions. The best RMS misfits to the North American data that I obtain using the nearest neighbour approach are marginally larger than that obtained by Forest *et al.* [1995]. Using the North American data set the nearest neighbour approach with 10 nearest neighbours and 3 CA axes, gives a RMS misfit of 4.5 kJ/kg. This should be compared with a standard error of 3.9 kJ/kg for predictions made using PCA with regression [Forest *et al.*, 1995]. An uncertainty of 5kJ/kg is approximately equivalent to about 500 metres in elevation Forest *et al.* [1995]. The addition of the New Zealand data set again demonstrates robustness. The estimates for moist enthalpy obtained using the nearest neighbour approach on the combined data, have a RMS misfit of 4.6 kJ/kg (see Figure 3.12), only 0.1 kJ/kg greater than for the North American data alone.

3.6 Differences between MAT estimates at adjacent sites

MAT estimates, for samples taken at adjacent sites, made using the nearest neighbour methodology (CA transformation, N=19, D=3) are listed in Table 3.3. In all cases the estimate fell within 3°C of the actual MAT (either measured at an adjacent meteorological station or calculated using the regressions of [Norton, 1985]). Flaggy Creek in Australia where a riparian and non–riparian sample was collected, showed the biggest difference between MAT estimates made using the adjacent samples. Here the estimates straddled the actual MAT at the site and differed by 4.2°C. Whilst conclusions could be drawn about the effect of the proportion of riparian vegetation in the sample on the MAT, caution should be exercised because of the isolation of these two sites in physiognomic space. The discovery that relations between physiognomy and climate change through physiognomic space (see Chapter 2) suggests that the more isolated a sample, the less confidence we should have in climatic estimates from it. The nearest 10 sites to the Flaggy Creek samples are on average about 2.4 units away. This is in comparison to a typical value for most of the New Zealand sites of about 0.6 (see table 3.2). Whilst the two samples were collected with a view to investigating the difference in climatic signals between riparian and non–riparian vegetation the subsequent discovery that these sites are so isolated in physiognomic space precludes the drawing of any conclusion.

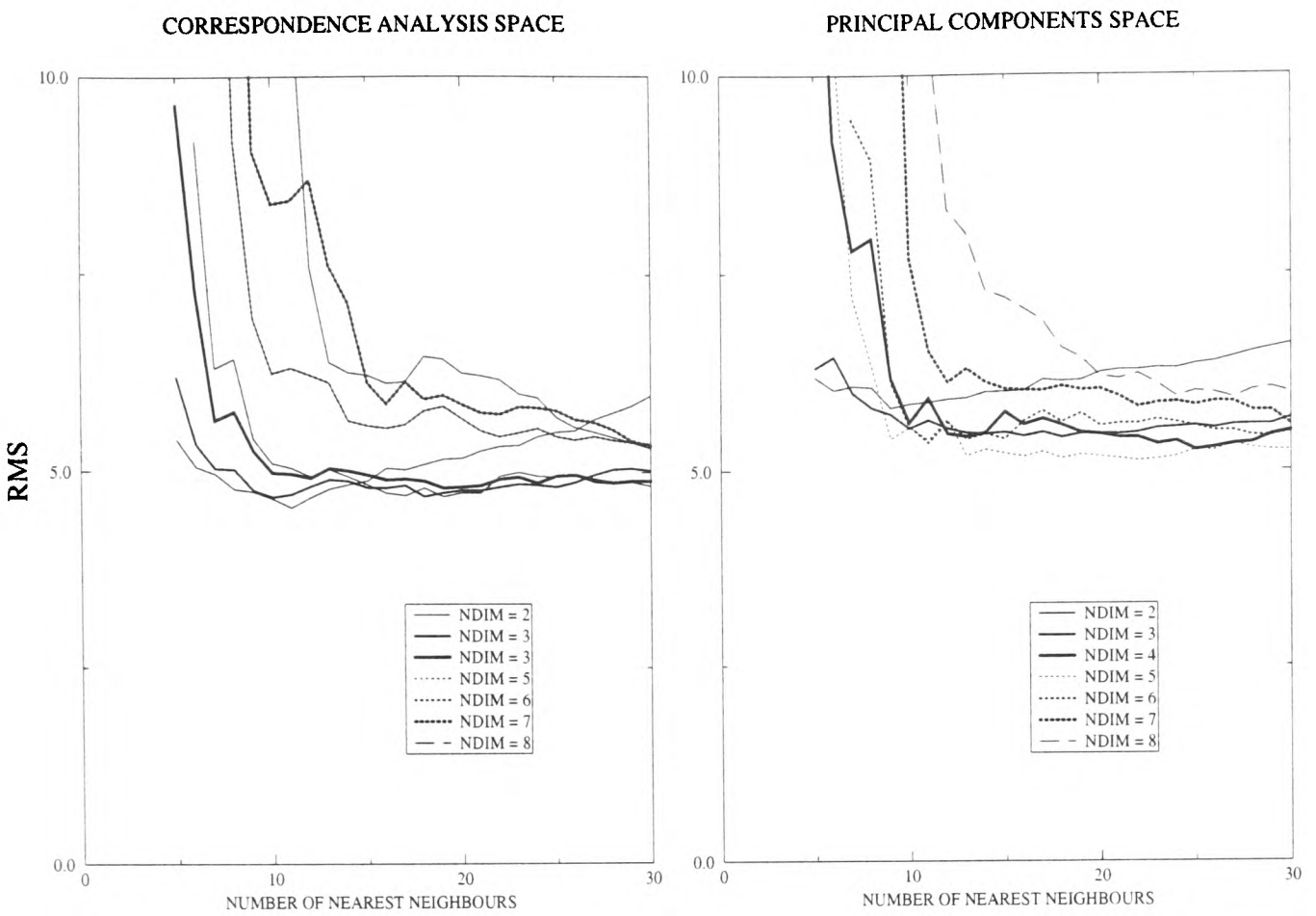


Figure 3.11: RMS misfit for moist enthalpy estimation for a range in number of nearest neighbours for the 92 North American sites in the CLAMP data set (Wolfe, 1993) varying also D (number of dimensions used in the calculation) and the transformation used to redescribe the data in terms of orthogonal axes (either correspondence analysis and PCA).

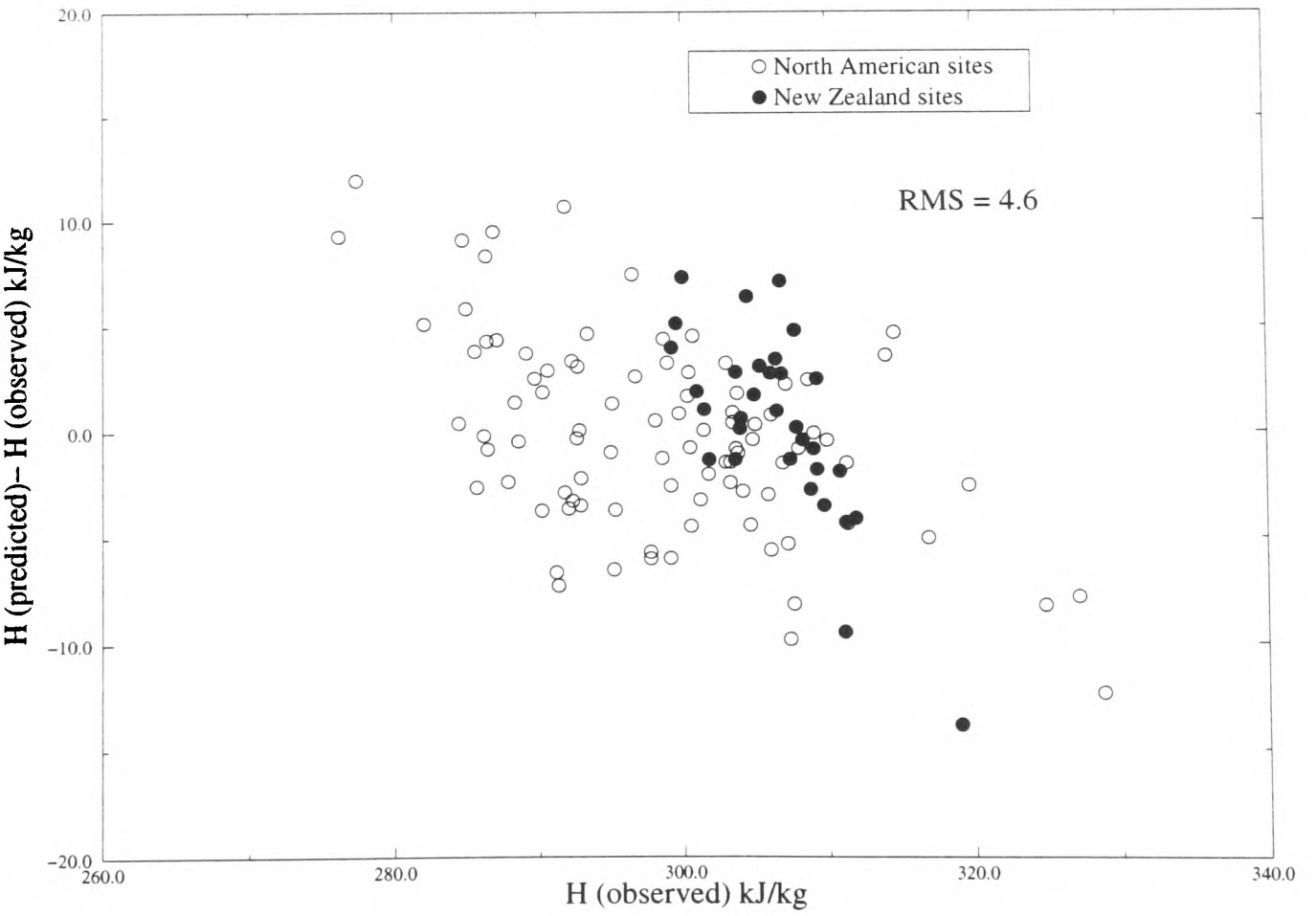


Figure 3.12: Misfits for moist enthalpy (predicted-observed) against H (observed) for all North American and New Zealand sites. Transformation used is correspondence analysis, D=3, N=19)

site name	site number	average distance from nearest ten neighbours
Otira Gorge one	OG1	0.81
Otira Gorge two	OG2	1.05
Otira Gorge three	OG3	0.52
Otira Gorge four	OG4	0.47
Otira Gorge five	OG5	0.54
Otira Gorge six	OG6	0.54
Alex Knob one	AK1	0.98
Alex Knob two	AK2	2.24
Alex Knob three	AK3	0.99
Alex Knob four	AK4	0.46
Alex Knob five	AK5	0.58
Link Track One	LT1	0.84
Link Track two	LT2	0.50
Link Track three	LT3	0.71
Link Track four	LT4	0.73
Tongariro one	T1	1.22
Tongariro two	T2	1.05
Tongariro three	T3	0.65
Tongariro four	T4	0.53
Punakaiki A	PA	0.61
Punakaiki B	PB	0.46
Ulva Island	UV	0.66
Lake Mary	LM	0.57
Okarito River Terrace	OK1	0.58
Okarito Glacial Moraine	OK2	0.82
Blue Duck Reserve	K1	0.52
Mount Fyffe	K2	0.65
Puhi-puhi	K3	0.54
Le Chateaux	LC1	0.95
Tronson Kauri Park	TK1	0.62
Banks Peninsula	BP1	0.58
Lady Lake	LL1	0.62
Flaggy Creek riparian	FC1	2.40
Flaggy Creek non-riparian	FC2	2.43

Table 3.2: Table showing average distance of southern hemisphere site from its ten nearest neighbours

Site name	Site number	MAT(°C)	estimated MAT(°C)
Punakaiki A	PA	12.3	11.3
Punakaiki B	PB	12.3	10.5
Okarito River Terrace	OK1	11.6	10.1
Okarito Glacial Moraine	OK2	11.4	10.8
Blue Duck Reserve	K1	12.0	9.9
Mount Fyffe	K2	11.0	9.4
Puhi-puhi	K3	12.0	9.4
Flaggy Creek riparian	FC1	25.0	23.5
Flaggy Creek non–riparian	FC2	25.0	27.7

Table 3.3: Table showing difference between mean annual temperature estimate using the nearest neighbour methodology at adjacent sites. For comparison the MATs measured at nearby meteorological sites or calculated using the regressions of Norton, 1985 are also included.

Transect name	Site number	altitude	MAT(°C)	estimated MAT(°C)	H (kJ/kg)	estimated H(kJ/kg)
Otira Gorge	OG1	945	5.9	7.6	301.0	302.9
Otira Gorge	OG2	840	6.5	7.9	304.0	304.1
Otira Gorge	OG3	700	7.2	10.8	305.3	308.4
Otira Gorge	OG4	550	9.3	10.9	306.8	309.5
Otira Gorge	OG5	400	10.1	10.2	308.2	307.8
Otira Gorge	OG6	140	11.5	11.1	310.8	308.9
Alex Knob	AK1	1222	5.7	4.7	299.2	303.2
Alex Knob	AK2	1045	6.6	8.6	300.0	307.3
Alex Knob	AK3	835	7.7	8.3	304.0	304.6
Alex Knob	AK4	625	8.7	10.8	306.1	308.8
Alex Knob	AK5	300	10.3	11.3	309.0	308.2
Link Track	LT1	1143	8.2	6.8	303.6	302.3
Link Track	LT2	1057	8.6	9.8	304.4	310.8
Link Track	LT3	1008	8.8	9.7	304.9	306.7
Link Track	LT4	825	9.8	11.5	306.7	313.9
Tongariro	T1	1400	6.6	11.4	299.5	304.7
Tongariro	T2	1170	7.8	12.5	301.8	300.5
Tongariro	T3	980	8.6	9.6	303.6	306.5
Tongariro	T4	690	10.1	11.8	306.5	307.5

Table 3.4: Table showing changes in moist enthalpy and MAT estimates with changing altitude in comparison to values for these variables measured at nearby meteorological sites or calculated using the regressions of Norton, 1985

The remaining three multiple sample sites fall in a well charted part of physiognomic space, close to numerous other New Zealand samples. At these sites there are two things to note. First the MAT estimates of adjacent sites are very close to one another (less than 1°C apart), and second that the adjacent sites MAT estimates fall on the same side of the actual climate as one another. Both samples at Okarito produce underestimates of the MAT at that location. The same is true for both samples at Punakaiki and all three at Kaikoura. The floras are 'seeing' the same climate at these adjacent sites, even though this value may differ from the measured (or estimated from regression equations [Norton, 1985]) value. Because an error is associated with the measured value of MAT, it is quite feasible that at these adjacent sites where MAT estimates using the nearest neighbour methodology are consistent, the apparent error in the estimate is in fact associated with the measurement error of the meteorological value.

Regardless of this it seems clear from these results that climatic signals from adjacent sites do not differ significantly from one another and that the climate–signal:noise ratio is high when climatic parameters are measured using the nearest neighbour approach developed here.

3.7 Change in MAT and moist enthalpy estimates within altitudinal transects

At the sites where altitudinal transects were taken few simple trends with altitude were apparent in the foliar physiognomy (see Chapter 2). The poor performance of the CLAMP methodology for climate estimation of southern hemisphere sites precluded any useful discussion of these transects in the light of our ability to extract altitudinal information from them using that methodology. Here I will look at the MAT and H estimates gained from the nearest neighbour approach developed in this chapter and discuss the potential, using that methodology, to extract altitudinal information from fossil floras.

The changes in estimated moist enthalpy and MAT are displayed in Table 3.4 along with the values for these parameters measured at nearby meteorological stations or calculated using the regression equations of [Norton, 1985] for MAT or extrapolating from nearby meteorological stations for moist enthalpy using Equations 3.5 and 3.6.

In the analysis of fossil floras to extrapolate altitude, rate of change of MAT or moist enthalpy with altitude is used. In the case of MAT this relationship is called the lapse rate and a common value used in the literature is -5.5°C/1000m [Axelrod & Bailey, 1976]. Consequently if we plot estimated MAT against altitude for our modern New Zealand altitudinal transects we would expect the gradient at individual transects to be approximately this value. In the case of moist enthalpy it follows from Equation 3.6 that

$$\Delta H = -g\Delta Z \tag{3.7}$$

If the estimated values of moist enthalpy (H) are plotted against the altitudes of the samples we should expect to see a straight line of gradient -g ($-9.8m/s^2$). Both moist enthalpy estimates

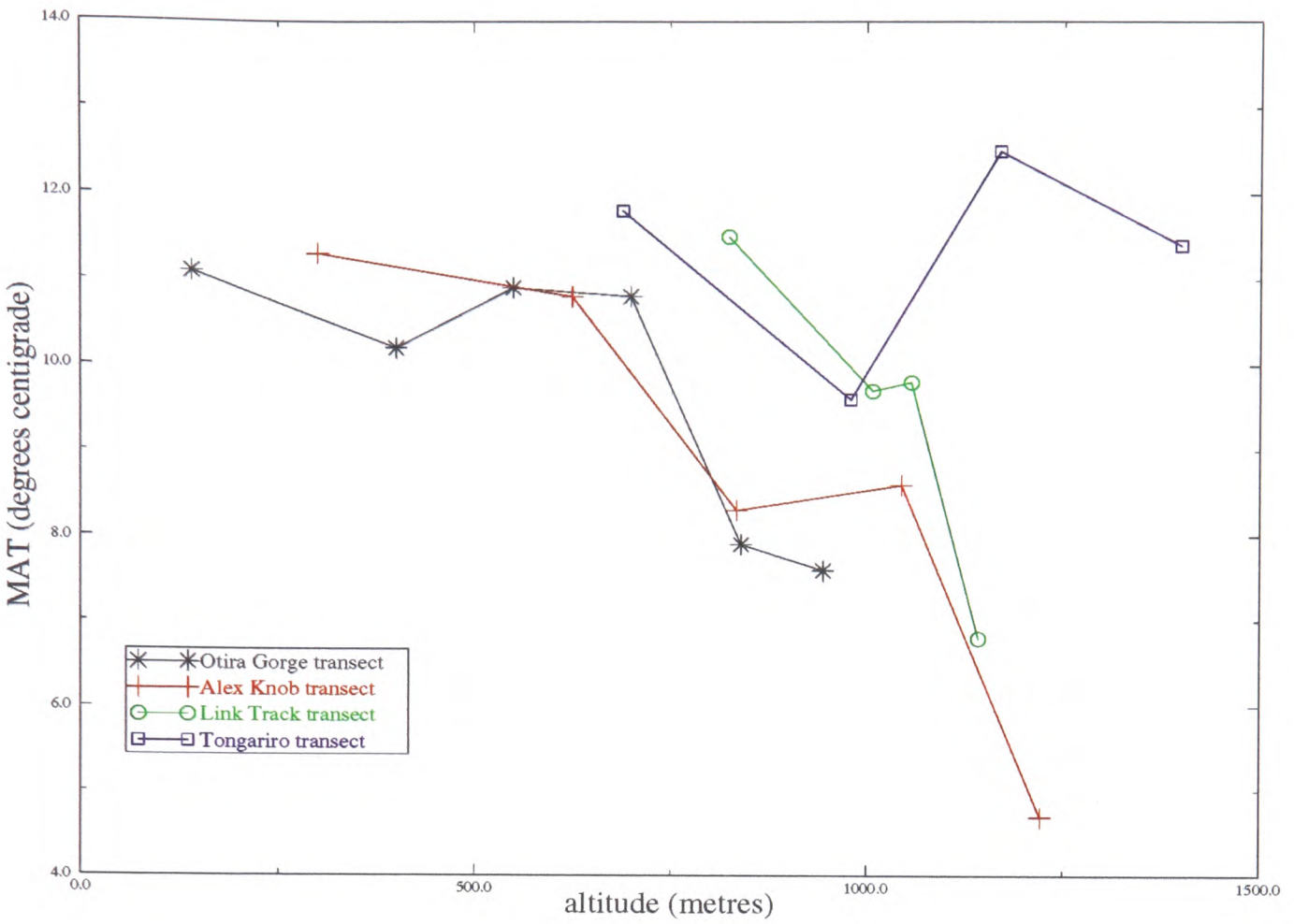


Figure 3.13: MAT (°C) estimated using the nearest neighbour methodology plotted against altitude for the four altitudinal transects

and MAT estimates are plotted against altitude (see Figures 3.13 and 3.14).

As expected, overall both MAT estimates and H estimates show a negative correlation with altitude. Locally however within each transect there are large fluctuations and even reversals in the slope of the plots. Indeed the Tongariro Park transect shows anomalously high values for both MAT and H at the highest altitude. This transect was collected from the slopes of an active volcano, and it seems feasible that this phenomena is in part attributable to the edaphic and climatic conditions brought about by regular eruptions.

In general one can perceive local altitudinal changes in the physiognomy of woody dicotyledon leaves, but these data show that even locally, where the signal is not complicated by factors such as continentality or latitudinal variation there is a fair amount of noise. Consequently to base altitudinal discussions on individual fossil floras is unwise. A good picture of surface elevation should be gained however if numerous fossil floras are examined using either moist enthalpy or altitude.

3.8 Conclusions

The nearest neighbour approach presented in this chapter shows the following advantages over the CLAMP methodology of Wolfe [1993]. First, whilst both methodologies split the data, the nearest neighbour approach is more theoretically defensible because the data is split on mathematical rather than subjective grounds. This is a more satisfactory way of dealing with the

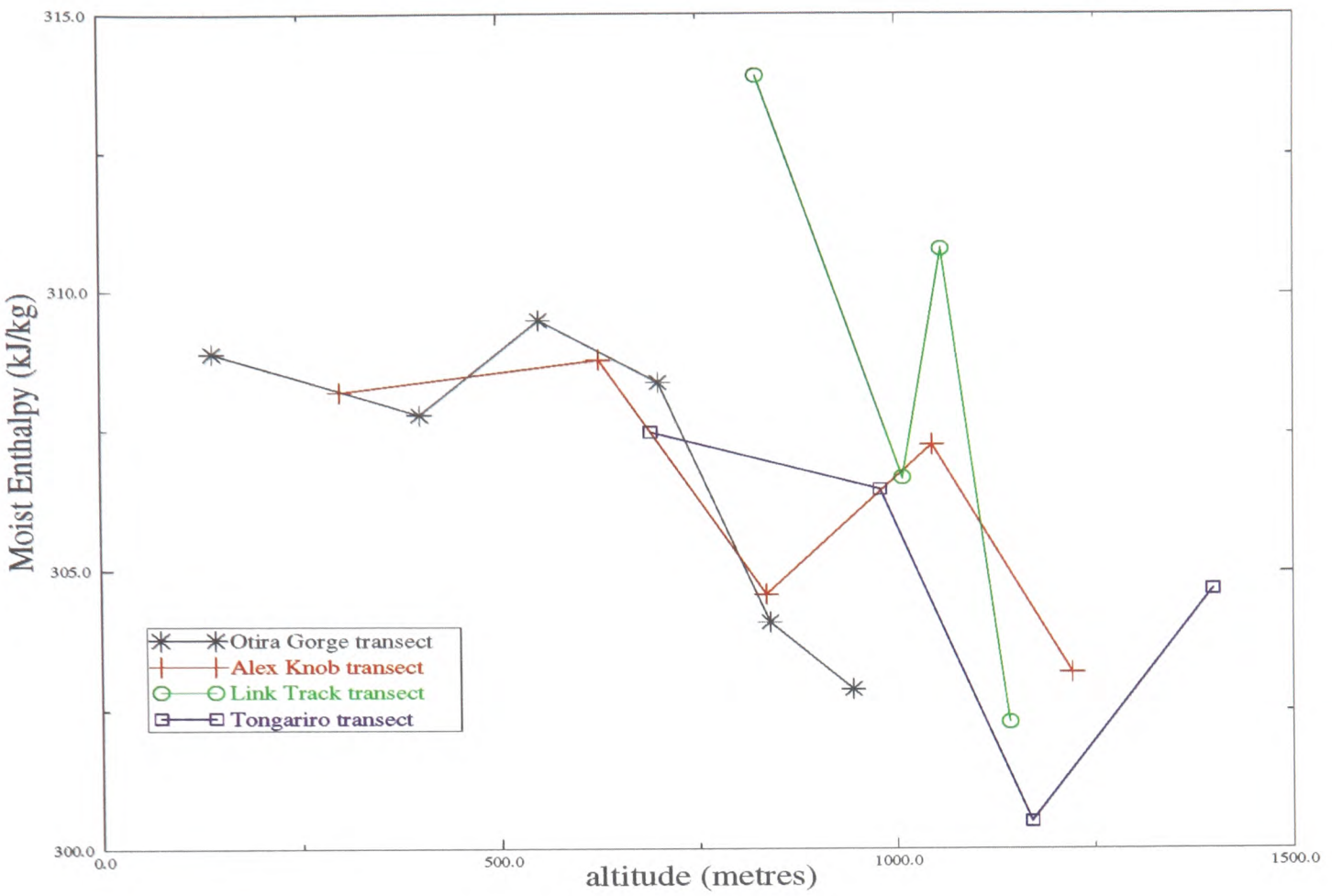


Figure 3.14: H (kJ/kg) estimated using the nearest neighbour methodology plotted against altitude for the four altitude transects

non–global nature of the physiognomic data's relationship with climate and produces better estimates of MAT for the problematic low temperature samples. Second it incorporates information from the third axis that appears to be important in terms of assessing the sample's physiognomic relationship with climate. The third advantage is that the resemblance structure allows us to look at the position and relative isolation of a fossil site. There appears to be potential for assessing the validity of any climatic estimates using this information. Climatic estimates from physiognomically isolated samples cannot be trusted because of the non–global nature of these data, combined with the well known dangers of extrapolating beyond the extent of the data.

Of the two ordinations used here to reduce the dimensionality of the data set, correspondence analysis performs consistently better than principal component analysis in its selection of climatically significant (useful) axes. This in combination with the theoretical weakness of PCA when used in combination with compositional data (See Section 3.2.2) leads me to advocate that CA be used when the nearest neighbour approach is applied to fossil floras. The results presented above show that the first three axes should be used in order to produce the best estimates of all climatic parameters investigated here. The best results are obtained when 19 nearest neighbours are used to form the estimate of the climatic parameter.

Both the nearest neighbour approach and the original CLAMP methodology agree that the signal for precipitational parameters is less strong than for temperature. Moist enthalpy [Forest *et al.*, 1995] also has a strong signal in the physiognomic data set although the basis for this relation is less clear. In general the results from the nearest neighbour experiments,

which look to extract information from the data in a very different way to Wolfe's methodology, corroborate his conclusion that useful climatic information is contained in the physiognomy of woody dicotyledon leaves. These results show the robustness of the data set and its potential use in the fossil record to ascertain climate and altitude, but indicate that local rather than global relationships exist between climate and physiognomy.

The collection of different samples from adjacent sites shows that the climate–signal:noise ratio is high, especially in areas of physiognomic space where there is locally a high number of samples. Peripheral samples with more distant nearest neighbours have a lower climate–signal:noise ratio. It seems likely that this could be at least partially rectified by the collection of more modern floras, although we should accept that there may be areas of climatic and therefore physiognomic space occupied by fossil floras that cannot be sampled in the present day.

The estimation of altitude from physiognomy has lowest errors when moist enthalpy rather than MAT is used. Individual errors in altitudinal estimates using moist enthalpy can still be as high as 700m. This, in combination with the fact that any fossil flora represents only a point on the earth's surface and cannot be used as a meaningful indication of average surface elevation, means that many coeval floras are required to build an accurate picture of surface elevation at any point in time.

Chapter 4

Taphonomic investigations at Lady Lake, Westland, New Zealand. Potential biases in the fossil record on physiognomic character states of woody dicotyledon leaves.

4.1 Introduction

As discussed in Chapter 1, a climatic signal is strongly displayed in the physiognomy of living vegetation [Wolfe, 1979; Richards, 1952; Raunkiaer, 1934]. Such a signal however, will to some extent become distorted by transport, burial, and diagenetic processes inherent in fossilization. Thus to interpret palaeoclimatic signals from fossil leaf assemblages, a sound understanding of how the physiognomic signals may be biased by these processes, is required. Taphonomy is the study of these biases. It quantifies how well the fossil record represents the living assemblage which is the ultimate source of climatic information. The answer to this question, depends heavily upon how we measure the similarity. In other words, the way in which we choose to characterise modern floras affects the accuracy with which we perceive them to be represented in the fossil record.

To illustrate this point, there are numerous ways in which we might characterise a source vegetation. These include: taxonomic diversity, species abundance and foliar physiognomy. It

is not difficult to envisage a fossil flora that poorly represents the species abundance of the source vegetation, whilst accurately representing its range of foliar physiognomy. In addition the geographic scale of the source vegetation [Burnham, 1989] and the accumulation time of the fossil assemblage [Meldahl *et al.*, 1995] will affect the accuracy with which we can expect it to be represented in single leaf beds.

Taphonomic biases (however measured) differ from one depositional environment to another. This is a result of the potential variation in the numerous factors that affect foliar taphonomy. Such factors include climate, sedimentary regime, water chemistry, matrix type, and the physical properties of the species of leaves present, such as their resistance to degradation by microbial attack and transport, and their hydrodynamic properties. For this reason, caution should be exercised in drawing general conclusions from individual taphonomic studies.

4.2 Previous work on foliar taphonomy

Since the realisation of the potential for using fossil leaves quantitatively as palaeoclimate indicators there has been an ever increasing body of work devoted to the taphonomy of fossil leaves. This work falls into two main categories. The first, sometimes referred to as a live/dead approach [Meldahl *et al.*, 1995] investigates the representation of live vegetation in adjacent to depositional environments. Leaves retrieved from litter fall traps or recently deposited sediments are compared to the surrounding vegetation. The majority of this work has been conducted in lacustrine settings [McQueen, 1969; Rau, 1976; Roth & Dilcher, 1978; Drake & Burrows, 1980; Spicer, 1981; Hill & Gibson, 1986], though fluvial sediments, [Burnham, 1989; Scheihing & Pfefferkorn, 1984] and flood-plain environments have also been investigated [Johnson, 1988].

A second approach, uses experimentation in a controlled environment to investigate parameters such as rates of lamina decomposition and degradation, and the dynamic properties of leaves in water or air [Spicer, 1975, 1981, 1980]. Much of this work has been summarised in Ferguson [1985]. The application of these results to the fossil record is complicated because of the large number of simultaneously operating processes that result in the formation of allochthonous plant fossil deposits.

4.2.1 Knowledge of physiognomic biases in foliar taphonomy

Foliar taphonomic studies have tended to concentrate on taxonomic biases. Physical properties of species (including physiognomy) are often cited as explanations for taphonomic biases in taxonomy, but only rarely investigated in their own right. When they are tackled, they are generally treated in a univariate way, looking at individual physiognomic categories [Roth & Dilcher, 1978; Burnham, 1989]. Of the six physiognomic categories used by Wolfe [1993]: margin, size, shape, apex, base and L:W ratio, only size and marginal characteristics have been closely examined using the live/dead approach. With regard to margin type, Burnham [1989] shows

that leaf margin ratios, (teeth:no–teeth) are reasonably well represented in single litter samples with an agreement of ±14%. Other margin characteristics such as tooth shape have not been investigated. Opinion on how size categories are affected by taphonomic processes agrees that smaller leaves tend to travel further from the parent tree than larger ones [Ferguson, 1985]. This is not least because sun leaves, which are generally smaller than other leaves on the same individual, are positioned high on the plant and are more prone to wind dispersal [Spicer, 1975]. One recognised taphonomic bias arising from this is that, in an open lake situation, distal sediments may be enriched in these small wind transported sun leaves [Spicer, 1975; Roth & Dilcher, 1978]. Roth and Dilcher observed that, using a univariate leaf size analysis to estimate climate, where leaf size is positively correlated with temperature and wetness, lake sediment samples yielded a colder and drier climatic interpretation than the surrounding vegetation. This analysis however did not use leaf fragments to estimate the upper size limits of species. 'Shape' which loosely covers the remaining four categories is thought to have little effect on differential leaf dissemination [Spicer, 1981; Ferguson, 1985].

4.2.2 How physiognomic studies of climate have tackled taphonomic bias in the fossil record

In any study attempting to use the physiognomy of fossil floras to infer palaeoclimates there are two steps. The first, is to investigate and describe the link between modern floras and climates. The second, is to use that relationship to estimate palaeoclimate from the physiognomy of fossil floras. The degree to which our modern collections represent what is found in the fossil record must be assessed if climatic estimates are to be meaningful. Early palaeobotanical climate investigations [Bailey & Sinnott, 1916; Wolfe, 1971] concentrated on finding and describing the link between physiognomy and climate. Understanding the degree to which that relationship might be discernible in the fossil record was not considered until that link was well established.

More recently, workers have acknowledged taphonomic bias and attempted to tailor the modern collections used in the comparison of physiognomy with climate, in order to mimic the sampling of the fossil record. Christophel and Greenwood [Greenwood, 1992; Christophel & Greenwood, 1989] attempt to by-pass taphonomic questions altogether by rolling both steps into one, using modern leaf beds rather than modern vegetation to measure physiognomic signals. In this quest to eliminate taphonomic problems however, the goal of gaining quantitative climatic estimates is abandoned. They settle instead, for characterising forest types with physiognomic fingerprint signals.

The approach of using leaf beds as opposed to living vegetation, may still appear an attractive route for obtaining qualitative climatic estimates from fossil floras. To use this approach however, is to side–step, but not eliminate the problem of taphonomy. A relationship between physiognomy and climate exists in living floras, such that a climatic signal may be detected in the physiognomy of those floras. The physiognomy of a fossil flora contains a climatic

signal overprinted by noise, some of which is attributable to taphonomic bias. This bias is not constant, as it depends on many variables including the attributes of the leaves of the species in the source flora, and the environments of transport and deposition. Taphonomic signatures differ with process and are not specific to particular forest types. Our aim should be to estimate the possible bias on the physiognomic signal, enabling us to put appropriate error bars on our climate estimates. To measure the physiognomic signal of a modern leaf bed, is to measure the physiognomic signal of the surrounding flora with a taphonomic bias already incorporated. As discussed in Section 4.1 this bias is variable, and therefore the bias incorporated into the modern sample will not necessarily equate with that incorporated in the signal from a fossil flora. The bias itself has not been quantified and consequently we are no closer to being able to put error bars on our climatic estimates.

How CLAMP deals with potential taphonomic bias

It is clear that Wolfe [1993] considered taphonomic bias in his attempt to construct a robust and valid method for comparing the floras of the fossil record to modern plants. His choice of sampling and scoring methodology, and of numerical analysis, are all strongly influenced by these considerations (see Table 4.1).

MacGinitie [1953] concluded that fossil floras are strongly biased towards riparian vegetation; accordingly Wolfe [1993] ensured that all modern physiognomic collections sampled the riparian vegetation fully. The working hypothesis that fossil floras are furnished with leaves from a limited area only is the basis for Wolfe's selection of a restricted geographic area, generally between one and five hectares, for the collection of modern sites. Within the literature there is strong evidence to support the claim [Burnham, 1989; Spicer & Wolfe, 1987] that the *majority* of leaves do in fact come from a very localised area. In addition however, several studies have shown that isolated leaves travel a lot further [McQueen, 1969; Drake & Burrows, 1980; Hill & Gibson, 1986]. McQueen suggested that such transport is most likely in an area of high topography where high energy streams are able to transport leaves over large distances. He reported leaves of *Nothofagus cliffortiodes* and *N. fuchsia* found in a river bed 8 km from and 600 m below the lowest station of these trees, and leaves. Drake and Burrows (*op. cit.*) observed leaves on a beach in Lady Lake that have travelled at least 3 km. *Olearia colensoi* and *Dracophyllum traversii* are both strictly subalpine and must have been derived from plants growing near the timber line. In itself, this may not appear to be a great problem, except when it is considered in conjunction with another working hypothesis used by Wolfe in constructing his methodology. This is that abundances within the fossil record do not correspond to species abundance in the original flora. This taphonomic bias is countered in Wolfe's methodology by weighting all species, irrespective of their abundance, equally. In combination with the restricted geographic nature of the modern samples this introduces a potential problem: a single leaf from a different altitude, and therefore a different climate regime, counts with equal weighting to the most abundant local species. Consequently a single fossil, out of a collection of possibly hundreds, representing a

WORKING HYPOTHESIS	EVIDENCE AGAINST	EVIDENCE FOR	COLLECTION STRATEGY
Riparian vegetation is overrepresented in fossil assemblages		MacGinitie 1953	Wolfe, 1993 advocated that all riparian species are sampled first, before the collection is expanded into the non-riparian vegetation
Large leaf sizes are underrepresented		a) Wolfe, 1981 observes that larger leaves are fragmented. b) Richards, 1952 noted that there is potential for unequal size distribution with depositional environment c) Spicer 1981, observes a bias towards smaller sun leaves	Leaf range estimated using both whole leaves and fragments
Fossil beds are furnished from a limited geographical area	McQueen 1969, Drake and Burrows 1980, Hill 1986	Burnham 1989 Spicer and Wolfe, 1987	Modern floras are collected from areas limited to between 1 and 5 hectares
Species abundance within the fossil record does not correspond to true abundance in source flora			All species collected are given equal weighting irrespective of their abundance
The overrepresentation of broad–leaved evergreens in fossil assemblages	Ferguson, 1985 suggests that because evergreens in temperate regions live longer than deciduous leaves they are underrepresented in the fossil record	Roth and Dilcher, 1978 suggest that evergreens are overrepresented in the fossil record because they are shed in the spring when precipitation and therefore the rate of sedimentation is high	Advocates the scoring of leaf fragment to counter any bias

Table 4.1: Working hypotheses incorporated into the collection technique of Wolfe, 1993

distal species, could significantly increase the noise/signal ratio of the climatic signal.

Size differentiation due to both the fragmentation of larger leaves during transport [Wolfe, 1971, 1969] and the differential transport by wind of smaller sun leaves over shade leaves [Spicer, 1981] is one potential source for bias. To overcome this Wolfe (1993) states that the maximum size score for fossil floras be estimated from leaf fragments. Wolfe also points out that the preferential destruction of comparatively thin deciduous leaves might cause an over representation of broad–leaved evergreens in fossil assemblages, and again advocates the scoring of leaf fragments to counter this bias.

4.3 Live/dead taphonomic experiment in Lady Lake

The taphonomic studies that Wolfe considered in the construction of his methodology were univariate. To assess how successfully he has constructed a taphonomically robust methodology however it was tested in a multivariate system.

In order to begin to assess the size of errors introduced by taphonomic biases it was essential to compare the climatic signal obtained from a CLAMP sample to that obtained from leaves trapped in adjacent sediments. This enabled me to question the assumption that fossil floras accurately reflect the physiognomic, and therefore climatic signal, that would have been obtained from a CLAMP sample collected in the vegetation immediately adjacent to the depositional environment.

To this end leaves were taken from lake bottom sediments and scored for the 29 physiognomic variables used in the CLAMP methodology. These scores were compared to the scores obtained from leaves on herbarium specimens collected from the surrounding vegetation using the CLAMP collection technique describe in Wolfe [1993]. In some of the most recent publications using the CLAMP methodology, [Wolfe, 1995; Herman & Spicer, 1996] the CLAMP data set has been expanded to 31 physiognomic variables by splitting the smallest and largest size categories into two. The data discussed here was amassed before this change. It is believed however, that any significant trends or biases in the size characteristics of lake bottom samples will be discernible using 7 as opposed to 9 size categories.

4.3.1 Previous work at Lady Lake

Lady Lake, a small lake on the west coast of South Island in New Zealand (see Figure 4.1) was chosen to conduct taphonomic studies concentrating on potential physiognomic biases in the fossil record. This lake was considered ideal not least because two taphonomic studies have been carried out there, although both with a taxonomic slant [Drake & Burrows, 1980; Pocknall, 1980]. Drake and Burrows conducted a taphonomic study of macrofossils including leaf fragments, and Pollock, of microfossils. It is hoped that the present study will tie in to these previous two giving a integrated taphonomic picture of the field area.

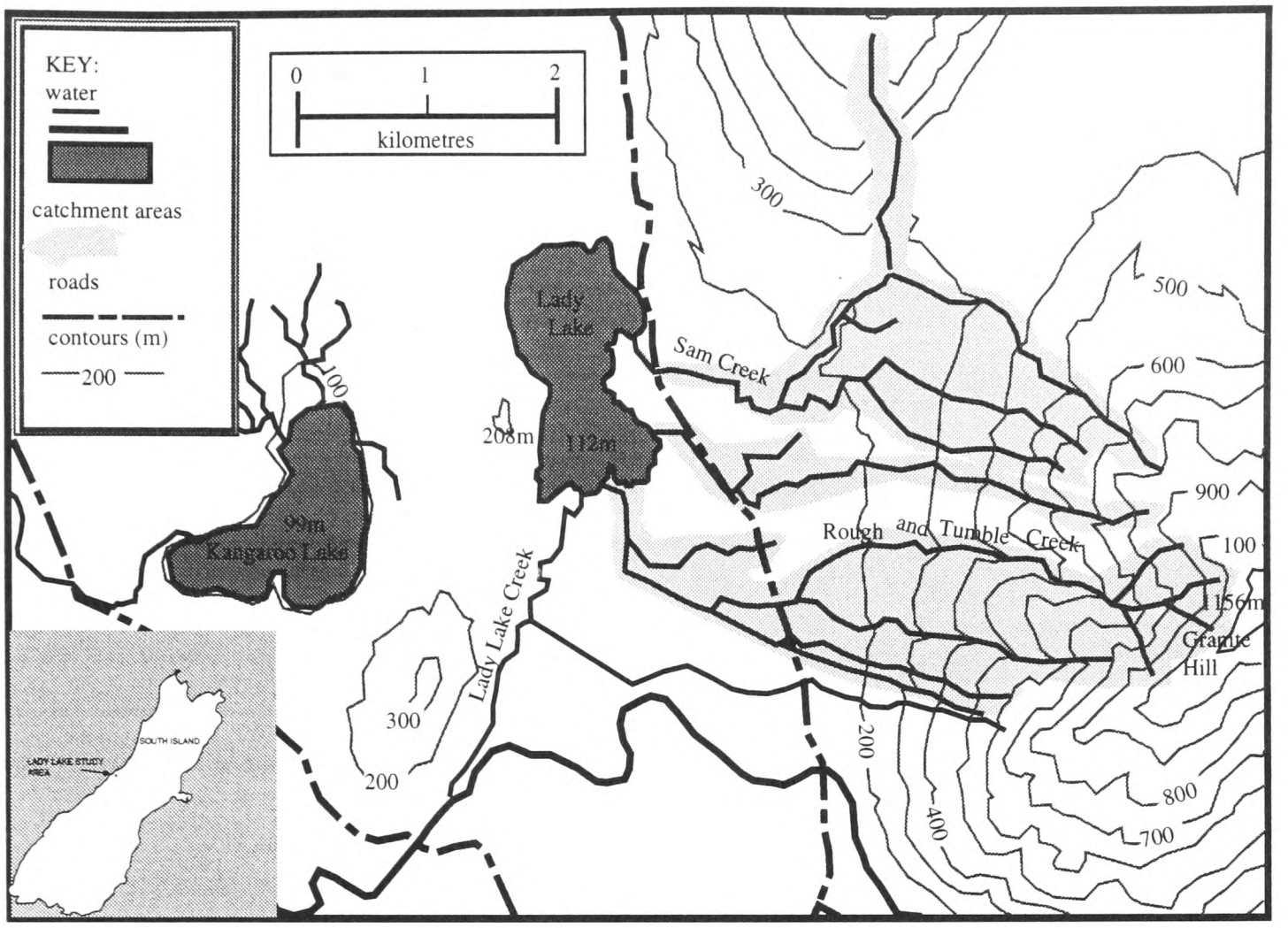


Figure 4.1: Map showing the locality and drainage pattern of Lady Lake in South Island, New Zealand

4.3.2 Location and description of Lady Lake

Situated on the lower western slopes of the Southern Alps, Lady Lake (46.6°S, 171.57, altitude: 112m) is a glacially formed lake, bounded to the north, west and east by glacial till and dammed at the southern end by alluvial gravel. It has an area of 1.75 km^2 and a maximum depth of 21.4 metres. This large depth:surface–area ratio results in organic rich sediments because oxygen diffusion rates are proportional to surface area, and because oxygen–producing rooted macrophytes are limited to shallow water. Its two main in–flowing streams are Sam Creek and Rough and Tumble Creek, both of which rise on Granite Hill (1156m) to the east (see Figure 4.1). The tributaries to Rough and Tumble Creek rise at close to 1000 metres above sea level; 900 metres above Lady Lake, whilst Sam Creeks tributaries start just under 800 metres above the lake. The lake drains into Lake Brunner to the west via Lady Lake Creek and Crooked River. Sam Creek enters the lake on the eastern side. It is at its delta that the taphonomic studies at Lady Lake have been conducted.

4.3.3 Description of surrounding vegetation

A vegetation survey around Lady Lake was carried out in conjunction with the taphonomic study conducted by Drake & Burrows [1980]. An inspection of areal photographs from 1979, 1984 and current maps shows that the distribution of vegetation around Lady Lake has changed little since this survey was conducted 16 years ago. There are three main types of vegetation around Lady Lake as described by Drake & Burrows [1980]. These are listed below and their

areal extent shown on Figure 4.2.

1) Areas of swamp dominated by monocotyledon vegetation skirt the eastern flank of Lady Lake and form the bulk of the vegetation found that encompasses the southern half of the lake margin (vegetation type 6 in Figure 4.2).

2) Podocarp/hardwood forest with *Weinmannia racemosa Quintinia acutifolia*, Rimu, Miro and Pokaka (*Elaeocarpus hookerianus*) extends right to the water's edge on the western shores of the lake. On the eastern side of the lake its western limits are approximately denoted by the road (vegetation types 1 and 2 in Figure 4.2).

3) Area running from Sam Creek to the road bridge west of the lake is an area rich in woody dicotyledon species. Drake & Burrows [1980] use total circumference per hectare by species as an approximation for leaf density and give nine species in this area as important single contributors. Of these, two are ferns, two gymnosperms, and the remainder are woody dicotyledons: *Metrosideros diffusa, Weinmannia racemosa, Carpodetus serratus, Quintinia acutifolia* and *Coprosma propinqua* (includes vegetation types 1, 2, 3 and 4 in Figure 4.2).

In the wet climate of the west coast of New Zealand the riparian vegetation is not very distinct from the slope vegetation with several species growing happily in both areas. Drake and Burrows (*op cit*) list the following dicotyledon species as common along the banks of Sam Creek: *Pseudowintera colerata, Melicytus ramiflorus, Fuchsia excorticata, Coriara arborea, Metrosideros diffusa, Aristotelia serata, Weinmannia racemosa, Carpodetus serratus, Rubus schmidelioides, Penantia corymbosa, Pseudopanax crassifolius, Schefflera digitata* and *Coprosma propinqua.*

The few aquatic species that grow in the lake itself (*Eloda sp. Myrophyllium sp.*, Charophytes,*Potamogeto sp., Typha orientalis, Eleocharis sphacelate* and *Juncus sp.*) were not found in great quantities in the lake sediment [Drake & Burrows, 1980]. They attributed this to the buoyancy of these species remains because they are so well represented in leaf litter washed up on a small beach on the western side of the lake.

The differing properties of evergreen and deciduous leaves must surely result in taphonomic biases towards one or the other. Ferguson [1985] argues that because in temperate climates evergreen leaves tend to live for much longer than the seven months that a deciduous leaf commonly survive, evergreen leaves might be under–represented in a flora containing both evergreen and deciduous trees. In contrast Roth & Dilcher [1978] argue that, because evergreens shed their leaves in the spring when there is often higher precipitation and consequently a higher influx into sedimentary environments, evergreens will be over–represented in the fossil record. On the other hand, summer degradation rates will tend to be higher because of higher temperatures, such that higher sedimentation rates are required if proto–fossils are to be buried before they decay. It is clear that the effects of the habit of a species on the preservation potential of its leaves are not well understood. In the context of looking for taphonomic biases caused by physiognomic differences this presents a problem. If a physiognomic character were highly correlated with the deciduous or evergreen habit, a taphonomic bias might be perceived in that character, as a result of the higher preservation potential of one or other of these habits. The vegetation around

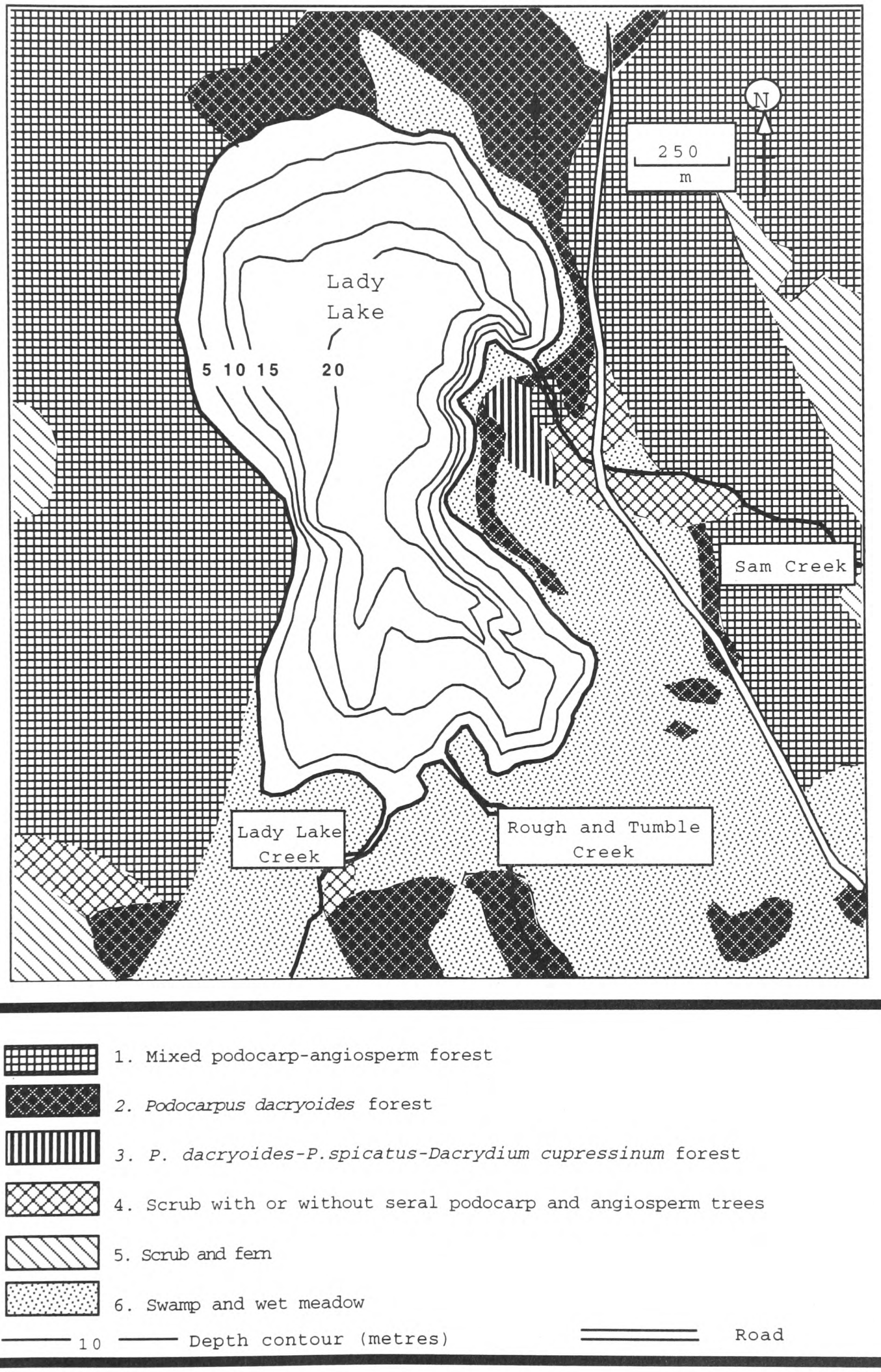


Figure 4.2: Vegetation surrounding Lady Lake, adapted from Drake and Burrows, 1980

Lady Lake, in keeping with the vegetation of New Zealand, is almost entirely evergreen. The only deciduous woody dicotyledons found in the CLAMP samples collected there, are *Fuchsia excorticata* and *Hoheria lyellii*. The almost completely evergreen nature of the New Zealand flora reduces the number of non–physiognomic taphonomic biases, consequently simplifying the task of understanding and analysing my results. This simplification is not applicable to all fossil floras and so serves to reiterate that care should be taken in generalising too broadly from the results presented here.

4.3.4 Questions raised by the Drake and Burrow (1980) taphonomic study

Several conclusions drawn in this previous study raise questions that should be addressed about potential sources for physiognomic bias in lake sediment assemblages specifically when physiognomy is measured using the methodology proposed by Wolfe [1993]. The first of these is that some species such as *Aristotelia serrata* and *Carpodetus serrata*, whilst ubiquitous in the living vegetation, are scarce in the lake sediments. This makes us question how the physiognomic signature for individual species might be affected by a paucity of samples. In addition we might ask, how robust is the physiognomic signal for a site measured using the CLAMP methodology which does not take into account abundance of species, and how is it affected by the absence or paucity of samples from a individual species. Conversely, some species are overrepresented in lake sediments, especially those species common only in river bank environments and scarce elsewhere in the forest. This bias was also taken into account in the methodology used for the collection of CLAMP samples, [Wolfe, 1993] with riparian species being thoroughly collected at all sites. How well this approach counters such biases will be investigated in this study. One final observation made in the 1980 study, is that individual specimens of species growing a great distance from the study site are represented in the sediment assemblage (see Section 4.2.2). The potential problem of increased noise in the climatic signal of the lake bed assemblage is investigated here.

4.3.5 Description of the sampling area at the Sam Creek Delta

Sam Creek flows into Lady Lake on the east bank. A band of swampy monocotyledon vegetation borders the lake all along this eastern bank such that no woody dicotyledon species overhang the lake in this region. The influx of vegetation into the lake by means other than fluvial is consequently minimised. The delta itself is asymmetrical with an active channel flowing on its eastern flank and the remains of an abandoned channel on its western flank. A rhomboidal tongue of gravel protrudes into the lake between these two channels. The gravel fines towards its apex. The western side is open to the main body of the lake and is severely over–steepened by wave action (see Figure 4.3). At a depth of three metres a thick organic mat comprising vegetation debris becomes established. This mat is laterally extensive across the delta front and extends far into the lake.

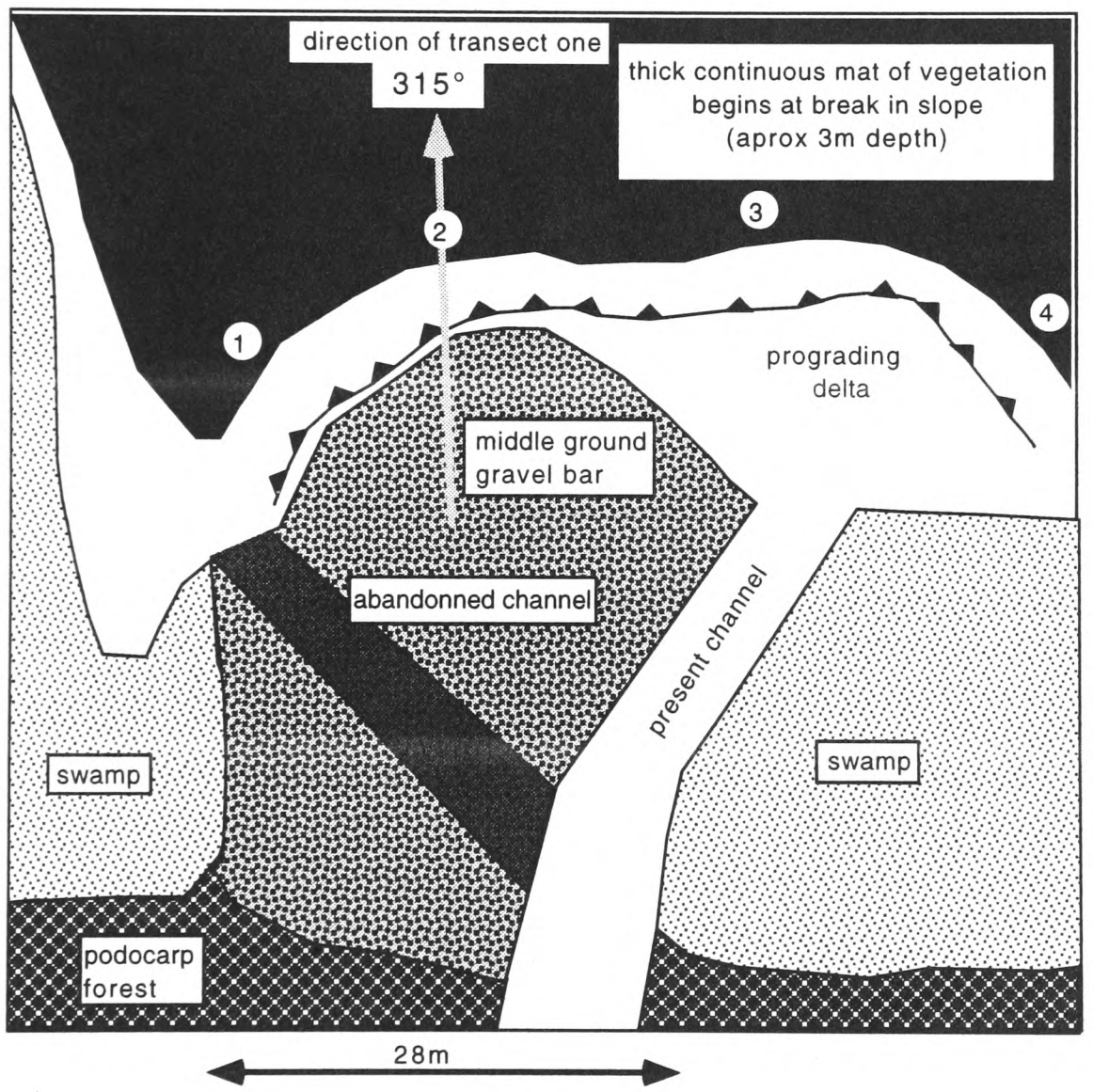


Figure 4.3: Sketch showing sample sites along transect two (numbered 1 to 4)

site number	1	2a	2b	3a	3b	3	4	5	6	7(6b)	8	9	10
distance from shore (m)	10	20	20	30	30	30	40	50	75	75	100	150	200
depth of sample (m)	5.9	8.5	8.5	8.5	8.5	8.5	11.0	11.0	11.3	11.3	14.5	16.0	16.3
number of species	15	13	10	9	14	11	13	20	5	16	5	14	7
Lobed	0	0	0	0	0	0	0	0	0	0	0	0	0
no teeth	50	42.31	60	50	67.86	70.83	65.38	45	50	68.75	60	75	71.43
teeth regular	25	23.08	10	16.67	17.86	8.33	11.54	8.33	20	6.25	20	16.67	28.57
teeth close	14.29	23.08	10	11.11	14.29	4.17	11.54	10.53	10	9.38	10	12.5	21.43
teeth round	21.43	23.08	10	22.22	14.29	8.33	11.54	20	40	12.5	40	16.67	14.29
teeth acute	28.57	34.62	30	27.78	17.86	20.83	23.08	35	10	18.75	0	8.33	14.29
teeth compound	7.14	7.69	0	13.89	7.14	0	3.85	2.63	5	6.25	0	4.17	14.29
lepto 1	4.71	8.33	0	18.75	0	20.83	13.83	13.89	10	31.25	46.6	55.5	41.67
lepto 2	9.5	2.08	25.89	12.5	19.85	23.58	4.83	2.78	16.6	8.31	26.6	11.08	30.5
micro 1	30.93	18.75	25.89	29.13	35.23	22.17	20.08	35.17	36.6	2.06	16.6	4.17	5.5
micro 2	41.64	52.08	48.11	35.38	39.08	22.17	40.92	39.33	36.6	52.06	10	20.83	22.17
micro 3	13.07	18.75	0	4.13	5.77	2.75	20.08	8.78	0	6.25	0	8.33	0
meso 1	0	0	0	0	0	8.33	0	0	0	0	0	0	0
meso 2	0	0	0	0	0	0	0	0	0	0	0	0	0
apex emarginate	9.09	0	0	0	9.09	41.67	0	21.43	25	14.29	0	22.22	0
apex round	36.36	55	68.75	58.33	43.91	70.83	60	40.43	62.5	57.14	90	72.22	87.5
apex acute	45.45	40	6.25	25	48.45	16.67	25	47.57	37.5	28.57	10	16.67	12.5
apex attenuate	18.18	5	25	16.67	7.55	12.5	15	11.86	0	14.29	0	11.11	0
base cordate	7.69	0	0	0	0	0	0	7.5	20	6.25	0	18.18	0
base round	76.92	90.91	83.33	88.89	84.62	83.33	69.23	57.5	70	87.5	40	72.73	75
base acute	15.38	9.09	16.67	11.11	15.38	16.67	30.77	35	10	6.25	60	9.09	25
L:W<1:1	0	0	0	0	0	9.09	0	0	0	6.67	0	22.22	0
L:W 1-2:1	22.73	28.3	59.22	69	31.92	33.27	10	37.94	60	38.87	70	33.33	63.83
L:W 2-3:1	45.45	48.3	20.33	26.14	44.42	42.36	75	34.22	40	45.53	20	38.89	13.83
L:W 3-4:1	27.27	18.3	20.33	4.71	15.25	10.55	15	12	0	8.87	10	5.56	22.17
L:W>4:1	4.55	5	0	0	8.33	4.55	0	15.72	0	0	0	0	0
shape obovate	9.09	5	5.56	6.25	12.5	22.73	33.33	22.22	0	16.67	20	5	0
shape elliptical	77.27	80	72.22	87.5	70.83	68.18	58.33	61.11	80	66.67	60	75	80
shape ovate	13.64	15	22.22	6.25	16.67	9.09	8.33	16.67	20	16.67	20	20	20
total	127	104	87	77	122	123	56	244	13	138	30	75	21
whole leaves	39	12	17	24	37	44	42	60	11	59	12	40	12
whole/total	0.31	0.12	0.2	0.31	0.3	0.36	0.75	0.25	0.85	0.43	0.4	0.53	0.57

Table 4.2: Physiognomic scores of transect one taphonomic samples

4.4 Materials and methods

4.4.1 Collection of CLAMP samples from living vegetation adjacent to Lady Lake

Two CLAMP samples were taken from the living vegetation adjacent to Lady Lake. The first (LL1) was taken from the species–rich area of vegetation along Sam Creek, see Figure 4.4. 34 species of woody dicotyledon were collected from this area. The second sample, which also acts as the lowest sample from the Otira Gorge altitudinal transect (OG6) was taken from the hillside above Lady Lake to the east, at an altitude of 120-160 metres. In this region 20 species were collected, three of which had not already been located at collection LL1. The physiognomic scores for these two sites are displayed in Table 4.3 and in Appendix Two.

4.4.2 Collection of CLAMP samples from lake sediments

The living vegetation samples were compared with leaves from a series of sediment samples collected from two transects along and across the delta of Sam Creek. The first of these went from the mouth of the delta out into the body of the lake, along a bearing of 315° (see Figure 4.5). Proximal samples were taken at intervals of approximately 10 metres to a distance of 50 metres. After this samples were collected at 75 metres, 100 metres, 150 metres and 200 metres. A second set of samples were collected along a line approximately perpendicular to transect one at a constant depth of 3 metres. 4 samples were collected along this transect.

The first transect was along the same line and therefore comparable to Line I of Drake &

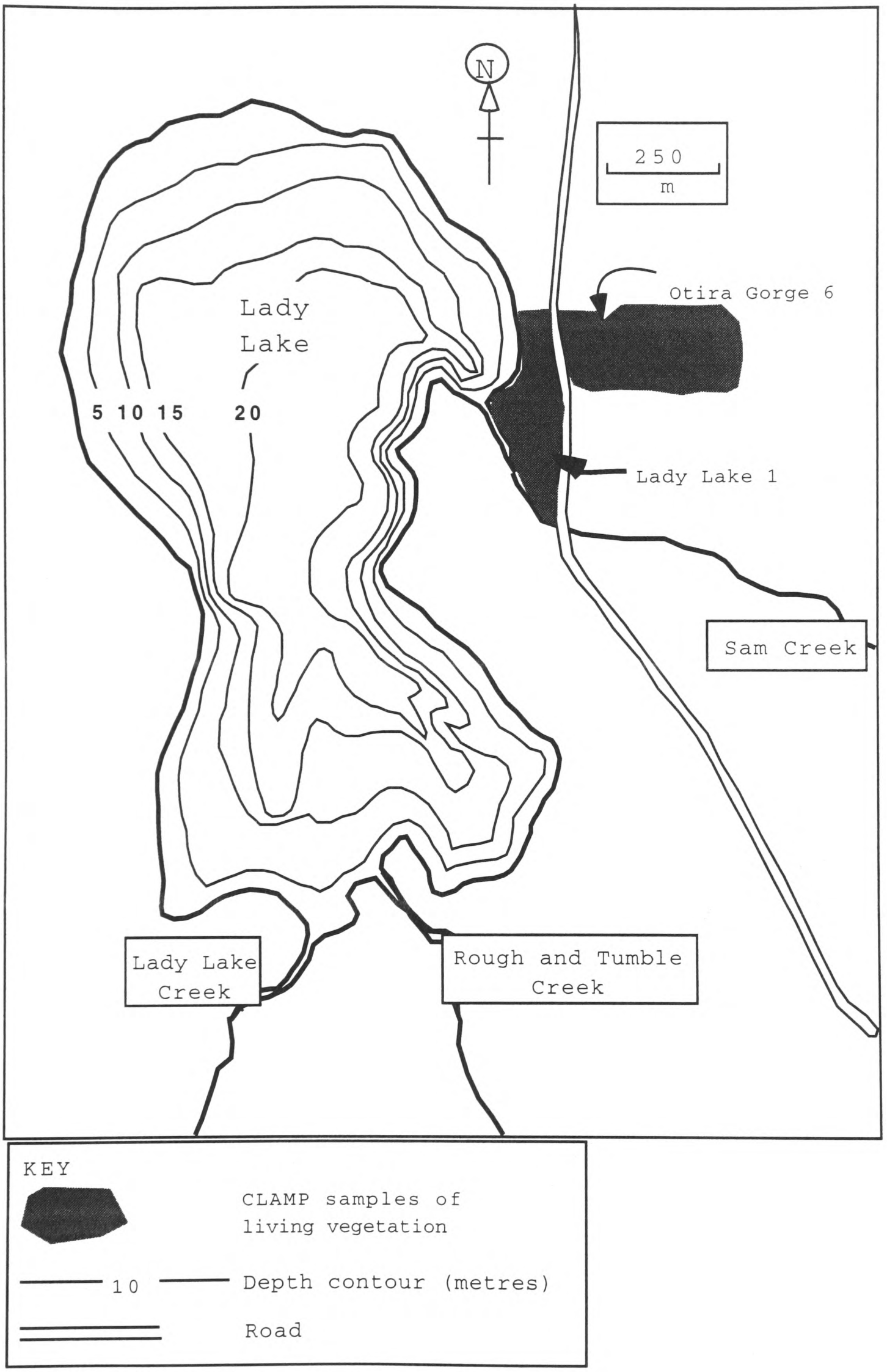


Figure 4.4: Location of living vegetation samples collected adjacent to Lady Lake

	OG6	LL1	1	2	3	4
distance from shore (m)			2	2	2	2
depth of sample (m)			3.0	3.0	3.0	3.0
number of species	20	35	9	10	19	13
Lobed	0	4.41	11.11	0	0	0
no teeth	55	54.41	50	80	57.89	46.15
teeth regular	18.75	20.59	11.11	10	2.63	15.38
teeth close	18.75	13.97	5.56	5	6.58	15.38
teeth round	18.75	19.12	16.67	10	10.53	15.38
teeth acute	26.25	26.47	33.33	10	31.58	38.46
teeth compound	15	16.18	5.56	0	15.79	11.54
lepto 1	8.3	12.24	11.11	16.67	16.67	11.54
lepto 2	16.15	12.82	0	20.33	9.22	7.69
micro 1	15.7	22.71	3.67	37	42.56	21.77
micro 2	24.05	26.15	64.78	25.89	17.56	48.69
micro 3	22.45	15.85	20.33	0	13.89	10.23
meso 1	7.9	9.5	0	0	0	0
meso 2	5	0.59	0	0	0	0
apex emarginate	25	29.41	33.33	11.11	0	18.18
apex round	45	42.15	58.33	66.67	53.33	34.82
apex acute	35	39.21	8.33	22.22	30	53
apex attenuate	20	18.62	33.33	11.11	16.67	12.09
base cordate	5	8.82	22.22	5	5.88	0
base round	45	75	61.11	65	70.59	70.83
base acute	50	16.18	16.67	30	23.53	29.17
L:W¡1:1	0	3.91	12.5	0	0	0
L:W 1-2:1	29.15	40.38	22.88	16.67	52.36	23.3
L:W 2-3:1	44.15	30.09	41.63	50	34.5	48.3
L:W 3-4:1	11.65	12.94	22.88	11.11	13.07	23.3
L:W¿4:1	15	12.5	0	22.22	0	5
shape obovate	15	12.74	6.25	16.67	14.29	15
shape elliptical	80	64.21	87.5	72.22	60.71	80
shape ovate	5	20.09	6.25	11.11	25	5
total			68	6.4	181	156
whole leaves			6	2.5	47	38
whole/total			0.09	0.39	0.26	0.24

Table 4.3: Physiognomic scores for Living vegetation collected adjacent to Lady Lake and tran sect two taphonomic samples

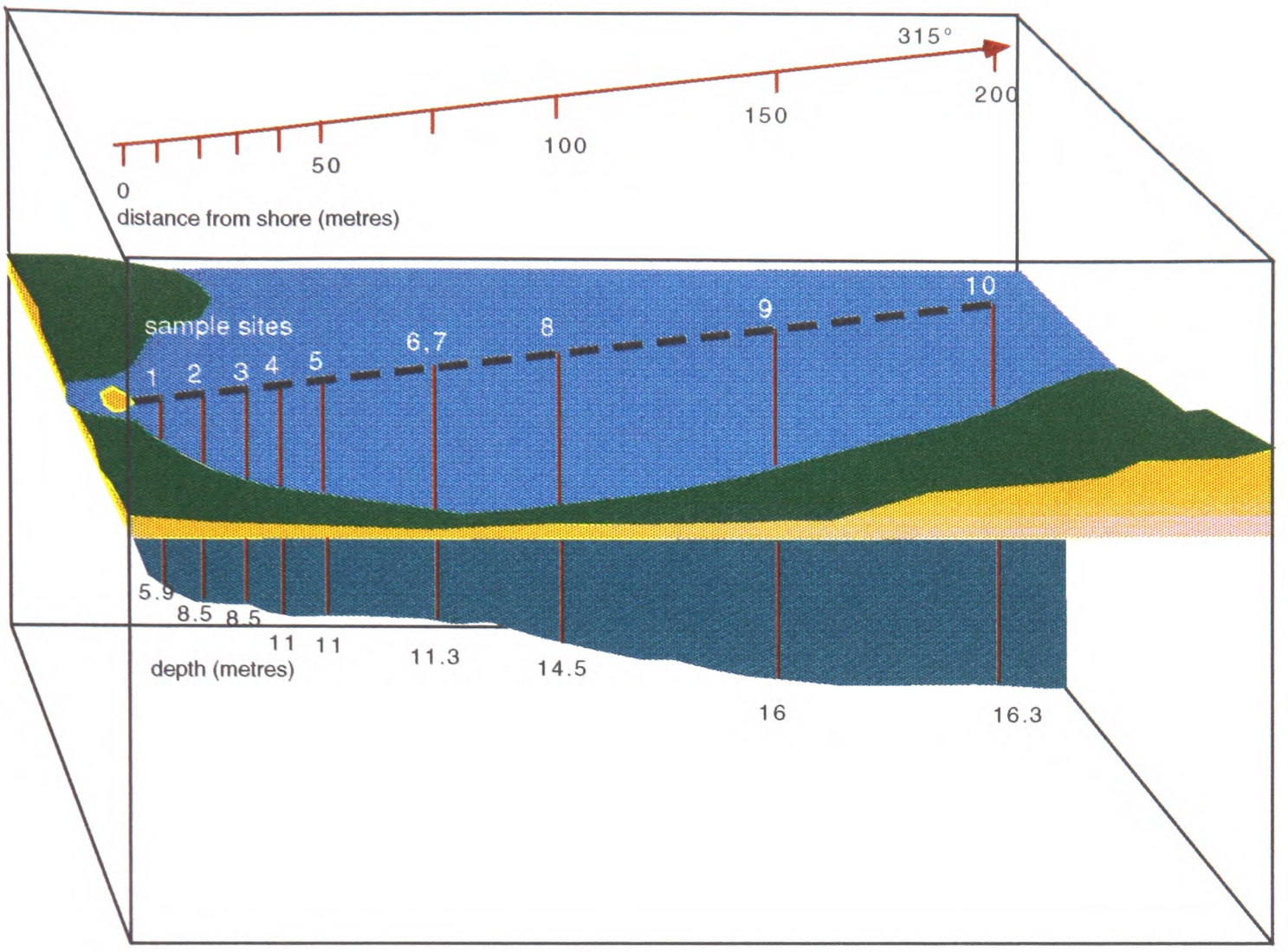


Figure 4.5: Cartoon showing sample sites along transect one

Burrows [1980]. Sampling began beyond the point where the vegetation mat became established, the first one being taken 10 m from the shore. A line between an anchored buoy and the shore was used to maintain a constant direction for the transect and to measure the distance from the shore. At each site the depth of the lake bottom was measured. Samples proximal to the delta front were collected using a Peterson grab (see photo 4.6) lowered over the side of a rowing boat. For the more distal sites (beyond 75 metres from the shore) this approach failed. This was because the vegetation mat was no longer well established and the fine sediment seeped through the jaws of the grab, keeping them ajar as it was raised. At these sites a diver collected the samples. The action of the grab was mimicked as closely as possible so that these samples would be comparable with samples taken by the grab. The grab was used as a marker for a diver and the samples taken by placing sediment into a bag from a radius of one metre west of the grab and to a depth of five centimetres.

Transect two was collected across the delta front at a depth of 3 metres, where the vegetation mat becomes established. Four samples were collected (see Figure 4.3). One from the direction of the original transect, one each from 45 degrees to the west of that transect, 45 degrees to the east and 90 degrees to the east.

Multiple samples were taken at 20, 30 and 75 metres from the shore in transect one. These samples however were kept separate so that the difference between single (small) and multiple (large) samples could be assessed.

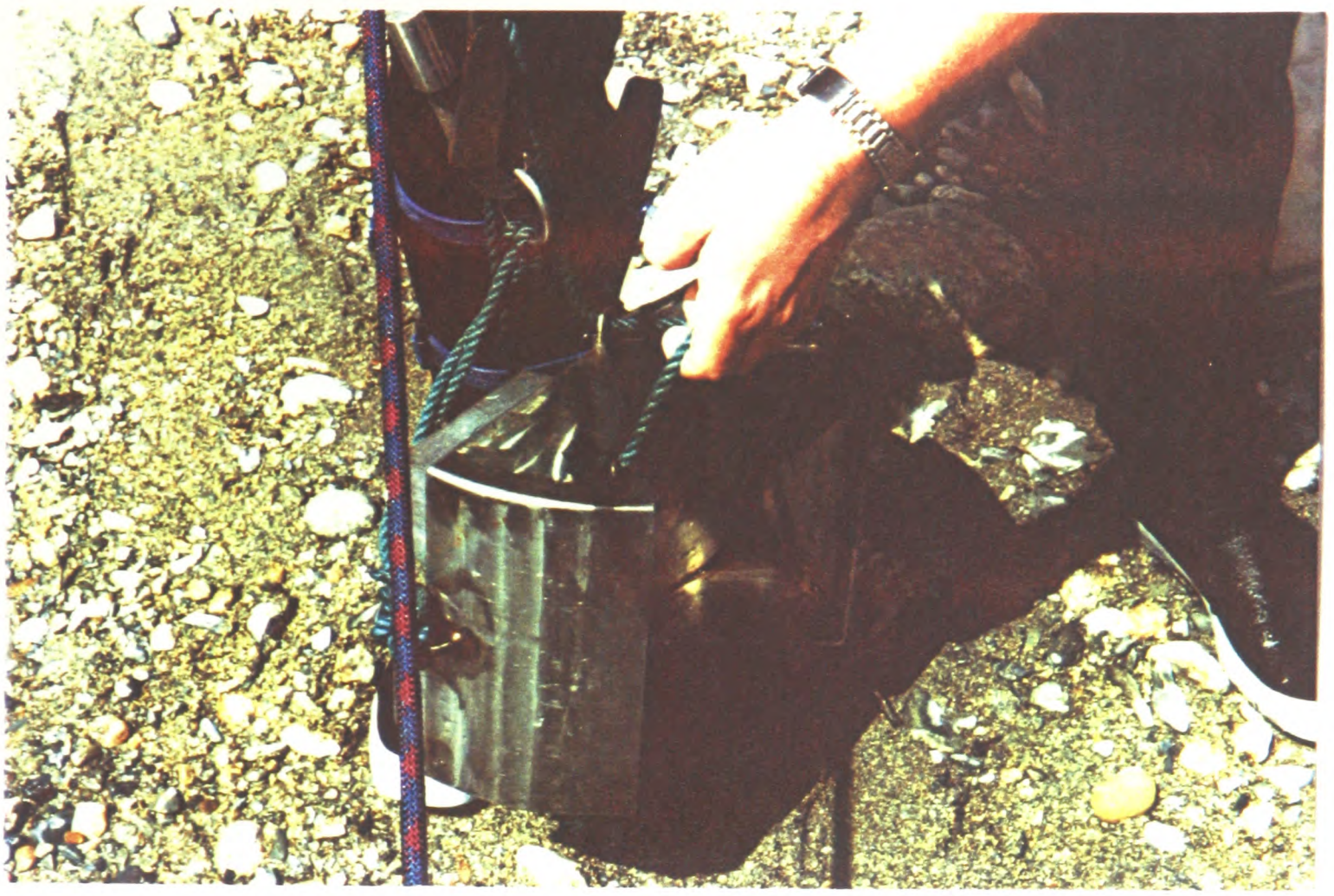


Figure 4.6: The Peterson grab used to collect proximal samples from the lake bottom

4.4.3 Sorting of lake bottom samples

In the laboratory the lake bottom samples were sorted into leaf megafossils (whole leaves and fragments) that contained physiognomic information that, in a fossil scenario, would contribute to the physiognomic scores of the species. A fragment was deemed to contain useful physiognomic information if it had any part of the margin preserved. Fragments of laminae that do not contain marginal information may be identified correctly to a specific level, but can contain no information about margin, base, apex L:W ratio or shape. It is possible that they contain useful information about the upper end of the size range if they are larger than other specimens within a species, and fragments falling into this category were kept.

4.4.4 Method of analysis

Each lake–bottom sample was treated as leaf assemblage from the fossil record would be treated in a CLAMP physiognomic analysis. Leaves and leaf fragments were divided into morphotypes, the majority of which were identified to a specific level. This complete, each morphotype was scored for all 29 physiognomic characteristics used in the original CLAMP methodology [see Wolfe, 1993, pages 21-28], and a score for that characteristic calculated as a percentage of the morphotypes exhibiting it at the site in question.

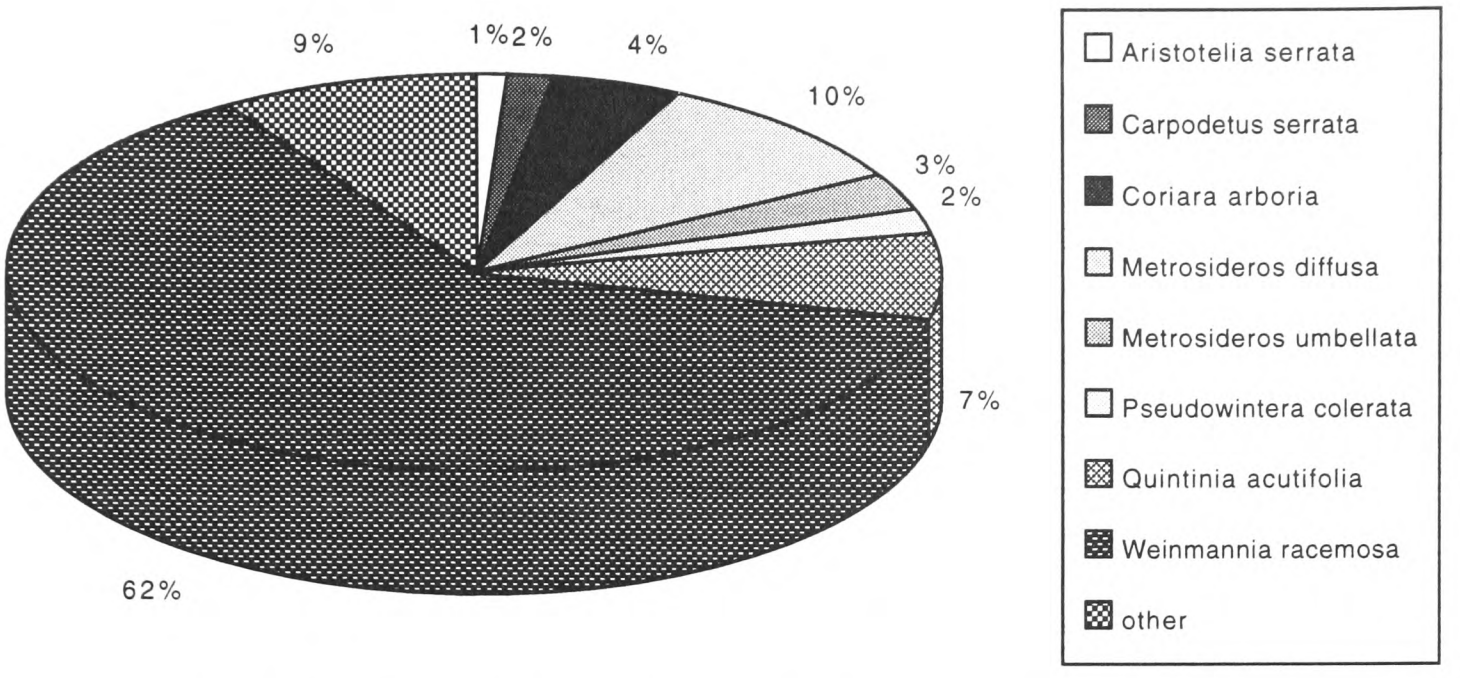


Figure 4.7: Relative abundance of species found in the sediments of Lady Lake

4.5 Results

A total of 1739 leaves and leaf fragments containing physiognomic information about at least one of the categories defined in Wolfe [1993], were collected. These were divided into 39 taxa, of which 34 were identified to a specific level. The remaining 5 taxa, along with a further 7 species were represented by a single specimen. 91% (by number of specimen) of the leaf litter is represented by 8 species (see Figure 4.7) and 61% by just one species, *Weinmannia racemosa*. Kamahe, as it is commonly known, is a spreading tree that grows up to 25 metres in height [Salmon, 1986]. In the vegetation survey of Drake & Burrows [1980] it is listed as one of the most important contributors to leaf density as well as a common inhabitant next to Sam Creek. Both of these factors contribute to the dominance of the species in the lake sediment but the physical properties of the laminae must also be used if its prevalence over other similarly distributes species, such as *Carpodetus serrata* and *Metrosideros diffusa*, is to be explained.

At individual sites up to 19 different species were identified, the average number being 11 (see Table 4.4). The number of species identified at each site shows no significant variation along either of the transects. As one might expect, a strong correlation exists between the number of specimens in a sample and the number of species present, see figure 4.8.

4.5.1 Variation in physiognomic signal within the lake sediments

The results will be discussed first by looking at the variation in the scores of individual physiognomic characteristics, and secondly in terms of position within physiognomic space and the accuracy of temperature estimates made using CLAMP. This will provide a breakdown of the effects of taphonomic biases on physiognomy in Lady Lake, concentrating on the consequences for using CLAMP as a palaeoclimatic tool. For the purpose of this discussion, when sites were discussed in the context of the transects, scores for sites where multiple samples were taken were averaged.

	transect two				transect one													
site number	1	2	3	4	1	2a	2b	3a	3b	3	4	5	6	7	8	9	10	species total
Aristotelia serrata			3	3	1	2		1			5	1				1	2	19
Carpodetus serrata	1		2	1	5	4	1	2	3		2	10	2					33
Coprosma foetidissima			1						1		1					1		4
Coprosma aereolata			1									2		1		1		5
Coprosma lucida				1														1
Coprosma rhamnoides		1																1
Coprosma propinqua	1	1	3	2	1	1			1	1		1		3				15
Coprosma rotundifolia			1											1				2
Coprosma tenuicaulis			1													1		2
Coprosma sp i												1						1
Coprosma sp ii																	1	1
Coriara arborea	8	3	26	11	4	8	6	2	2	1				1		1		73
Elaeocarpus dentatus	1		1	1	1	1						5		1				11
Fuchsia excorticata						2												2
Griselinia littoralis		1								1				2				4
Hebe odora														1				1
Hebe salicifolia							1											1
Hebe sp i																	1	1
Hedycarya arborea					7						5			3				15
Melicytus ramiflorus				1	1	1					2			1		1		7
Metrosideros diffusa		4	4	2	6		1	9	6	24	8	9	7	27	15	33	8	163
Metrosideros umbellata		4	5	8	11	5		2	5	7	1	3					2	53
Metrosideros colensoi			1															1
Myrsine australis	2	2		1					3	2	1	2						13
Myrsine salicina												1						1
Neomyrtus pedunculata							1	1		4	1			2	1	4		14
Parsonsia heterophylla									1							1		1
Penantia corymbosa										2		1			1	1		5
Pittosporum colensoi						6			3									9
Pseudopanax crassifolia			1									1						2
Pseudowintera colerata		1	1		3	4	3		1	6	2	6	1	4		1	1	34
Quintinia acutifolia	6	7	9	10	18	8	9	6	7	2	10	24	4	2		1		123
Rubus australis			2	2	1		1	2				2		1				11
Rubus cissoides									1			4						5
Rubus schmideloides			1		2	1						1						5
Schefflera digitata									1			5						6
Weinmannia racemosa	46	40	117	113	60	61	63	52	85	72	55	157	10	86	12	27	6	1062
unidentified	1																	1
unidentified																1		1
site total	68	64	181	156	127	104	87	77	122	123	98	244	25	138	29	75	21	1739
total species	8	10	18	13	15	13	9	9	14	12	12	19	5	15	4	14	7	39
average number of species per sample																		

Table 4.4: Species identified at each taphonomic site

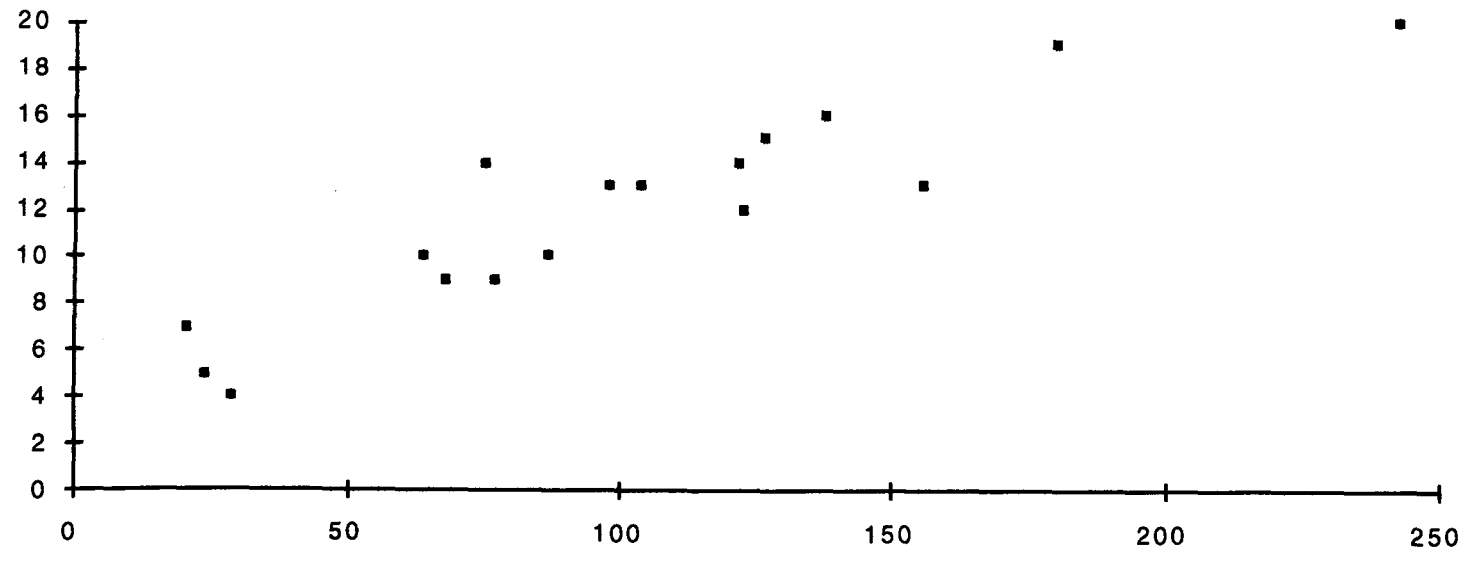


Figure 4.8: The number of specimen (x axis) in a sample plotted against the number of species (y axis)

4.5.2 Margin characteristics

The no–teeth characteristic, the first aspect of leaf physiognomy to be recognised as containing climate information [Bailey & Sinnott, 1915], is appropriately the first to be discussed here. The two samples of the living vegetation around Lady Lake give scores of 55 and 54.41% for this characteristic (see Figure 4.9). Lake bottom sample scores range from between 42 and 75 percent no–teeth (see Figures 4.10 and 4.11 and Tables 4.2 and 4.3). Using the univariate approach of leaf margin analysis where, for southern hemisphere floras, a 4% increase in entire margined species correlates with a 1°C increase in MAT [Wolfe, 1979; Wolfe & Upchurch Jr., 1987] this corresponds to large errors in MAT estimate, (see Table 4.5).

Within transect one, the no–teeth character scores are highest at the two most distal sites, 150 and 200 metres from the shore. This is at least partially attributable to the dominance at these sites of small leaves (see subsection 4.5.3 below). In the size category leptophyll 1, 83% of the species in the living vegetation display the no–teeth characteristic. This is nearly 30% greater than the ratio displayed in the living vegetation as a whole. It is considered that the bias towards entire margins at distal sites is a result of taphonomic filtering on size categories, rather than on the margins themselves, because leaf size has been shown to cause differential leaf dissemination [Spicer, 1981; Ferguson, 1985].

Across transect two there is a large peak in percent no–teeth at site two. This does not however correspond with a similar peak in the leptophyll size category.

All other marginal characters, apart from the category 'lobed', are linked to the no–teeth characteristic, in that their upper limit is defined by the no–teeth score subtracted from 100 see Section 2.2.1. The variation of these scores with distance from shore is shown in Figure 4.12 and across the delta front in Figure 4.13. No trends are discernible along either transect. Teeth–regular scores span from between 2.63 and 25.00 in single lake samples. This compares with scores of approximately 20 in both living vegetation samples see Figure 4.14. Teeth–regular, teeth–close, teeth–round, teeth–compound and teeth–acute scores also all bracket the living vegetation scores. This distribution is skewed in two senses: first, in that more lake sample scores undercut the living vegetation scores than overshoot it, and second in that the errors are greater on the lower side of the living vegetation scores.

In the living vegetation only 3/42 species display the lobed characteristic. Two of these species are represented in the lake litter but neither of the specimens display the lobed characteristic.

4.5.3 Size categories

The largest size category represented in the vegetation surrounding Lady Lake is mesophyll 2, (see figure 4.15). This size is exhibited in 3/37 species, but is not represented in any of the lake sediment samples. The next largest category, mesophyll 1, is represented at only one lake sample. This lack of the larger size categories is in spite of using leaf fragments to estimate the

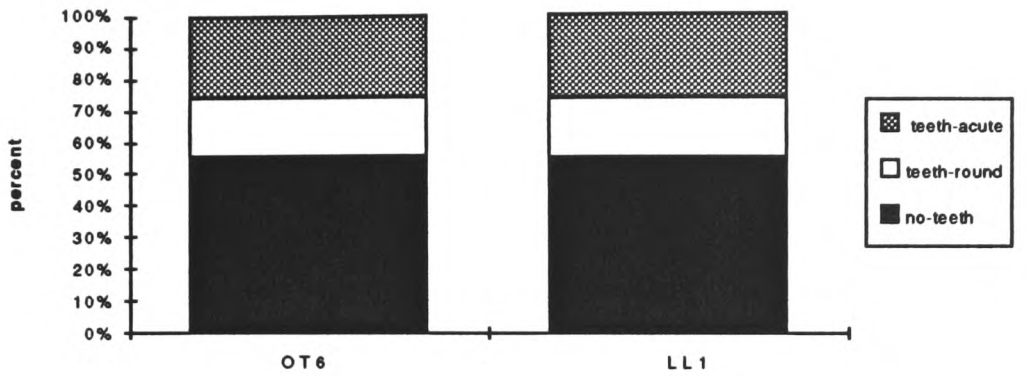


Figure 4.9: Percentage scores for no–teeth, teeth–round and teeth–acute in the two living vegetation samples collected adjacent to Lady Lake

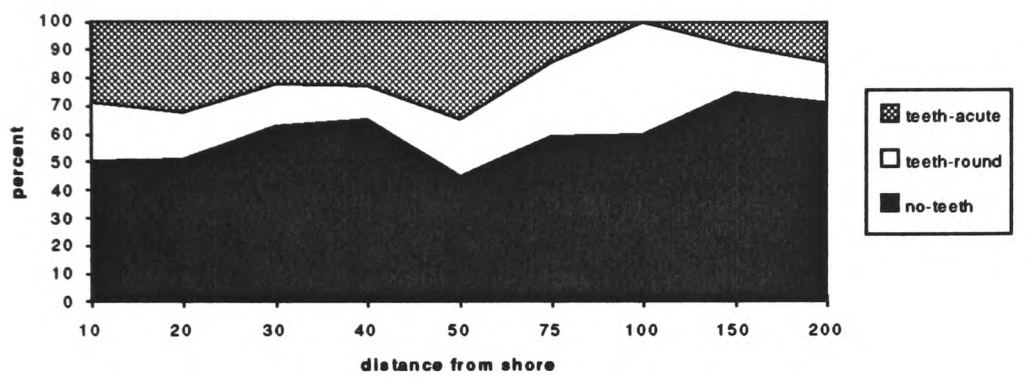


Figure 4.10: Distribution of no–teeth, teeth–round and teeth–acute along transect one (from proximal to distal sites)

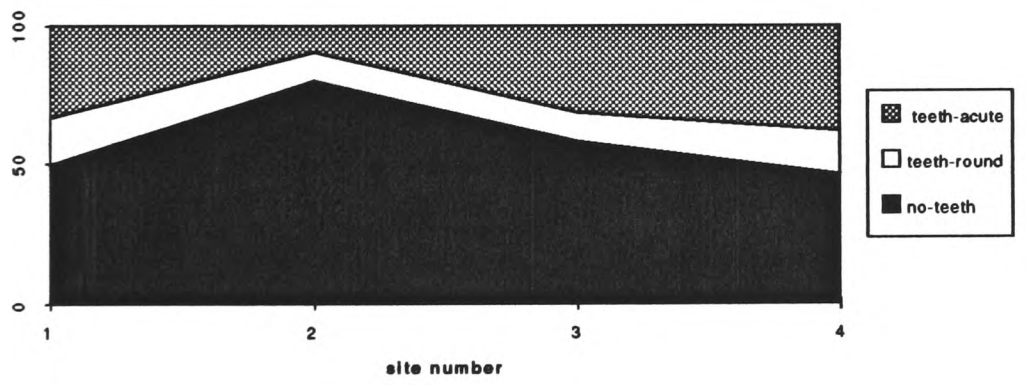


Figure 4.11: Distribution of no–teeth, teeth–round and teeth acute along transect two (across delta front)

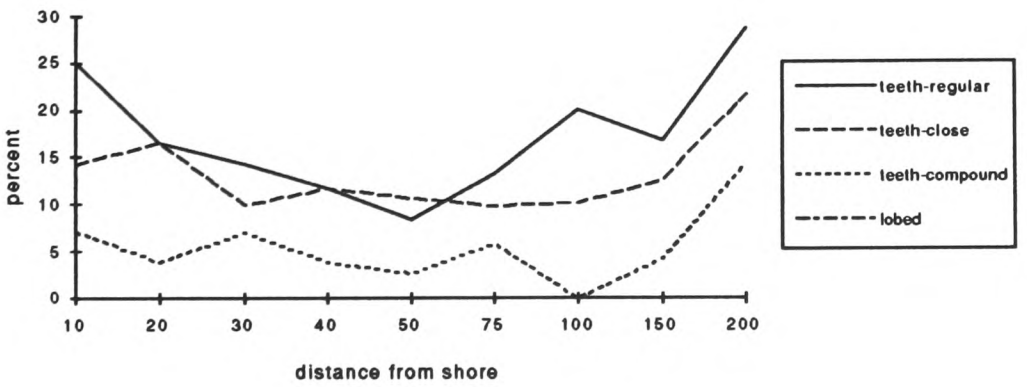


Figure 4.12: Distribution of teeth–regular, teeth–close, teeth–compound and lobed–margin along transect one (from proximal to distal sites)

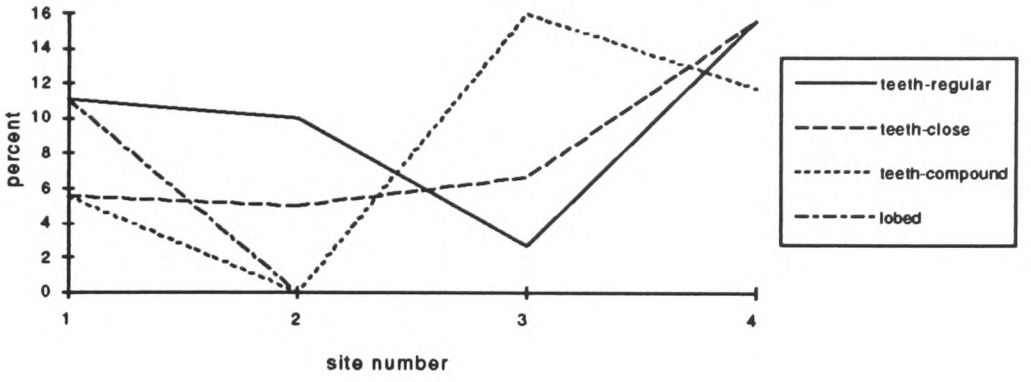


Figure 4.13: Distribution of teeth–regular, teeth–close, teeth–compound and lobed–margin along transect two (across delta front)

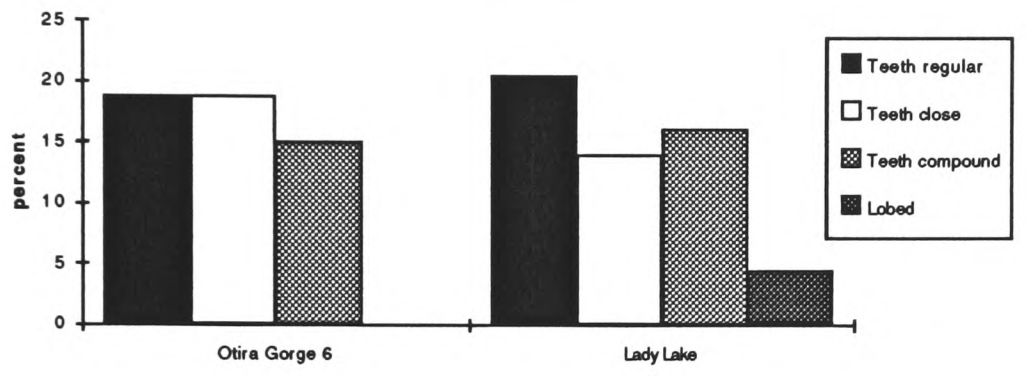


Figure 4.14: CLAMP scores for teeth–regular, teeth–close, teeth–compound and lobed–margin in the living vegetation adjacent to Lady Lake

larger size ranges of a species.

In both transect one and two, the lake litter represents the smaller size categories of the living vegetation reasonably well (see Figures 4.17, 4.15 and 4.16). Distal sites however show a large increase in the proportion of species representing the smallest size category, leptophyll 1 (Figure 4.16). To illustrate this, two sites that contain the same number of species were compared: 3b, transect one and 9, transect one. 3b is situated 30 metres from the shore, and contains no species with leptophyll size leaves, whilst the 3 microphyll categories score just over 80% between them. In contrast at site 9, situated 150 metres from the delta front, leptophyll 1 scores just over 50% with the three microphyll sizes combined scoring 38.47%. This dominance of small leaves at distal sites has in the past been attributed to wind blown sun leaves [Spicer, 1981] however many of the small leaved plants represented in distal sites are in fact small trees climbers or shrubs (e.g. species *Coprosma 4* and *Metrosideros diffusa*) which do not protrude into the canopy. It seem likely therefore, that small size or some physical property related to it, also enhances the buoyancy of these leaves allowing them to travel further into the body of the lake before being deposited.

4.5.4 Apical characteristics

Of the four apical characteristics three may be discussed together because they are mutually exclusive and therefore sum to 100 (see Section 2.2.1). These are apex–attenuate, apex–acute

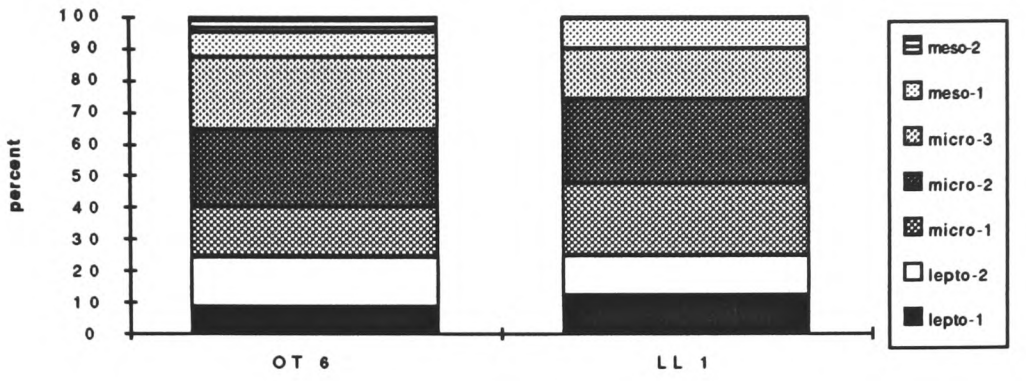


Figure 4.15: Percentage score for each size categories in living vegetation samples collected adjacent to Lady Lake

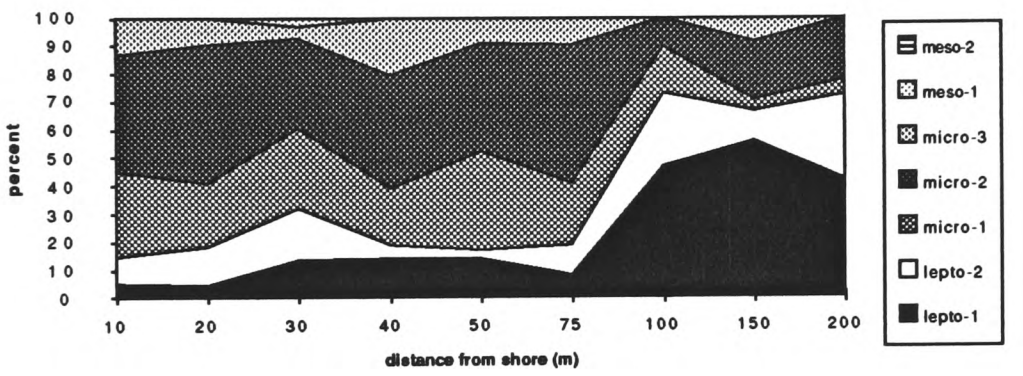


Figure 4.16: Distribution of size categories along transect one (from proximal to distal sites)

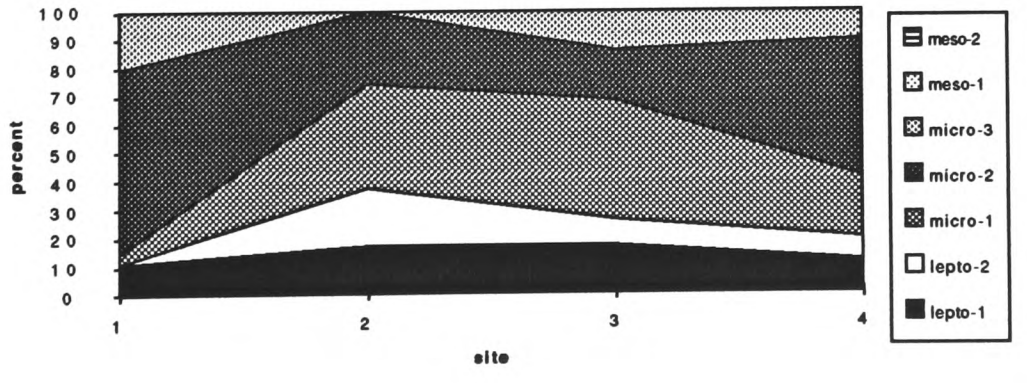


Figure 4.17: Distribution of size categories along transect two (across delta front)

and apex–round and their distribution in living and taphonomic samples is represented in Figures 4.18–4.20. The fourth character state, apex–emarginate, will be discussed separately. In all the transect one sites bar two, at 10 metres and 50 metres, apex round is overrepresented compared to the two living vegetation samples (see figure 4.18, 4.19). This bias is stronger in the more distal sites. Indeed at 100 and 200 metres from the shore, it is almost double that of the living vegetation scores. If one examines the score sheet for these samples (see Appendix C) it is immediately apparent that the apex is one of the more delicate parts of the lamina. It is often absent from all specimens of a species at a particular site, and therefore the apical characteristics cannot be scored. The delicacy of this part of the leaf cannot be used however, to explain the taphonomic bias of distal samples towards apex–round because there is no relationship between percentage of species with apices destroyed and the distance from the shore. As with the no–teeth characteristic this bias seems to be caused by a correlation in the living vegetation between the smallest size category, and a round apex. The species in the living vegetation which exhibit the leptophyll 1 characteristic, score 76% for apex round , if treated separately. This contrasts with the scores of 45% for OT6 and 42% for LL1. It is possible that to a certain extent, this relationship is specific to the local vegetation. Wolfes definition of apex–attenuate however, in which the attenuated part of the apex must be over 1cm in length, means that it cannot be exhibited in the smaller size categories. Whilst the same cannot be said for apex–acute, this may at least partially explain the bias of apex–round in small leaf categories and therefore in the distal lake bottom samples.

The apex–emarginate characteristic is underrepresented at all sites in transect one, sometimes being entirely absent (see figure 4.21). It is also underrepresented in three out of four transect two sites (see Figure 4.22). It was observed when scoring the living vegetation that this characteristic was often displayed in as few as 1/20 leaves of a species. Only the species *Myrsine divaricata* displayed the characteristic in every leaf. Using Wolfe's scoring methodology only one leaf needs to display this characteristic for that species to score 1 in this category. Consequently the number of specimens for each species scored is crucial. In these samples it was normal for a species to be represented by less than 10 specimens, and the underrepresentation of apex emarginate is a consequence of this. Indeed even when all sites were combined, 14 species were still only represented by one specimen, and the combined apex emarginate score still fell short of the smallest living CLAMP score by 5.5%.

4.5.5 Basal characteristics

The three basal characteristics: base–cordate, base–round and base–acute score less consistently in the living vegetation than the apical character states (see Figure 4.23). Again in contrast with the apical scores no trends are apparent in either of the two transects (see Figures 4.24 and 4.25). In general the lake sediment samples from both transects reflect the living vegetation scores. Base–cordate, which does not score greater than 9 in either of the living vegetation samples is absent in 9/17 of the lake bottom samples and has a maximum score of 22%. Base–

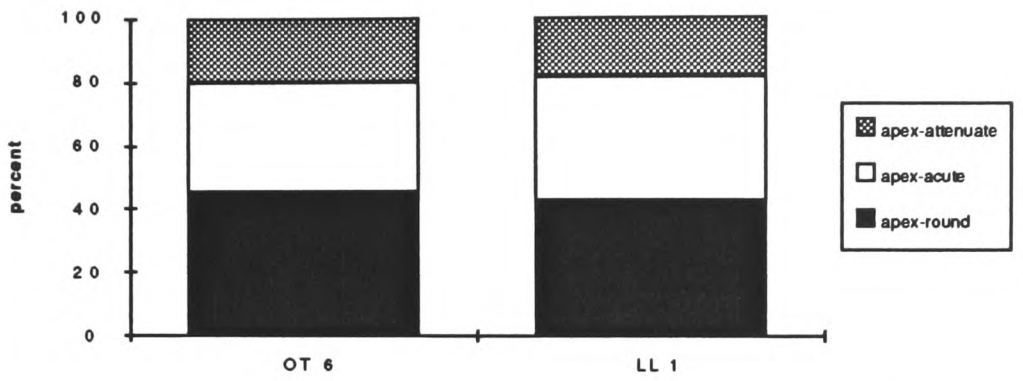


Figure 4.18: Proportions of apical categories in living vegetation samples collected adjacent to Lady Lake

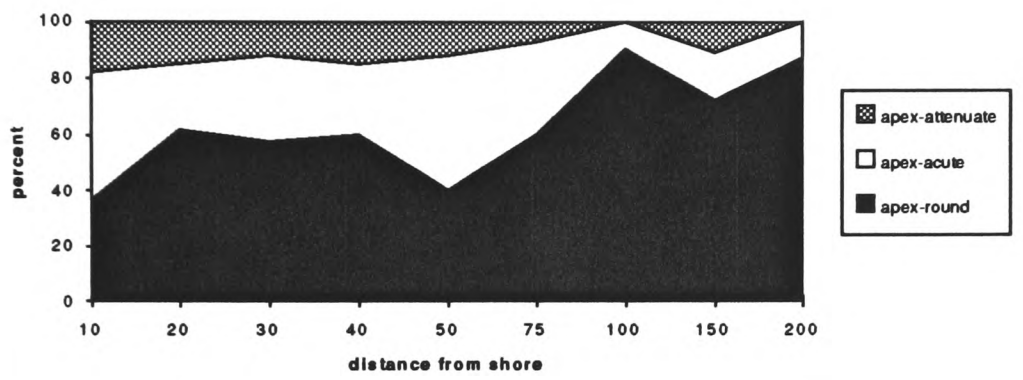


Figure 4.19: smallDistribution of size categories along transect one (from proximal to distal sites)

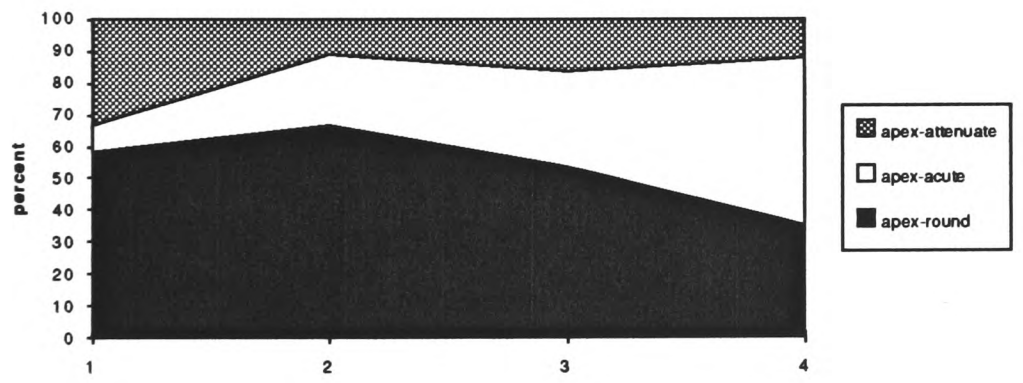


Figure 4.20: Distribution of size categories along transect two (across delta front)

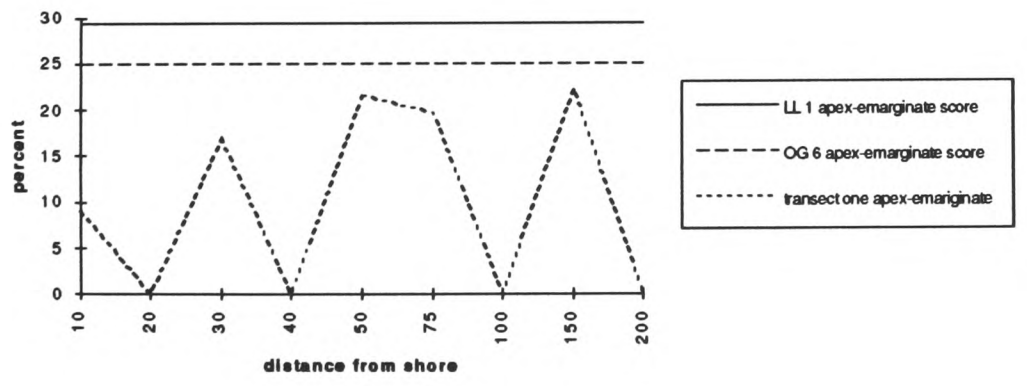


Figure 4.21: Distribution of apex–emarginate along transect one (from proximal to distal sites) in comparison to scores for living vegetation samples

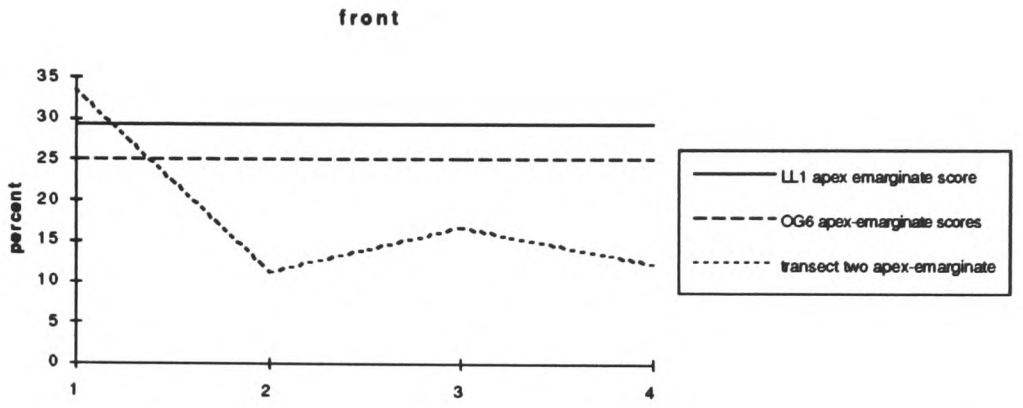


Figure 4.22: Distribution of apex–emarginate along transect two (across delta front) in comparison to scores for living vegetation samples

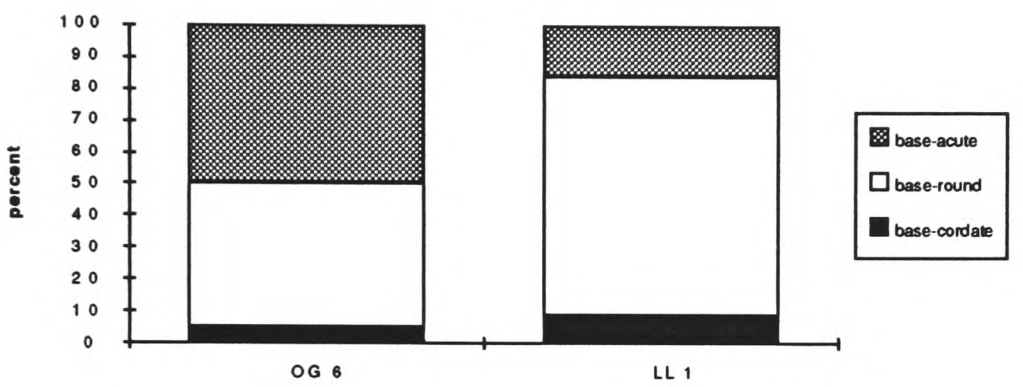


Figure 4.23: Proportions of base characteristics in living vegetation samples collected adjacent to Lady Lake

round scores range from 40-91%, in comparison with scores of 45 and 75% in the living vegetation. Base–acute scores fall between 9% and 60% in comparison with living vegetation scores of 16% and 50%.

4.5.6 Length:Width characteristics

In the two living vegetation CLAMP samples, the two most elongate L:W character states: L:W3-4:1 and L:W>4:1, score almost identically, see figure 4.26, whilst the three more equant character states: L:W<1:1, L:W 1-2:1 and L:W 2-3:1 are less consistent. In transect one L:W>4:1 is generally underrepresented, being entirely absent beyond 75 metres from the shore (see Figure

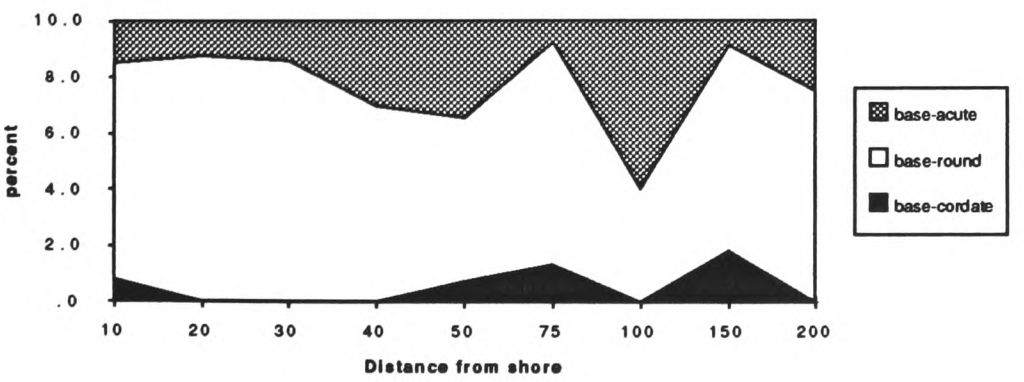


Figure 4.24: Distribution of base characteristics along transect one (from proximal to distal sites)

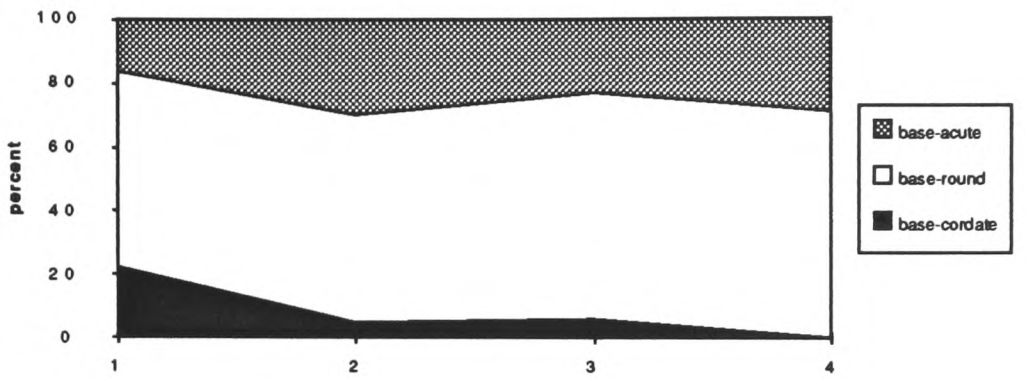


Figure 4.25: Distribution of base characteristics along transect two (across delta front)

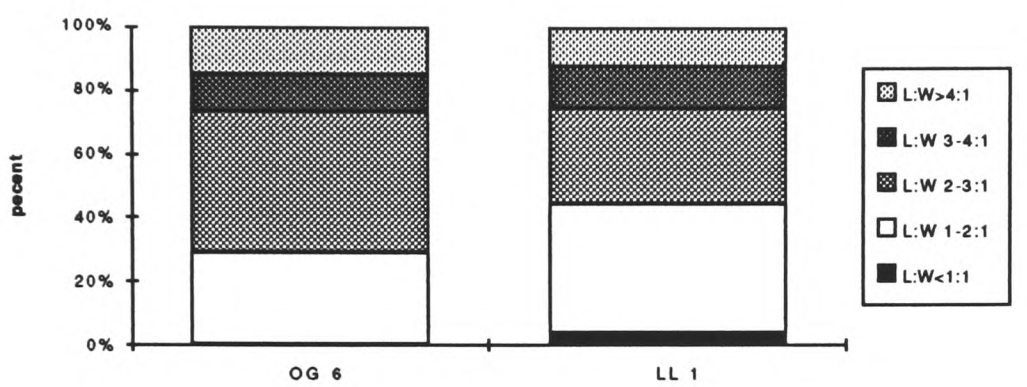


Figure 4.26: Proportions of LW characteristics in living vegetation samples collected adjacent to Lady Lake

4.27). Even at the proximal sites of transect two it is absent in half the samples, see Figure 4.28. L:W3-4:1 is present in all but one of the transect one samples, with a maximum score of 27% at site 1, more than double its score in the living vegetation. It is present in all of the transect two samples and over represented in three of these. Mirroring the large variation of scores in the living vegetation for L:W2-3:1 and L:W3-4:1, large fluctuations are also observed along transect one, although there is no obvious trend moving from proximal to distal sites. In transect two the L:W3-4:1 score is reasonably stable ranging from 34-50%. L:W 2-3:1 are more variable, ranging from 17 to 52% of the species. L:W<1:1 is not exhibited at all in OT6 but scores 3.9% in LL1, where it is displayed in 3/34 of the species collected: *Penantia corymbosa, Schefflera digitata* and *Coprosma tenuicaulis.* In transect one the paucity of this characteristic is reflected; it is absent in all but three of the samples (see Figure 4.27). Similarly in transect two it is represented at only one of the three sites. L:W 2-3:1 and 1-2:1 show the most variation between the two living vegetation samples, differing by 14% and 11% respectively. Large fluctuations are also observed along transect one although again there is no obvious trend moving from proximal to distal sites. Along transect two L:W 2-3:1 has a maximum score of 75% and a minimum of 20% whilst for L:W 1-2:1 individual sample score range from between 10 -70%.

4.5.7 Shape characteristics

In the living vegetation the woody dicotyledon leaves are dominantly elliptical (see Figure 4.29). This characteristic scores 80% in OT6 and 64% in LL1. Shape–obovate scores 15% in OT6 and

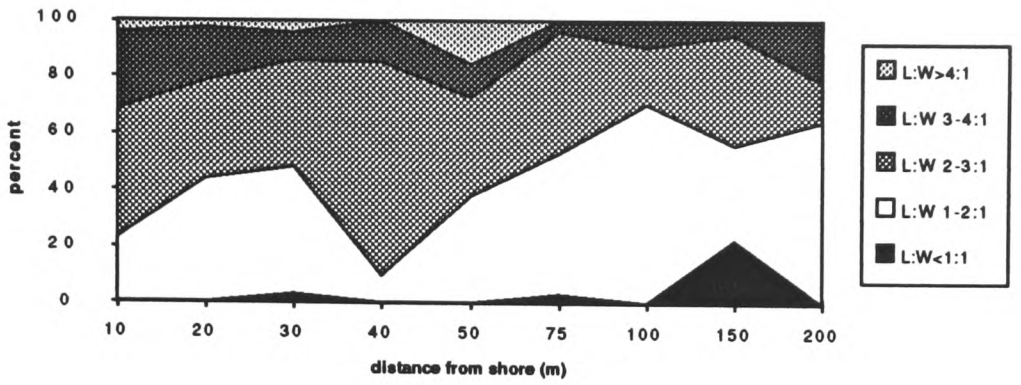


Figure 4.27: Distribution of length:width characteristics along transect one (from proximal to distal sites)

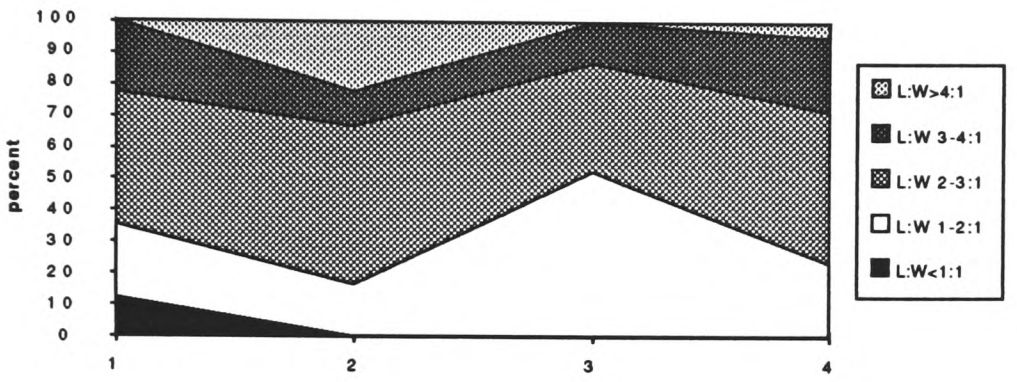


Figure 4.28: Distribution of length:width characteristics along transect two (across delta front)

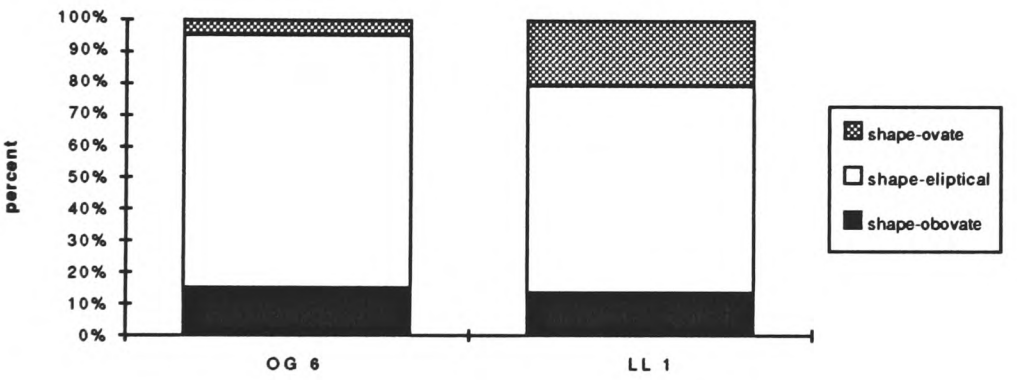


Figure 4.29: Proportions of shape characteristics in living vegetation samples collected adjacent to Lady Lake

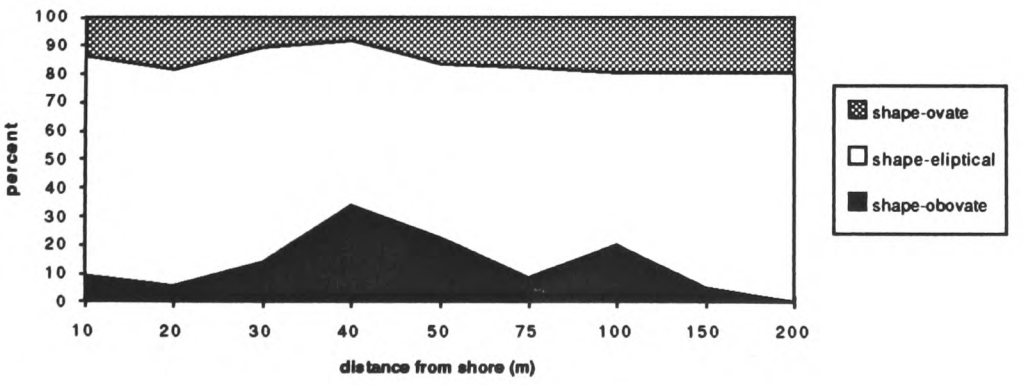


Figure 4.30: Distribution of shape characteristics along transect one (from proximal to distal sites)

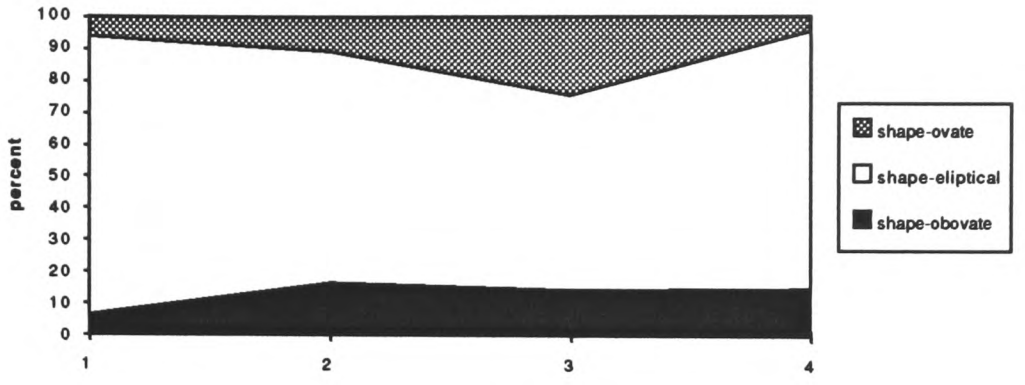


Figure 4.31: Distribution of shape characteristics along transect two (across delta front)

13% in LL1, whilst shape ovate scores 5% and 21% respectively in these two CLAMP samples. The transect one samples generally reflect these scores well (see Figure 4.30) the largest variation being for shape–obovate which scores between 0 and 33% for this characteristic. Transect two tells a similar story with little variation in any of the three shape characteristics (see Figure 4.31). This is in keeping with the findings of Spicer [1981] who states that leaf shape has little effect on differential leaf dissemination.

4.6 Variation in position of lake samples in physiognomic space and the consequences for MAT estimation.

To investigate the position of the Lady Lake taphonomic samples in physiognomic space, the full data matrix of northern hemisphere sites [Wolfe, 1993] and the New Zealand and Australian sites collected for this thesis was combined with each of the taphonomic samples in turn and transformed using CA. This minimises the distortion of the data matrix by the taphonomic samples in question, whilst allowing their position within physiognomic space relative to the existing CLAMP samples to be investigated.

The distribution of the Lady Lake taphonomic samples, in the first four dimensions of correspondence analysis, relative to both the northern hemisphere samples collected by Wolfe (*op cit*), and the southern hemisphere samples collected in this study, are displayed in Figures 4.32 and 4.33. In axes 1, 2, and 4 the spread of the taphonomic samples is very similar to that of the New Zealand CLAMP samples. On axis three the taphonomic samples overlap both the northern hemisphere and southern hemisphere living vegetation CLAMP samples.

Looking at transect one sites in axis one–two space (see Figure 4.34) with one exception (site 3), the near-shore sites are closer to, and therefore more physiognomically similar to, the living vegetation collections than the distal sites. This pattern is not so obviously displayed in axis 3–4 space (see Figure 4.35), where site 10 (collected 200 metres from the shore) is one of the closest sites to the living vegetation samples. In keeping with these results, the proximal sites collected in transect two are found to lie close to the living vegetation sites in physiognomic space, with the exception of site 2.2 which has an anomalously high axis one score (see Figures 4.36 and 4.37).

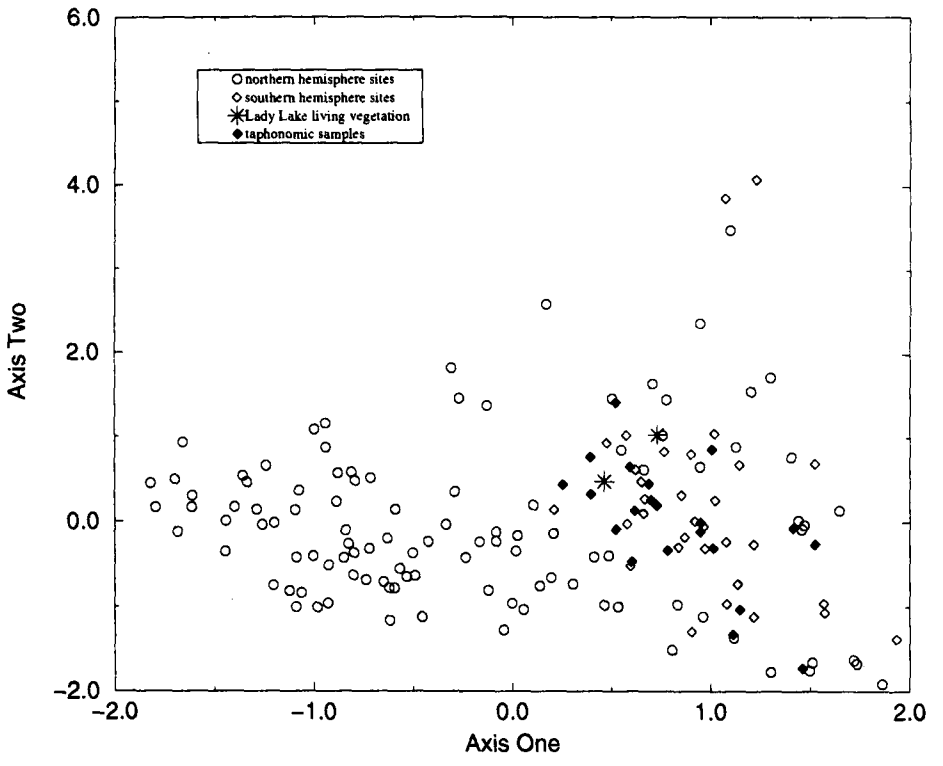


Figure 4.32: The position of all taphonomic samples in axis one–axis two space relative to the northern and southern hemisphere sites

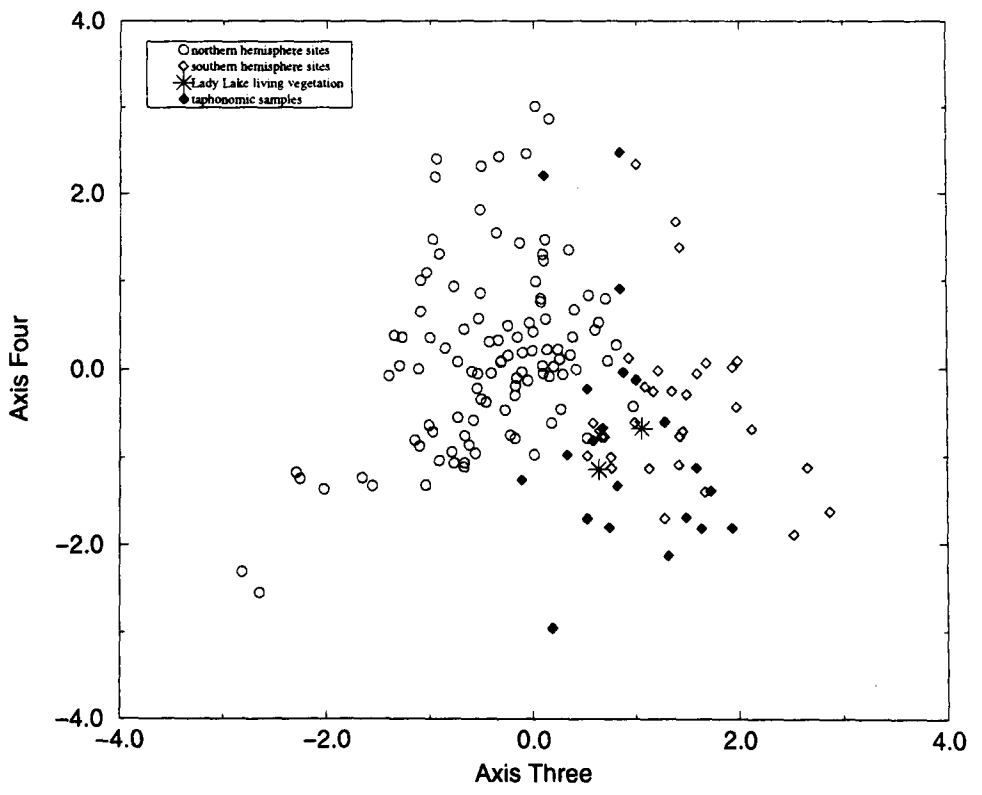


Figure 4.33: The position of all taphonomic samples in axis three–axis four space relative to the northern and southern hemisphere sites

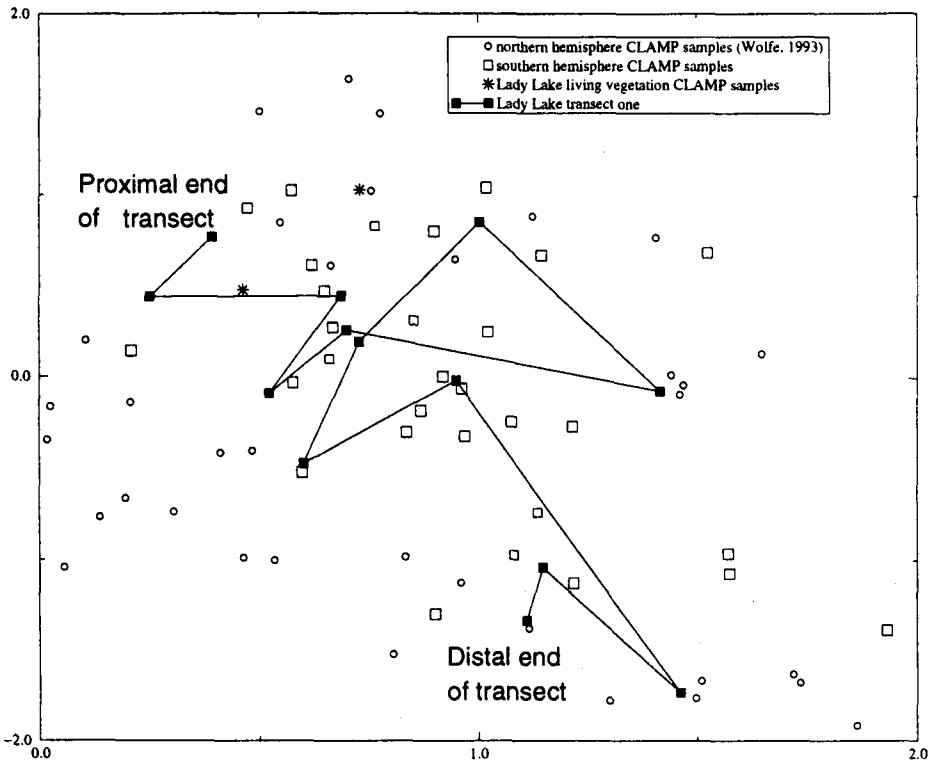


Figure 4.34: The position of the transect one taphonomic samples in axis one–axis two space relative to the northern and southern hemisphere sites (close up)

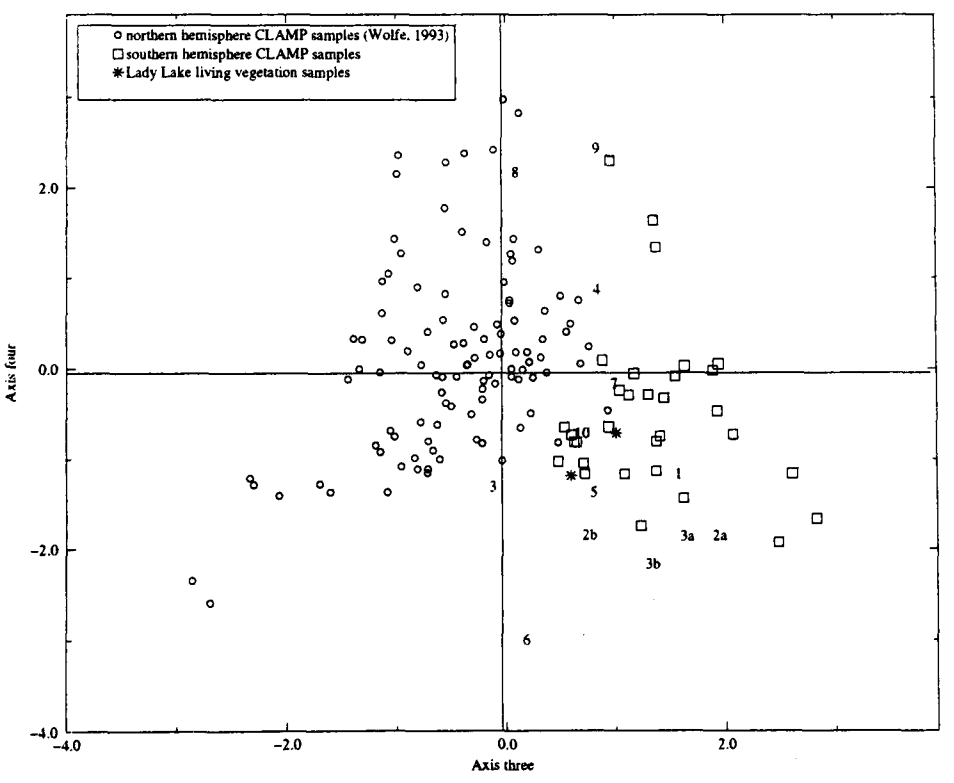


Figure 4.35: The position of the transect one taphonomic samples in axis three–axis four space relative to the northern and southern hemisphere sites

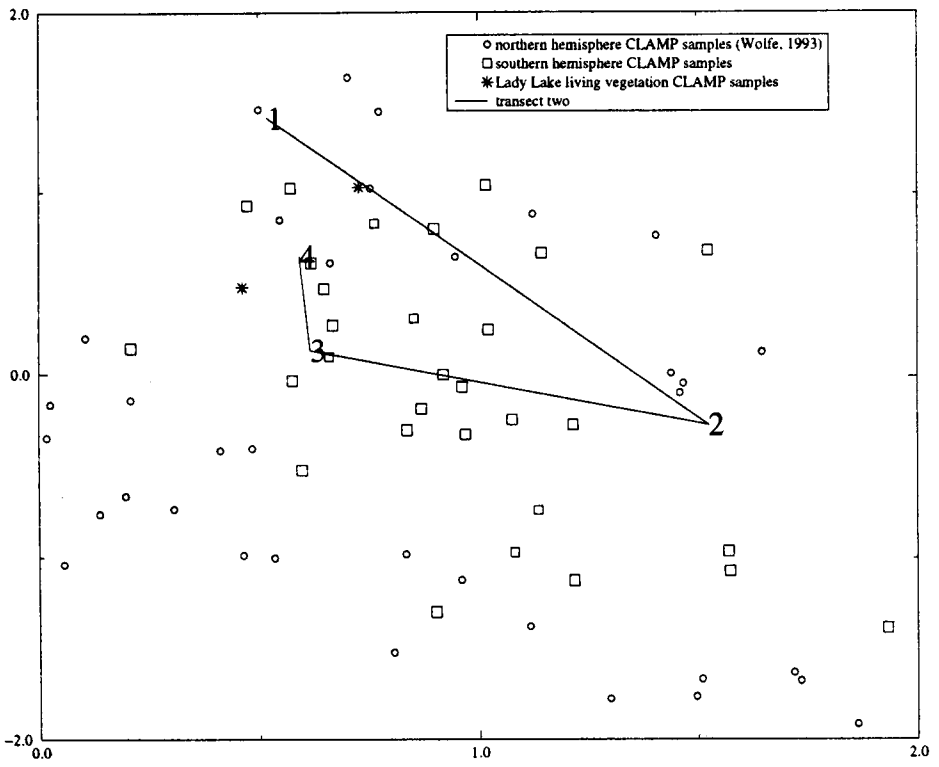


Figure 4.36: The position of the transect two taphonomic samples in axis one–axis two space relative to the northern and southern hemisphere sites (close up)

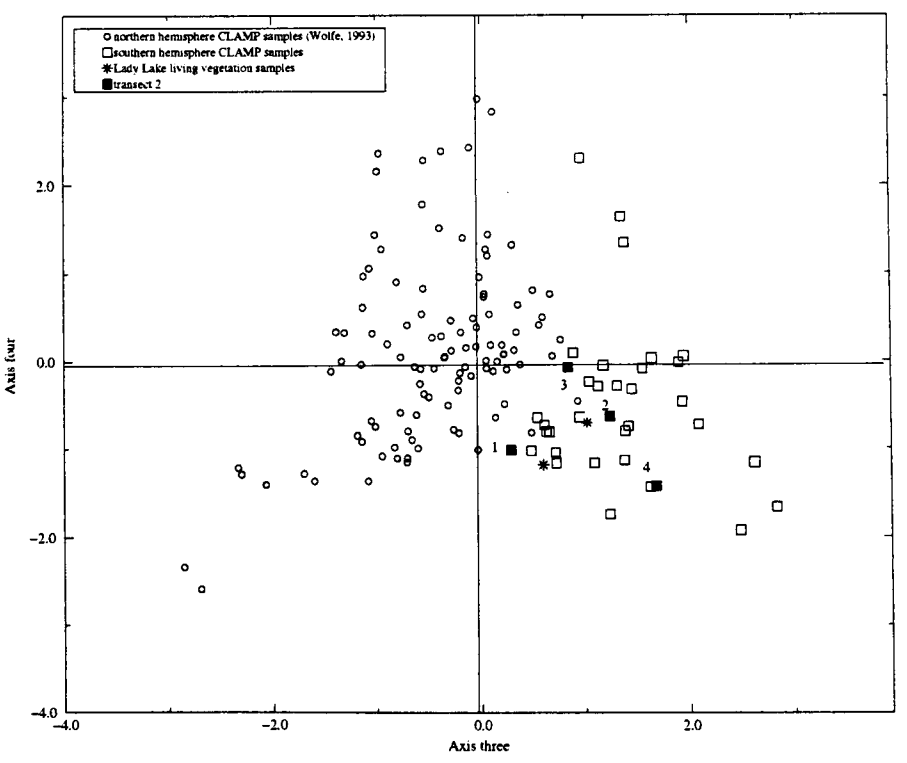


Figure 4.37: The position of the transect two taphonomic samples in axis three–axis four space relative to the northern and southern hemisphere sites

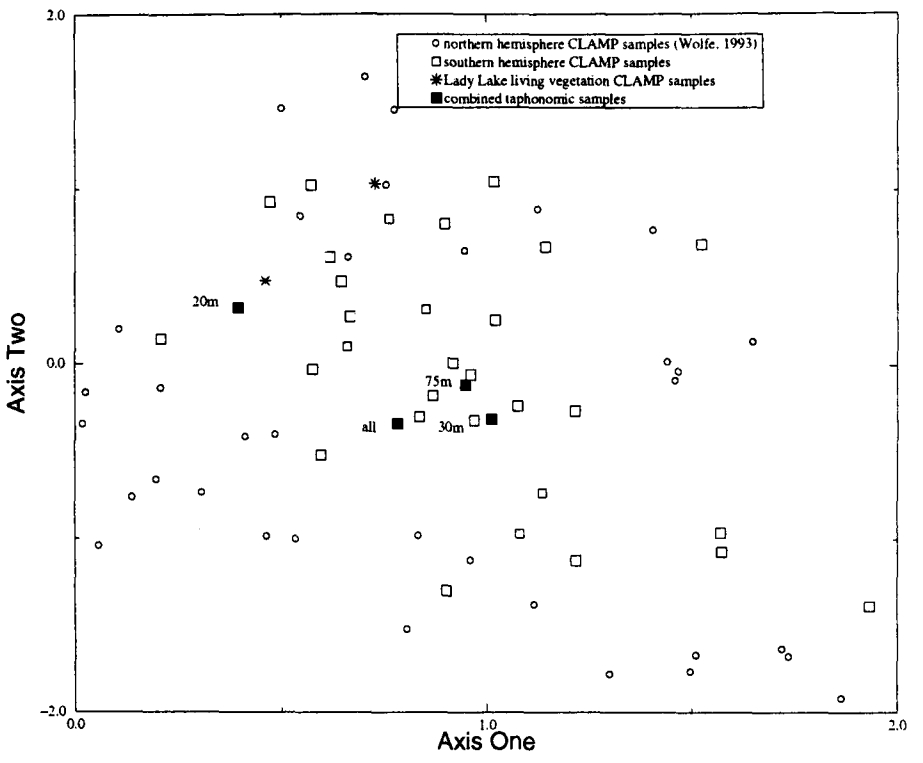


Figure 4.38: The position of the combined taphonomic samples in axis one–axis two space relative to the northern and southern hemisphere sites (close up)

For the sites where more than one sample was collected (transect one, 20 metres, 30 metres and 75 metres) the samples were combined and scored. In addition to this, all the taphonomic samples from Lady Lake were combined to produce one overall CLAMP score. In this context, combination means that all the lake bottom specimens representing each species, were used to form the physiognomic score for that species. These combined scores are plotted in physiognomic space in Figures 4.38 and 4.39.

The discussion so far has shown how much the physiognomic signal can vary for individual lake bottom samples in comparison to samples of the adjacent flora. Perhaps more importantly in the context of this study is the effect of the physiognomic variability on climatic estimates using the various multivariate palaeobotanical approaches developed to date. Mean annual temperature was chosen because it allows the comparison between univariate and multivariate techniques.

4.6.1 MAT estimates using CLAMP, leaf margin analysis and the nearest neighbour approach

The aim of this experiment is to examine how sensitive the various methods for extracting climate information from foliar physiognomy are to bias introduced by taphonomy. The aim is not to compare the techniques power as predictive tools, but to isolate the error attributable to taphonomic bias. For leaf margin analysis I use the temperature difference represented by the difference between percent no–teeth scored in the living vegetation and the taphonomic samples. This is effectively a measure of the error in MAT estimate introduce by taphonomic bias when applying this technique. For CLAMP the errors are calculated as the difference between the living vegetation estimate and the taphonomic samples estimate using only the southern hemisphere

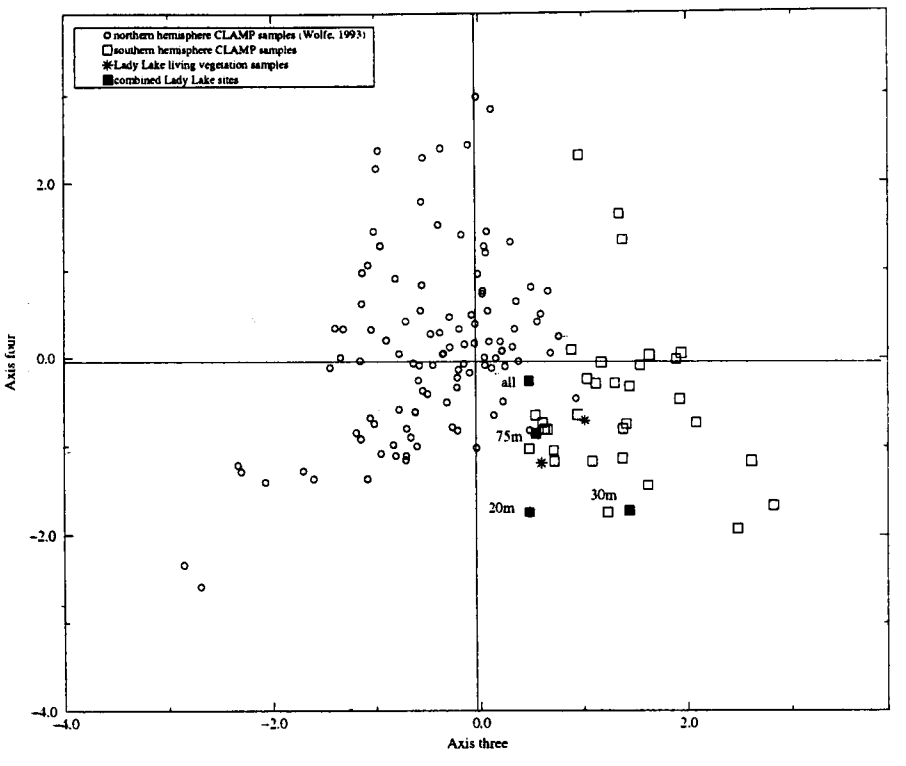


Figure 4.39: The position of the combined taphonomic samples in axis three–axis four space relative to the northern and southern hemisphere sites

sites in the analysis. This eliminates much of the error attributable to the shortcomings of the method. Whilst the arbitrary splitting of the data set is not advocated, it is appropriate here because it allows the taphonomic error to be assessed.

The nearest neighbour methodology (developed in Chapter 3) was also applied to the taphonomic samples. Estimates of MAT were formed using the combined CLAMP data set of southern hemisphere samples collected for this study and the 106 northern hemisphere sites from Wolfe [1993]. The data set was transformed using correspondence analysis and the 19 nearest neighbours to each taphonomic site were selected using the euclidean distance in the first 3 dimensions.

The MAT from combined multiple samples at 20m, 30m and 75m from the shore in transect one are displayed in Table 4.5 along with the estimates produced when all lake bottom samples are combined. The RMS for these larger samples is an improvement standing at 0.879 for the CLAMP type methodology and 0.835 for the nearest neighbour approach.

All three methods show an improvement in the accuracy of MAT estimates when the combined samples are used to form the temperature estimates, illustrating the need for maximising the size of fossil collections from which estimates are formed. The multivariate approaches are more robust to taphonomic bias than the univariate technique, both displaying errors of $<1°C$ when the larger combined samples are used.

4.7 Conclusions

Several conclusions may be drawn from this work. First, it is apparent from this study that both individual character states and the overall physiognomic signal vary spatially within the lake.

		Errors in MAT estimates made using various methods (°C)		
site number	percent no–teeth	univariate leaf margin analysis	CLAMP	nearest neighbour
1,1	50.0	-1.3	-0.1	1.1
2a,1	42.3	-3.2	-1.7	1.2
2b,1	60.0	+1.3	1.6	0.9
3a,1	50.0	-1.3	-1.2	2.0
3b,1	67.9	3.2	0.7	1.1
3,1	70.8	4.0	-0.3	-0.2
4,1	65.4	2.6	2.0	.8
5,1	45.0	2.5	0.2	1.1
6,1	50.0	1.3	-1.5	-0.7
7,1	68.8	3.5	.5	1.2
8,1	60.0	1.3	-1.8	-0.7
9,1	75.0	5	-0.5	-0.2
10,1	71.5	4.1	-2.8	-1.4
1,2	50.0	-1.3	-0.6	-2.9
2,2	80.0	6.3	0.1	2.1
3,2	57.9	0.7	1.6	1.3
4,2	46.2	2.2	-1.2	1.1
RMS error		2.6	1.3	2.1
combined 20m	50.0	-1.3	-0.7	1.1
combined 30m	64.6	2.4	-0.3	0.6
combined 74m	63.9	2.2	-1.5	0.8
all sites combined	61.9	1.7	0.4	0.7
RMS error using combined sites		1.9	0.9	0.8

Table 4.5: Error in mean annual temperature estimates for individual taphonomic samples using various physiognomic techniques

In general proximal sites represent the individual physiognomic characteristics of the adjacent living vegetation better than distal sites. This is also apparent in axis 1–axis 2 space, where the physical proximity of a taphonomic sample to the shore is reflected in its proximity to the living vegetation. In terms of MAT estimates it is only reflected in the univariate approach where a week trend may be seen moving from proximal to distal sites.

Wolfe [1993] clearly recognises that such biases exist, for example that small leaf sizes may be overrepresented in distal sediments. His solution to this problem is to estimate larger leaf sizes by scoring leaf fragments. These results show that this solution goes only part way to solving the problem with smaller leaf sizes still dominant in distal sediments despite the scoring of leaf fragments.

In the living vegetation at Lady Lake, the leptophyll 1 size category is strongly correlated with both the no–teeth characteristic and the apex–round characteristic. Consequently differentiation caused by the size of the lamina is also exhibited in these other foliar physiognomic characteristics. The use of an ordination technique to select orthogonal axes in multivariate space should go some way to avoiding the multiplicity of this effect by eliminating covariance between axes. Both multivariate approaches appear to be fairly robust with no obvious trend in the goodness of MAT estimates moving from proximal to distal sites. These results begin to suggest that a multivariate approach has more potential for use in the fossil record because it is less prone to errors induced by taphonomic bias than univariate techniques.

Wolfe [1993] recommends that a large number of species (greater than 25) be used in CLAMP samples in order to produce accurate results. In this study, lake samples with fewer than 20 species do show larger errors than those with more, but the paucity of samples with more than 20 species (only when samples were combined were such figures obtained), means that it is not possible to assess this relationship further. A similar experiment carried out in an area where the source vegetation is more diverse would go some way to answering this question. In addition this study has shown that the number of samples per species collected is also important, especially when a character state is expressed in only a small fraction of leaves on the living plant. Apex–emarginate is one such characteristic, and is consequently consistently underrepresented in the lake bottom assemblages. The size of a fossil assemblage collection is obviously limited by the extent and accessibility of the exposure, and the abundance of fossils. Despite these constraints it should be remembered by workers implementing a multivariate palaeobotanical technique to estimate climate parameters, that not only the number of species, but also the number of samples representing each species should be maximised.

It is clear from the results listed in Table 4.5 that a strong climatic signal may be preserved in the leaf assemblages of lacustrine sediment. This information has been extracted more successfully using a multivariate approach than a univariate approach has also been shown, with errors for the univariate leaf margin analysis exceeding those for either of the multivariate approaches.

Chapter 5

The re–examination of fossil floras using the new nearest neighbour methodology

5.1 Introduction

Recently the CLAMP methodology and related techniques have been applied to fossil floras of western North America [Povey, 1995; Gregory & McIntosh, 1996; Meyer, 1986; Gregory & Chase, 1992; Povey *et al.*, 1994] in order to obtain information about uplift and surface elevation over geological time. If it is accurate and valid, this work is of particular interest to geophysicists to test and develop theories about the tectonics of the area. In the present day the Western United States has a high mean elevation. Until quite recently, discussions about the tectonics of this region have tended to centre around the widespread extension and magmatism that occurred in this region during the Tertiary. The fundamental link between surface uplift and work done against gravity [England & Molnar, 1990] (see section 1.2.1) however means that information about surface uplift could be very useful in assessing the validity of hypotheses explaining these phenomena and uplift in the region.

5.1.1 Possible mechanisms for uplift in the Tertiary of the western United States

Mechanisms that have been proposed to explain the uplift of the western United States and southwestern Canada include: a) lithospheric thickening and b) processes in the upper asthenosphere. The Laramide orogeny of Mesozoic and early Cenozoic times was the result of the convergence of the Farallon and North American plates and resulted in lithospheric thickening. Whilst this thickening undoubtedly resulted in some uplift, it is debatable whether it alone is responsible for the high altitude of western North America today. Houseman *et al.* [1981] suggest that if the root of the thickened portion of the lithosphere became unstable due to its weight and to lateral temperature gradients, it could become detached from the rest of the lithosphere. Once detached the space that it had occupied would fill with hot buoyant asthenosphere inducing a rapid increase in surface height. Best & Christiansen [1991] propose a model that is similar,

in that the movement of hot asthenosphere into a space previously occupied by cold crust induces uplift. In their model however it is the slowing of the convergence rate of the oceanic and continental plates that results in a steepening of the subducting oceanic plate that makes the space for the influx of hot asthenosphere. This would result in observations of rate of surface uplift similar to the Houseman model [Platt & England, 1994]. Palaeoelevation observations however could potentially be used to distinguish between the asthenosphere assisted uplift and that associated with mere crustal thickening.

5.1.2 Climate change and mountain uplift

Climatologists too, can use information about rates and timing of surface uplift. This is because such processes may be linked with climate fluctuation of the past. It has been postulated that, as a result of several different mechanisms, the introduction of large upland areas would have had a dramatic effect on local and world climate. The presence of high altitude plateaus affects flow in the atmosphere with east–west airflow being deflected north or south depending on the hemisphere [Ruddiman & Kutzbach, 1991]. Severe monsoonal climates, such as those observed in south east Asia could also be induced by the presence of areas with high regional elevation [Ruddiman & Kutzbach, 1991]. High altitude mid–latitude plateaus could also trigger or enhance the albedo–temperature feedback effect, in which snow cover reflects solar radiation which in turn causes an increase in snow cover, which in turn reflects more solar radiation [Birchfield & Wertman, 1982]. An understanding of the timing and extent of Tertiary uplift in conjunction with our knowledge of Tertiary climates gained from oxygen isotope studies [eg Savin [1977]] and terrestrial climate studies Wolfe [1994] would allow us to begin to understand the relationship between climate change and mountain uplift more thoroughly.

5.2 Previous work on the surface elevation histories using palaeobotany

Axelrod [1965] was the first to use a palaeobotanical approach to compare high altitude and low altitude floras and extrapolate elevation information from associated palaeoclimatic estimations. His methodology can be divided up into two steps. The first is to estimate palaeotemperature from fossil floras. The second is to compare estimates from coeval fossil floras and produce a picture of the topography or, if one flora can be shown to have grown at sea level, the palaeoelevation. The floristic methodology that he used to complete the first step has since been widely disregarded in favour of physiognomic approaches (see section 1.3.1) His comparison of climate estimates from coeval floras at similar latitudes, to elucidate altitude remains the central part of all modern methodologies that estimate palaeoelevation using palaeobotanical means. More recently Axelrod [1986] has chosen to abandon the use of sea level floras to estimate absolute elevations instead choosing to assess local uplift directly by comparing the palaeotemperatures of fossil floras with the temperature in the same location in the present day. This simplistic approach ignores entirely changes in climate that have occurred since the deposition of the original

flora and consequently is a step backwards from the methodology he originally developed in the late 1960's.

Over the last decade other workers have moved forward, by abandoning floristic methodologies for physiognomic ones [Meyer, 1986; Gregory & Chase, 1992; Povey *et al.*, 1994; Povey, 1995; Wolfe, 1994; Gregory & McIntosh, 1996]. Their use of a physiognomic approach to extract climatic information from plant fossils has made this step of altitude estimation more theoretically defensible and more repeatable than Axelrod's floristic work, (see section 1.3.1). The multivariate data set collected by Wolfe [1993] which forms the basis for this thesis, has been utilised to extrapolate climatic information from fossil floras in several different ways ranging from multivariate regression [Gregory & Chase, 1992; Gregory & McIntosh, 1996; Forest *et al.*, 1995; Wing & Greenwood, 1993] to the CLAMP methodology developed by Wolfe [Wolfe, 1993, 1995] (see section 2.2.3) and used by Povey *et al.* [1994]; Povey [1995] which looks for trends in 2 dimensional physiognomic space after parsimoniously summarising the data using correspondence analysis. It is clear from the range of methods used to achieve the step from fossil flora to palaeoclimatic estimate, that this is still the subject of some debate. Indeed I criticise all these approaches for their assumptions of a global relationship between physiognomy and climate (see Chapter 3) . The second step, which takes us from palaeoclimate estimates to palaeoaltitude involves several assumptions and warrants equal consideration. Whilst it is beyond the scope of this thesis to take such discussions further, previous work on this part of the methodology is outlined below.

5.2.1 From palaeoclimate to palaeoaltitude

To date two environmental variables have been estimated from physiognomy with a view to making palaeoaltitudinal estimates from fossil floras. These are mean annual temperature and moist static enthalpy.

Using temperature variables as a proxy for altitude

Mean Annual temperature or similar temperature variables are by far the most commonly used despite the fact that the relationship between altitude and temperature is only empirically understood. The rate at which temperature varies with altitude $\frac{dT}{dA}$ is called the lapse rate. Its value measured in the present day forms the basis for palaeoaltitude estimates from fossil floras. This value varies depending on where and when it is measured. Consequently the value chosen for palaeoelevational reconstructions is the source of some debate

In his work on the elevation of Tertiary floras from the Rio Grande Rift, Meyer [1986] considered factors that affect the rate at which temperature varies with altitude. The terrestrial lapse rate, i.e. the rate at which temperature changes with altitude along a ground transect, as opposed to within a column of air (environmental lapse rate Barry [1981]), is affected by both continentality and base level change. Continentality is the decreasing effect of large bodies of water on climate as one moves into the interior of large land masses. Diurnal and seasonal

temperature fluctuations are greater in the interior than on the coast because water heats and cools more slowly than land, damping temperature fluctuations. A high base level, i.e. the presence of regional elevation in a continental setting can reduce lapse rate because the ground absorbs solar energy and heats the surrounding air by radiation. Meyer [1986] noted that values for lapse rates can deviate significantly from the mean value used by Axelrod & Bailey [1976] of 5.5°C/km observing a range of between 3.6 and 8.1°C/km. Meyer [1986] attempted to correct for these factors by estimating the difference between the sea level MAT at the coast, and the sea level temperature at the inland site. He admitted however, that estimates of this difference are largely subjective. His assertions that lapse rates vary greatly are based on very localised calculations, often without a sea level data point. In contrast Wolfe [1992] compared coastal climate stations with those in the continental interior situated in intermontane basins. These were considered good analogues for sites of fossil flora deposition and showed only small variations in lapse rate. He noted three important things about lapse rates: first, that lapse rates decrease with decreasing latitude, second that lapse rates differ between leeward and windward sides of mountain ranges, and finally that the relationship between Mean Annual Temperature and elevation is non–linear with $\frac{dMAT}{dA}$ decreasing with increasing altitude. It is clear from this that the selection of an appropriate lapse rate for fossil floras is far from simple.

Povey [1995] based his selection of appropriate lapse rates for palaeoaltitude estimation on present day lapse rates but qualified this because several factors have changed since the deposition of the assemblages he studies. Because modern climates are less equable than the Early Tertiary climates of the fossil floras he studied ([Savin, 1977]) he selected modern lapse rates from regions of lower latitudes than his fossil sites to compensate for this. In addition the winter incursions of arctic air in modern America keep todays lapse rates lower than they would otherwise be. The absence of these incursions at the time when his fossil floras lived is deduced because the Arctic sea was not then yet frozen [Clark, 1982] such that cold air masses from Siberia were not yet deflected over America by the Tibetan plateau. Consequently Povey [1995] used higher values than modern lapse rates. Finally Povey [1995] considered the palaeogeography surrounding his fossil sites when selecting an appropriate lapse rate.

Using moist static enthalpy as a proxy for altitude

The complicated and somewhat subjective nature of the selection of lapse rate is one argument for the use of moist static enthalpy (H) over mean annual temperature (MAT) as a proxy for altitude, because it is based on the laws of the conservation of energy rather than on an empirical temperature/altitude relationship [Forest *et al.*, 1995; Forest, 1996]. As discussed in Section 3.5.2 moist static energy (see Equation 3.5) has been shown to be conserved to a good approximation along lines of latitude [Forest *et al.*, 1995; Forest, 1996]. The rate of change of moist static enthalpy with altitude is g, the gravitational acceleration, which is essentially constant for our purposes. The relationship between H and altitude is clear but the question remains how clearly we can pick up a moist static enthalpy signal from the foliar physiognomy of

vegetation. Equation 3.5 shows that moist static enthalpy consists of a temperature component and a humidity component. These factors directly affect the way a leaf may function and therefore presumable exert evolutionary pressures on foliar physiognomy. It is therefore not hard to see why a relationship might exist between physiognomy and moist static enthalpy. This relationship is demonstrated empirically in Forest *et al.* [1995]; Forest [1996].

In the ensuing discussion of palaeoaltitudinal estimation the nearest neighbour methodology on fossil floras both MAT and H will be calculated.

5.2.2 The merit of using numerous sea level and inland floras

Whichever methodology is used to extract environmental parameters from fossil floras, and whatever the environmental parameter used as a proxy for altitude, one problem cannot be overlooked, and that is the difficulty of finding and matching contemporaneous floras, one at sea level, and one at elevation. The degree to which we know two floras are contemporaneous affects our confidence that the two floras existed in identical global climate conditions. This knowledge is the basis for all palaeoelevation deductions and is the reason why Axelrod's [Axelrod, 1986] comparison between modern and ancient floras at the same locality to deduce uplift is not valid. Povey [1995]; Povey *et al.* [1994] advocated the use of several floras at both sea level and elevation to alleviate this problem, stating that errors resulting from climate change between the deposition of two floras that are directly compared, will be averaged out if enough floras are examined. A similar method might be used to compensate for errors in altitude estimates derived from anomalous micro-climates, such as those resultant from temperature inversions in enclosed valleys.

The ultimate aim of this work, and other projects like it, has been to extract information from fossil plants that widens our understanding of tectonic processes in the region. An additional argument for the use of numerous fossil floras in analyses of palaeoelevations is derived from the nature of the information required to enhance our understanding of tectonics. To evaluate work done against gravity we need to have information about the *surface* elevation history. A single point in space and time gleaned from the analysis of a single pair of contemporaneous flora, is of less use. It could give misleading information about the average surface elevation of the region and it is only the uplift of this hypothetical surface that gives information about work done against gravity. In contrast the study of several floras allows us to approximate the average elevation in a region.

Whereas many researchers have tended to use only one or two sites in their palaeoaltitudinal reconstructions [e.g. Gregory & McIntosh, 1996], two recent studies have attempted to synthesise numerous floras into their palaeoaltitudinal estimations. Povey [1995] used 14 sites to study altitude in 3 areas in western North America during the Early Tertiary, using the CLAMP methodology first developed by Wolfe [1993]. Forest [1996] took 28 floras ranging in age from the Eocene (48 Ma) to the middle Miocene (14 Ma) to investigate palaeoaltitudes of Western North America with special attention paid to Miocene palaeoelevations of the Great Basin and the

Sierra Nevada. His estimates were based on the modern CLAMP data base collected by Wolfe, but using a principal components analysis in conjunction with multivariate regression [Forest, 1996]. These studies are almost mutually exclusive with only two of the floras in common: the Republic flora and the Copper Basin flora.

5.3 The fossil floras

All of the scores discussed in Povey [1995] were made available to me by the author for study. In addition the scores for approximately 1/3 of the sites discussed by Forest [1996] were made available for study by J.A. Wolfe (pers. comm). The floras discussed are listed in table 5.4.2 along with the other floras examined in Povey [1995] and Forest [1996]. These floras are re–examined using the nearest neighbour approach below. The nature of this technique has allowed me to examine their position in physiognomic space relative to the modern sites collected to date, and this will also be discussed. In combination this information will shed light on the power of the palaeobotanical approach of palaeoclimate and palaeoaltitude estimation, both in general, and more specifically the various different methodologies that have been used to date.

The addition of fossil sites to the physiognomic data set and the subsequent transformation of that data set using correspondence analysis results in a slight distortion of the original data because of the addition of a new data point. To avoid large amounts of distortion the 21 fossil sites were added to the data set individually such that transformations were only ever performed on $x + 1$ sites unless otherwise stated, where x is the number of sites in the modern data set.

5.4 The relevance of position in physiognomic space

5.4.1 Variation observed within the modern data set

It is clear from the analysis of modern data (see chapters 2 and 3) that the position of sites in physiognomic space is all important. Analysis has shown that physiognomic response to climate is locally consistent but varies globally. This is apparent at two different scales. The first scale of variation can be observed within the original CLAMP data set, where subsets distinct from one another in an environmental as well as a physiognomic sense, show different responses to climate. As discussed in section 3.1.1 these subsets are divided by thresholds within climate space, on either side of which the controls on physiognomy change. The physical threshold of the freezing point of water is an example of this. Beyond the point in climatic space where water regularly freezes, the relationship between physiognomy and rainfall must change, because the plant can no longer utilise *all* of the precipitation. It is thought that this at least partly explains the existance of the sub–alpine outliers in the CLAMP dataset [Wolfe, 1993].

On a broader scale, the southern hemisphere data with its Gondwanan heritage occupies a different portion of physiognomic space from the predominantly North American sites of the

original CLAMP data set. Coupled with this physiognomic distinction is a differing relationship between climate and physiognomy. Whilst many of the southern hemisphere samples are climatically different, several overlap in climatic conditions with the northern hemisphere samples yet have very distinct physiognomy. For an explanation of their differing physiognomy therefore we must look for something other than physical thresholds. The very different evolutionary histories of the floras contained in the two data sets is one feasible explanation, indeed the predominance of evergreen plants in the vegetation of the southern hemisphere has already been used as an explanation for the differing values of $d(\frac{entire:teeth}{dMAT})$ between southern and northern hemisphere floras in leaf margin analysis [Wolfe, 1979].

5.4.2 Position of fossil floras in physiognomic space

Before forming MAT and H estimates for the fossil sites it is essential to chart their position in physiognomic space relative to modern sites. If they do not lie in a realm occupied by modern floras we must question the validity of any palaeoclimatic estimates.

The fossil sites were transformed using correspondence analysis within both the full combined data set and the northern hemisphere data set alone. This enables them to be viewed both in the context of all modern sites collected and in the context of the northern hemisphere alone, which in an evolutionary sense is more appropriate.

Figure 5.1 shows the position of the fossil sites in axis one–two–three space relative to the combined northern and southern hemisphere sites whilst Figure 5.2 shows their position in axis one–two–three space when the correspondence analysis transformation is carried out with the original CLAMP data set alone. These plots show that the presence of the physiognomically different New Zealand and Australian sites has a significant effect on the position of the fossil sites relative to the original CLAMP data set; the data from which climatic information has previously been extracted in Forest [1996] and Povey [1995]. When the southern hemisphere sites are included in the analysis, several of the fossil sites are drawn out of the northern hemisphere cluster on axis three. One sample, Puget 9731, is drawn right into the southern hemisphere cluster such that 9 of the 10 nearest neighbour sites selected are from the southern hemisphere.

To explain this effect I compare it to parallax: the apparent change in position of objects cause by a change in position of the observer. The insertion of the southern hemisphere sites forces CA to select new principal axes; this is analogous to changing the angle from which we view the data. This is illustrated in Figure 5.3, which shows how the addition of the New Zealand sites to the data set could affect the selection of principal axes such that the fossil site is no longer contained within the space defined by the modern North American floras. From this it is clear that at least some of the North American fossil sites are physiognomically distinct from their modern counterparts, but that this distinction is not important in terms of the physiognomic variation of the modern north America data set, and is only selected in the first few axes of correspondence analysis when southern hemisphere samples are included in the ordination.

The fossil sites that lie outside the cluster of northern hemisphere modern sites on axis

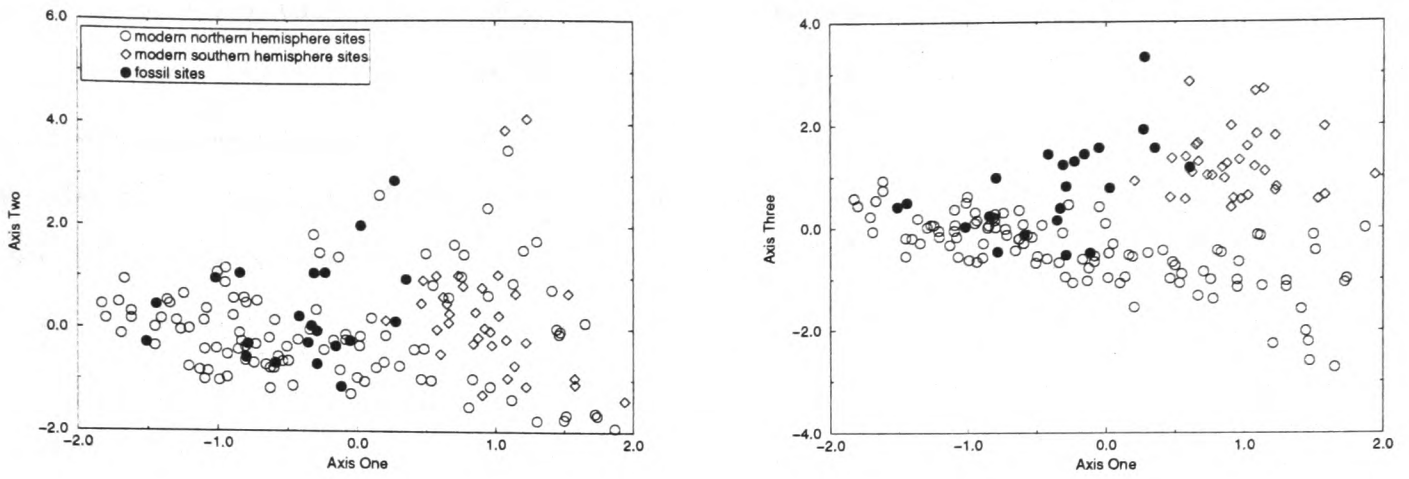


Figure 5.1: Position of fossil sites in axis 1–2–3 space after correspondence analysis relative to the combined northern and southern hemisphere data set. To minimise distortion each fossil sites is added individually to the data set before the transformation is conducted.

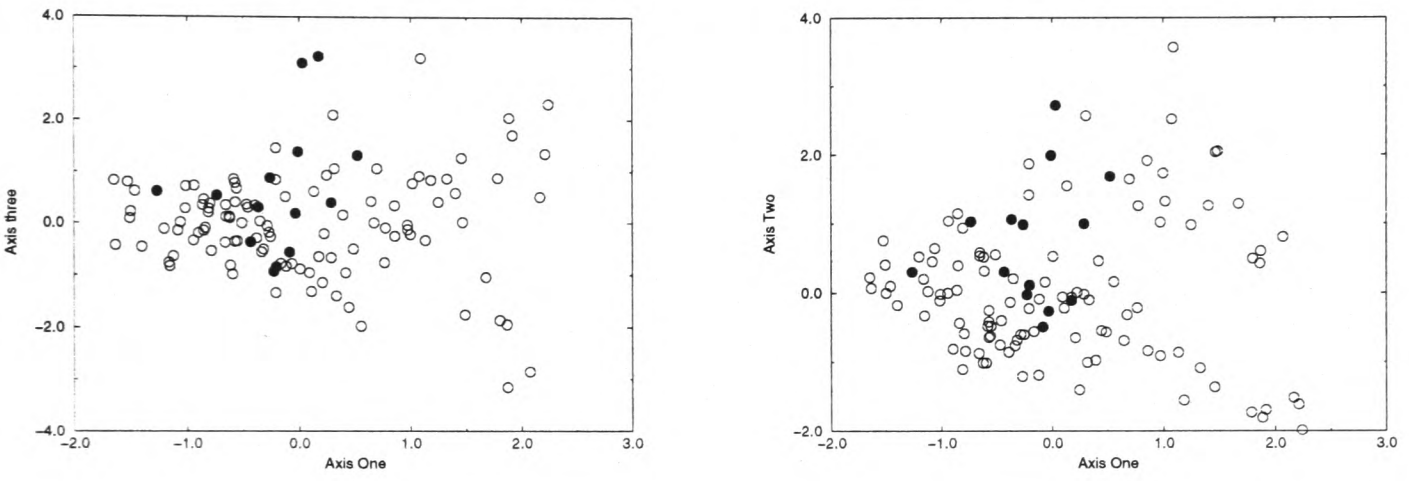


Figure 5.2: Position of fossil sites in axis 1–2–3 space after correspondence analysis relative to the northern hemisphere data set. To minimise distortion each fossil sites is added individually to the data set before the transformation is conducted.

three are: Bullhead Ranch, Buffalo Canyon, Cape Blanco, Coal Mine, North Elko, Nut Bed, South Elko, Trapper Creek, White Cliffs, and Wishkaw. These outlying fossil sites are, apart from Buffalo Canyon, all Povey [1995] sites. Several hypotheses could be forwarded to explain this result. That these fossil sites were almost exclusively scored by one person, and therefore could have been scored with a systematic bias is one possible explanation. The scoring method developed in Wolfe [1993] is designed however to be objective, although this can only be tested by several people scoring the same flora independently. The samples scored by Povey [1995] are in general much older than most of those analysed by Forest [1996] (see Table 5.4.2), and it seems possible that it is their antiquity that best explains their physiognomic distinction from modern, and more recent fossil, sites. A more in depth discussion of why these fossil sites are physiognomically distinct from modern northern hemisphere floras is beyond the scope of this thesis, however, given the extensive investigation of the nature of physiognomic space and the relationship between climate and physiognomy contained in previous chapters, a discussion of the validity of the climate estimates made using such fossil sites is not.

Estimates of MAT and H made using the nearest–neighbour approach are presented in Table 5.4.2. As one might expect the two sets of climate estimates for those fossil sites that

are dragged out of the northern hemisphere cluster by the addition of the southern hemisphere data are very different. MAT estimates made for the sites that remain within the northern hemisphere cluster for both ordinations are very similar. In contrast however the estimates for H differ by as much as 40kJ/kg. A closer inspection reveals that the relative position of these sites within the northern hemisphere cluster changes. This is illustrated by the difference in nearest neighbours selected in the two experiments. For the Chalk Hills fossil site for example only 5 of the 19 nearest neighbours selected are common to both the experiments. The MAT estimates appear quite robust to this change, whilst the H estimates are plainly not. This difference could be explained by the smaller modern northern hemisphere data set available with H values calculated, thus making it more prone to distortion by the addition of the southern hemisphere sites.

Site name	Age	MAT(°C)/H(kJ/kg			
		Povey:1995	Forest:1996	NN nh	NN nh+sh
Wishkaw(DRP)	48Ma	16.9/-		17.1/322.0	13.6/312.7
Republic(DRP)	48Ma	11.6/-	12.4/307.9	12.5/324.8	12.2/280.7
Copper Basin(DRP)	39.41±0.7Ma	12.6/-	10.8/300.3	12.0/323.4	7.9/288.3
Fingerrock(JAW)	15.4Ma		3.1/279.1	6.2/324.9	5.4/296.3
Middlegate(JAW)	15.48±0.2Ma		7.9/289.7	9.0/320.8	8.8/286.9
Buffalo Canyon(JAW)	15.6±0.02Ma		7.7/288.0	4.4/320.0	3.2/297.1
Stewert Spring(JAW)	14.9±0.4Ma		9.3/290.6	7.9/320.1	5.7/299.6
Aldrich Station(JAW)	12.4-13.3m		13.1/294.5	9.7/313.3	9.6/288.4
Chalk Hills(JAW)	12.5Ma		7.4/293.6	7.6/313.6	8.7/299.7
49CAMP(JAW)	15.5-16Ma		11.7/299.0	14.3/323.9	13.9/280.2
Princeton(DRP)	45-48Ma	6.9/-		7.3/325.5	7.6/289.2
North Elko(DRP)	Early Eocene	13.6/-		9.6/312.7	6.5/296.8
Coal Mine(DRP)	47.9±0.45Ma	13.3/-		10.2/320.6	6.0/296.9
South Elko(DRP)	47.85±0.95Ma	11.2/-		11.9/319.4	8.8/300.9
Trapper Creek(DRP)	9.7-13.5Ma	12.3/-		11.0/320.9	7.3/300.5
Bullhead(DRP)	not well dated	14.3/-		11.4/321.8	7.3/290.3
Nut Bed(DRP)	43.8±0.7Ma	19.0/-		21.4/313.5	19.5/311.5
West Branch(DRP)	43-46Ma	13.8/-		13.7/325.3	12.4/289.8
White Cliffs(DRP)	44.67±0.77Ma	13.6/-		14.2/325.1	12.2/289.8
Puget 9731(DRP)	Middle Ravenian	19.3/-		18.8/324.2	11.5/310.4
Cape Blanco(DRP)	~12Ma	16.9/-		16.3/321.4	11.1/290.8

Table 5.1: Table showing fossil sites of Povey, 1995 (DRP) and Forest, 1996 (JAW) with MAT estimates and where data available H estimates using the nearest neighbour approach. Note that the nearest neighbour approach is carried out using both the original northern hemisphere CLAMP data set (nh) and the combined data set including southern hemisphere sites (nh+sh)

5.5 Discussion

These results raise several questions for the palaeobotanist keen to apply a physiognomic approach to fossil floras in order to estimate climates and altitudes of the past.

First, the fossil sites scored to date do not all lie within the space defined by the modern floras and therefore should not all be used for climate estimation. One explanation of this is the antiquity of the outlying samples, which are mostly Eocene. Whilst Wolfes scoring methodology is designed to be an objective means of describing the physiognomy of a fossil flora, the fact that all but one of the outlying samples were scored by the same person, is also noted. It is difficult to see where in the scoring method, scope for subjectivity may lie, but ultimately the only way of eliminating this explanation is by testing this, and comparing the scores produced by several workers given exactly the same material to work with.

Second, the addition of a single fossil flora to a physiognomically restricted modern data set does not enable us to see differences between the fossil datum point and the modern floras, because such differences are not expressed in the principal axes selected by ordination. It is the presence of the southern hemisphere sites in the ordination which allows us to observe that some of the fossil sites were indeed outliers to the modern northern hemisphere data. This is clearly dangerous in the light of the fact that physiognomic response to climate changes as we move through physiognomic space.

In contrast, to view the fossil floras in CA space produced by the transformation of the entire modern data set produces local distortions because the principal axes selected are compromise solutions, which do not necessarily best represent the local variation in physiognomy and, significantly the climate signal from the physiognomy.

These two opposing points seem to suggest that further advances in the analysis of fossil floras' physiognomy might be made by using more than one ordination in the analysis. The first could include all modern sites and would allow the position of the fossil flora in physiognomic space to be properly assessed. This might be followed by an ordination of the modern floras that plot near to the fossil site so that the estimation of climatic parameters is carried out using the most appropriate data space.

Clearly the collection of new modern sites has added to our understanding of the physiognomy of fossil floras although our confidence in some of the climate estimates from these floras have been reduced. The addition of still more new modern samples to the data set can only improve our understanding of the relationship between physiognomy and climate and consequently our appreciation of the application of this relationship to the fossil record to ascertain climate and altitude of the past.

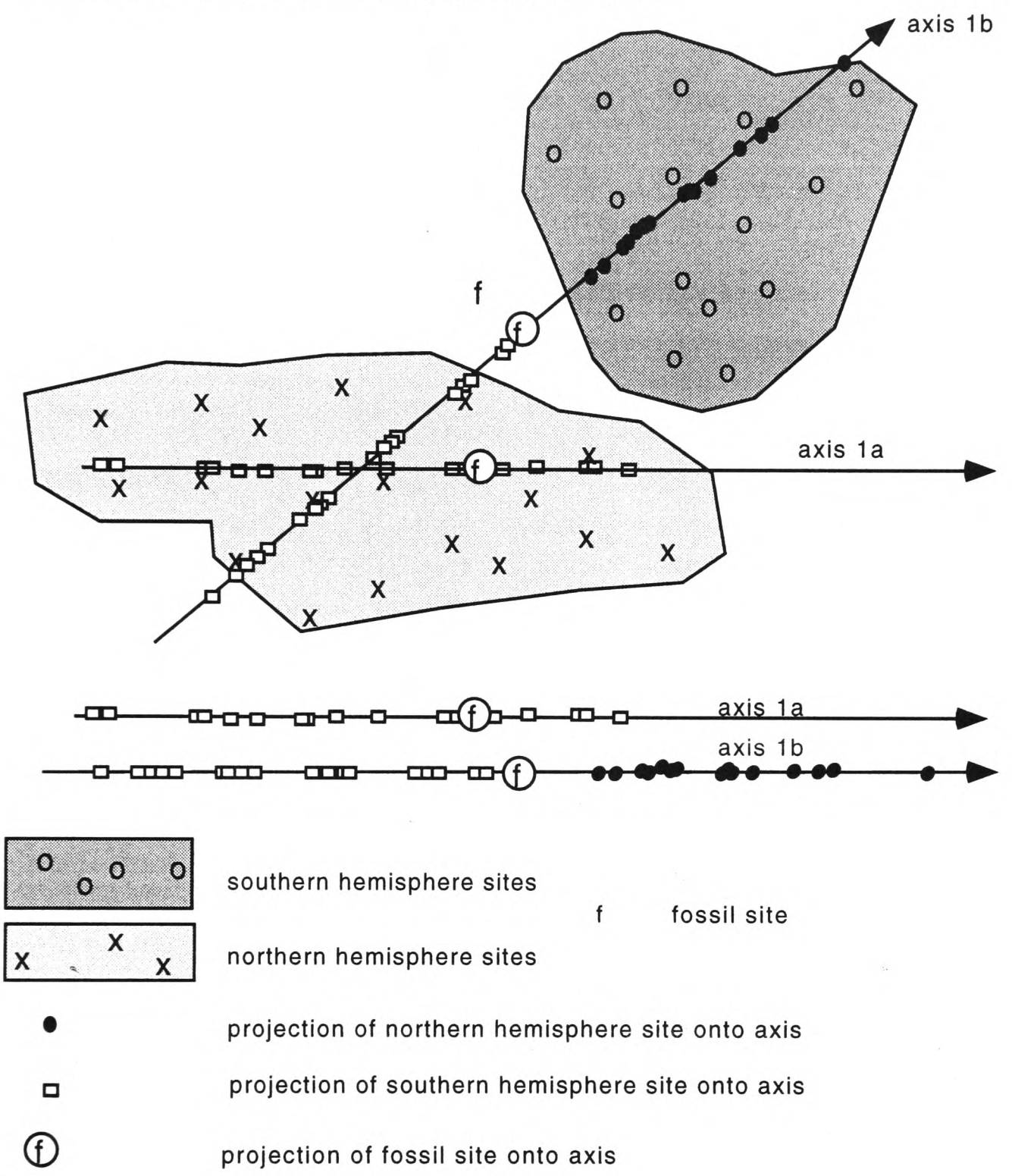


Figure 5.3: Cartoon showing how the addition of the southern hemisphere sites could preferentially drag fossil sites away from the north America cluster. Axis 1a represents the first component selected by correspondence analysis when only northern hemisphere modern sites are included in the transformation whilst axis 1b represents the component selected when the southern hemisphere modern sites are also included in the transformation

Chapter 6

Summary and Conclusions

6.1 Introduction

The underlying aim of the research that directed this thesis has been the assessment of palaeoclimate and palaeoaltitude using a multivariate physiognomically based botanical method. This is following on from a substantial amount of work completed in recent years [Wolfe, 1971; Givnish, 1979; Dolph & Dilcher, 1979, 1980b] which have culminated in several palaeoaltitude estimates for regions in west central America [Gregory & Chase, 1992; Gregory & McIntosh, 1996; Meyer, 1986; Povey *et al.*, 1994; Povey, 1995; Meyer, 1992; Forest *et al.*, 1995; Forest, 1996]. Whilst advocates of CLAMP and related techniques have raced forward to apply the method to fossil floras, it should be remembered that the method is still in a developmental stage with many questions remaining unanswered. These unanswered questions make it easy for the sceptic to dismiss palaeoclimate and altitude estimates made using CLAMP. Such scepticism can only be countered by critically challenging the method itself, questioning wherever possible the premises and assumptions made therein. Whilst the preliminary application of the method to the fossil record has been an essential part of its development, important work remains to be done in expanding the modern data set and analysing the limitations of the methodology.

To leap on the bandwagon, applying CLAMP as a 'black box' to newly collected fossil floras would be open to criticism because it would not, at this juncture, take the methodology any further forward. Instead I have pursued a more constructive line of research. This has entailed investigating and challenging the method itself, such that the technique may be applied in the future with an increased knowledge both of the nature of the relationship between physiognomy and climate and the sources of error in palaeoclimate and palaeoaltitude estimation. New collection of new modern CLAMP samples from the southern hemisphere, including adjacent samples from different vegetation types, altitudinal transects, and taphonomic samples from a lacustrine environment are presented here. The analysis of this enlarged CLAMP data set has increased our understanding of the potential of the use of foliar physiognomy to analyse climate and will result in the more critical selection of appropriate fossil flora for analysis and the wider

acceptance and application of this approach.

6.2 Limitations of CLAMP [Wolfe, 1993]

Even within the somewhat limited biogeographical and environmental extent of the original CLAMP data set [Wolfe, 1993], it is clear that the model developed by Wolfe to describe the relationship between physiognomy and climate fits better in some regions of physiognomic space than others. This non–global behaviour of the data should be expected if one considers the physical thresholds within climatic space which change the control on physiognomy that climatic parameters exert. Undoubtedly the reduction of temperatures to below the freezing point of water changes the plants ability to utilise precipitation. The physiognomic expression of this climatic parameter consequently changes across physiognomic space.

The addition of southern hemisphere samples collected in New Zealand and Australia, only serves to enhance the heterogeneity of the physiognomic data set. The southern and northern hemisphere data overlap in terms of climate. From this we can conclude that they do not all plot on either side of a physical threshold that alters the effects of climate on physiognomy. Despite this, the two data sets are distinct from one another, both in terms of their position in physiognomic space, and the relationship exhibited between physiognomy and climate. A direct comparison between the two data sets using the product moment correlation coefficients between physiognomic variables shows that they differ even in terms of their internal structure.

The use of palaeobotany as a means of exploring climates of the past is not negated by this result. It does mean however, that the analyses of the CLAMP data set conducted thus far, which search for a global relationship between physiognomy and climate, may unavoidably overlook important aspects of the relationship between physiognomy and climate.

A second assumption made in the CLAMP methodology, is that sufficient information for successful climate estimation is contained within the first two axes of correspondence analysis. The subsets within Wolfes original data that, along with the southern hemisphere sites introduced here, do not conform to Wolfes model of the relationship between climate and physiognomy are distinguishable from other sites on the basis of their axis three score. This suggests that axis three contains essential information that should not be ignored.

6.3 The use of nearest–neighbours to form estimates of climatic parameters

A new method to predict climatic parameters from the foliar physiognomy of woody dicotyledons has been developed here which attempts to deal with both of these problems. The Euclidean distance between sites in physiognomic space (transformed into orthogonal space using either correspondence analysis or principal component analysis) was used to inspect the resemblance

structure of the dataset. Varying both number of nearest neighbours and number of dimensions (orthogonal axes) used, environmental variables were estimated at each of the modern sites using physiognomically proximal sites only. In all cases analyses based on a correspondence analysis outperformed those based on principal component analysis. Correspondence analysis is also preferred on theoretical grounds because of the problems of using principal component analysis with compositional data. The best climate estimates for modern sites resulted when the first three CA axes a nd 19 nearest neighbours were employed to form estimates of climate parameters.

Perhaps most importantly, it corroborates the results of Wolfe [1993] that a relationship exists between climate and foliar physiognomy, using a very different approach to the analysis of the data set.

6.4 The application of this method to the fossil record

That a relationship exists between physiognomy and climate is clear. Whether it can successfully be applied to fossil floras in order to extract climate and altitude, however remains to be resolved.

The question of the speed at which species to adapt to a new environment is important in this context but in this study has proved difficult to assess. The adaptation of New Zealand's upland floras to the relatively new microthermal environment has shed little light on this matter. This is because the response of southern hemisphere sites in general cannot be compared to those of northern hemisphere sites. There appears to be a fundamental difference, which is probably strongly linked to their very different heritage. Consequently we cannot tell whether the upland floras of New Zealand have equilibrated in an evolutionary sense, with the microthermal environment, because we cannot validly compare their response to that of the northern hemisphere upland sites. Indeed, given the heterogeneous nature of the relationship between climate and physiognomy in both climate and physiognomic space it is difficult to think of an experiment to test this.

6.5 Taphonomy

If the relationship between physiognomy and climate is to be employed to give us clear ideas about the climate in which fossil floras grew it is essential that the potential taphonomic biases in the physiognomic signal and therefore in the climatic signal is more clearly understood than at present. The accuracy with which a fossil flora represents the flora which was its source is greatly dependent on how we choose to measure that similarity. Wolfes sampling strategy of modern floras is clearly influenced by our understanding of plant taphonomy. This understanding gleaned from both live/dead comparisons in the natural environment, and controlled laboratory experimentation is based almost entirely on univariate experimentation.

A multivariate live/dead experiment was conducted in Lady Lake, New Zealand which

monitored the change in all 29 physiognomic characteristics employed by Wolfe between living vegetation adjacent to the lake and leaves from samples of lake sediment at the lake bottom. The variation in proportions of physiognomic characteristics within the lake bottom sediments themselves was also investigated. Several important conclusions are drawn from this work. It is clear that, both in terms of individual physiognomic characteristics, and in terms of position in physiognomic space after ordination, the proximal sites represent the adjacent living vegetation better than more distal sites. Trends exist in several physiognomic characteristics when moving from proximal to distal sites. One of these, an increasing absence of larger leaves with increasing distance from shore has already been observed in previous taphonomic works. In the past this has been attributed to the increasing dominance of 'sun' leaves from the upper parts of the canopy transported in by wind. In Lady Lake this explanation alone cannot be used because many of the species dominant in distal sites are shrubby and do not protrude into the canopy.

Several other trends apparent in individual physiognomic characteristics are attributable to this bias in size, including an increase in the no–teeth and apex round characteristics with increasing distance from the shore. These are both strongly correlated with the smaller leaf sizes in the living vegetation. In terms of climate estimations, such trends are of greatest significance in univariate methodologies such as leaf margin analysis. In this approach, where the proportion of species with entire margins increases linearly with increasing Mean Annual Temperature, the distal sites have large errors associated with the dominance of entire leaves at these sites. Using multivariate approaches there are no such obvious trends in goodness of estimate from proximal to distal sites. Larger samples, both in terms of number of species and number of specimen, not surprisingly produce better MAT estimates. Unfortunately because of the limited diversity of the living vegetation around the study site few very diverse samples were obtained and so this conclusion cannot be fully backed up. Further experimentation at similar sedimentary localities adjacent to more diverse floras would help to clarify this.

The dangers of scoring floras where species are represented by only a few specimens are illustrated when one inspects the scores for the apex–emarginate characteristic. In the living vegetation this is generally expressed in a small proportion of leaves in any of the species displaying that characteristic, the exception being *Myrsine divaricata*. This characteristic is consistently under–represented in the lake for the sole reason that not enough specimens from each species are examined to give a true representation of its expression in the flora. Such dangers presumably vary from flora to flora and are unquantifiable in the fossil record itself. Our best guard against the underrepresentation of such characteristics in fossil floras is thorough sampling and the maximisation not only of number of species as Wolfe recommends, but also of number of specimens within species. Whilst as I have said, the number of specimen required per species is not quantifiable, in the real world this is often limited by the extent and richness of the fossil beds themselves. Suffice to say that poorly collected samples should be treated with extreme caution.

These results show that multivariate physiognomic approaches to analysing the climate

in which fossil assemblages grew are not crippled by taphonomic bias. They are more robust to taphonomic bias than the commonly used univariate leaf margin analysis. To minimise taphonomic noise in the climatic signal from fossil floras however, certain procedures should be followed. First the diversity of the assemblage and the number of samples representing each species should be maximised by thorough collecting of the fossil site. In a lacustrine environment, sites proximal to the source of input are preferred because they represent the living flora more accurately than distal sites. It is acknowledged that the palaeobotanist is often limited by the richness and extent of a fossil locality, and that some collections are unavoidable poor. Climatic deductions from such floras should be treated with extreme caution.

6.6 Fossil Floras

The analyses of fossil floras to estimate mean annual temperature, moist enthalpy and ultimately palaeoaltitude are re–examined here using the nearest neighbour technique. The results show that the position of fossil floras in physiognomic space must be carefully examined before climatic estimates are made. This examination should be in the light of as expansive a modern data set as possible. The ordination of a fossil flora within a restricted modern data set may result in physiognomic differences between the fossil and modern data not being visible on the primary axes selected by ordination.

In contrast the more physiognomically diverse a modern data set, the more the primary axes selected by ordination are compromise solutions. Consequently the distribution of sites may be locally distorted. This is illustrated on CA axis three where the northern hemisphere sites distribution is squashed by the addition of the southern hemisphere data.

Future work should include the collection of as many new modern sites as possible, such that the position of fossil sites in physiognomic space may be more accurately viewed. In addition the possibility of ordinating the data in a more localised way, once the position of the fossil site in physiognomic space has been established, should be investigated.

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APPENDIX ONE

Plate 1-7
Australian Species

Plates 8-15
New Zealand Species

Plates 16-18
Examples from taphonomic collections at Lady Lake

These images are intended to link in with the data sheets in Appendices Two and Three only, and not to enable the reader to re-score the floras; a process that requires numerous leaves from each species.

Where necessary to show the range of physiognomy, more than one leaf is illustrated.

Scale bars adjacent to each image represent 1 cm. When only one scale bar appears on the page this scale applies to all images on that page.

Australian species: Plates 1-7
Plate One

APOCYNACEAE a) *Alstonia meulleriana*
ARALIACEAE b) *Polyscias australiana*
c) *Polyscias elegans*
CELASTRACEAE d) *Hedraianthera porphyropetala*
e) *Salacia disepala*
BIGNONIACEAE f) *Pandorea pandorana*
CLUSIACEAE g) *Garcinia warrenii*

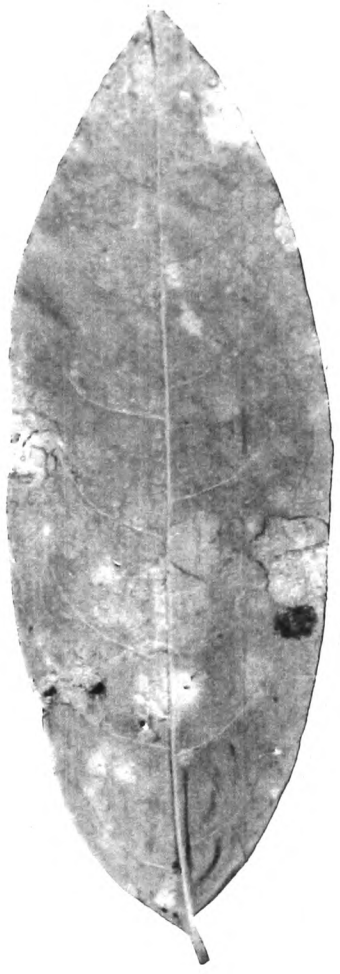
a)

b)

c)

d)

e)



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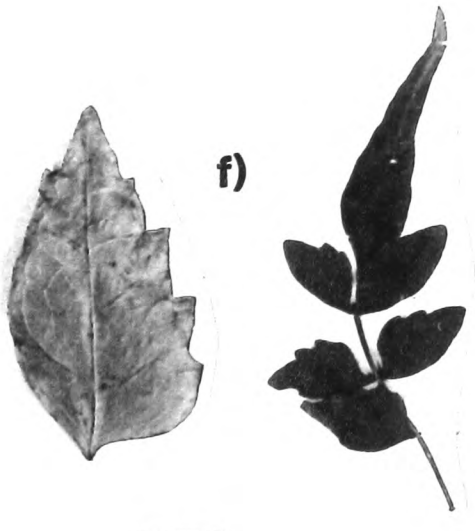
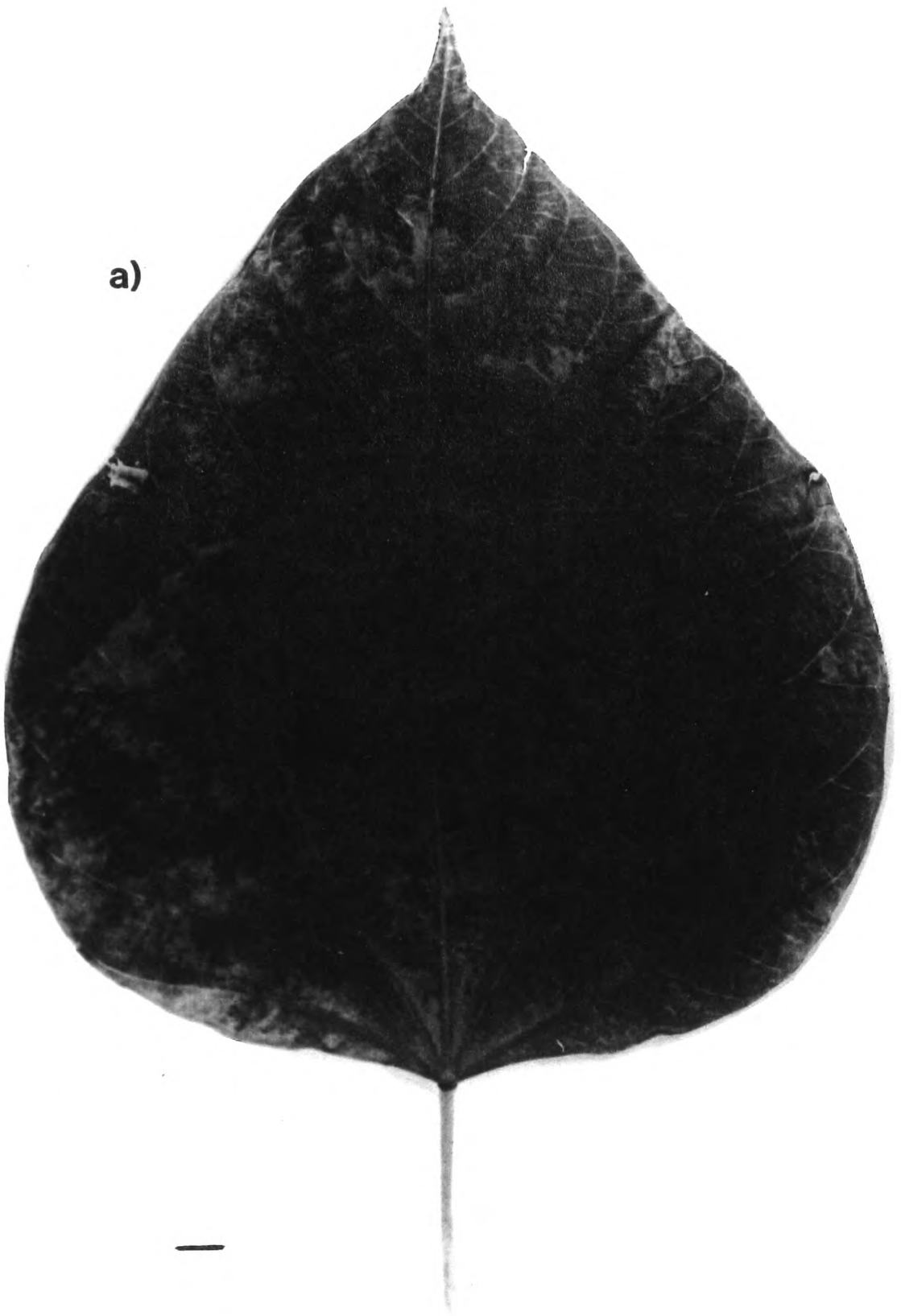


g)

Plate Two

CONNARACEAE a) *Connarus conchocarpus*
DILLENIACEAE b) *Tetracera nordtiana*
ELAEOCARPACEAE c) *Sloanea langii*
d) *Aceratium megalospermum*
EUPHORBIACEAE e) *Cleistanthus discolor*
f) *Macarange subdentata*

a)



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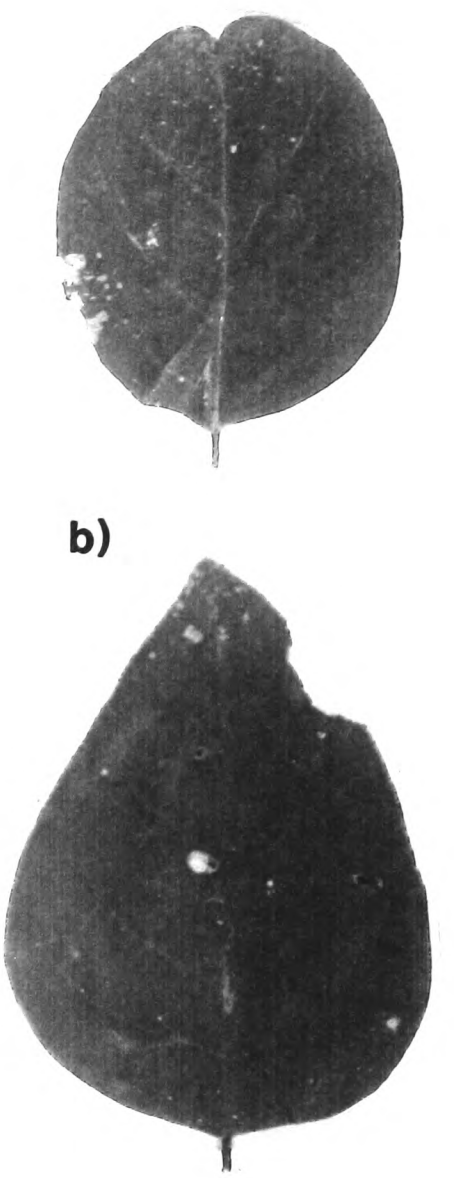


c)

d)

e)

f)

Plate Three

EUPHORBIACEAE a) *Aleurites moluccana* var. rockinghamensis b) *Breynia stipitata*
LAURACEAE f) *Beilschmiedia obtusifolia*
FABACEAE c) *Castanospermum australe*
d) *Austrosteenisia stipularis*
FLACOURTIACEAE e) *Casearia s*p.
EUPHORBIACEAE g) *Rockinghamia angustifolia*
h) *Glochidion sumatranum*

a)

b)

c)

d)

e)

f)

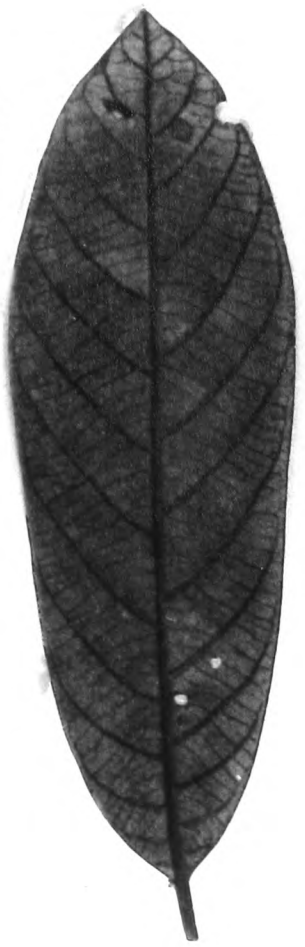
g)

h)

Plate Four

LAURACEAE a) *Cryptocarya mackinnoniana* b) *Cryptocarya murrayi* c) *Cryptocarya sp.*
d) *Neolitsea dealbata*
MELIACEAE e) *Dysoxylum oppositifolium*
MONIMIACEAE f) *Tetrasynandra laxiflora*
g) *Doryphora aromatica* h) *Hedycarya loxocarya*
MORACEAE i) *Ficus destruens* j) *Ficus leptoclada*
MYRSINIACEAE k) *Maesa muelleni*

a)



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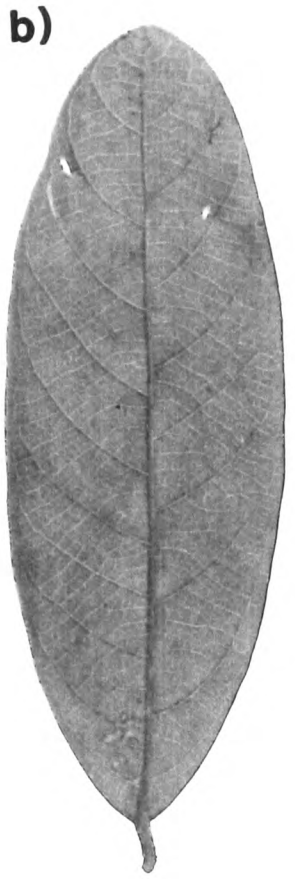

c)

d)

e)

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i)

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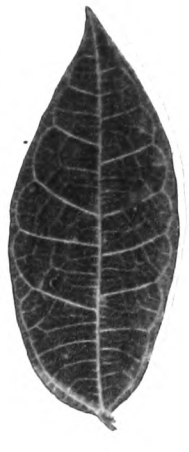


k)

Plate Five

MYRTACEAE a) *Austromyrtus* sp. b) *Decaspermum humile* c) *Rhodamnia spongiosa* e) *Rhodomyrtus macrocarpa*
d) *Rhodomyrtus pervagata* f) *Syzygium kuranda*
g) *Syzygium tierneyanum*
PASSIFLORACEAE h) *Passiflora* sp.
PROTEACEAE i) *Carnarvonia araliifolia*
k) *Musgravea heterophylla* j) *Helicia nortotiana*

a)

b)

c)

d)

e)

f)

g)

h)

l)

j)

k)

Plate Six

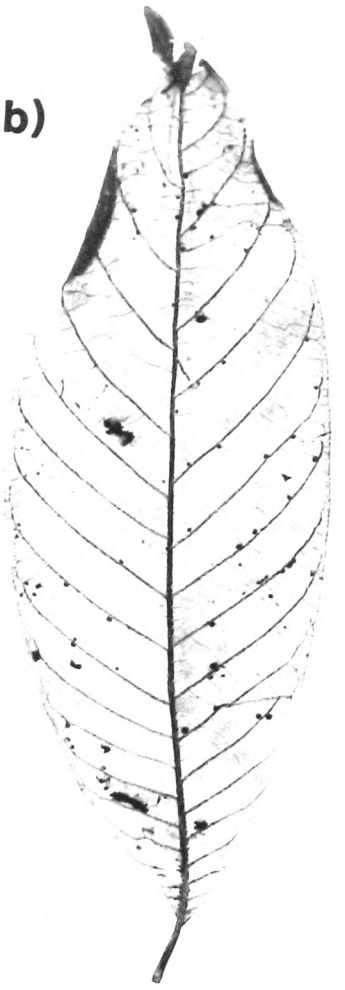
PROTEACEAE a) *Placospermum coriaceum*
(i juvenile ii adult)
RHAMNACEAE b) *Alphitonia whitei*
RUBIACEAE c) *Gardenia ovularis* d) *Guettardella tenuiflora*
RUTACEAE e) *Flindersia acuminata*
f) *Flindersia ifflaiana*
g) *Melicope elleryana*
SAPINDACEAE h) *Cupaniopsis foveolata*
i) *Mischocarpus lachnocarpus*
SAPOTACEAE j) *Pouteria chertarea*

a)

i

ii

b)



c)

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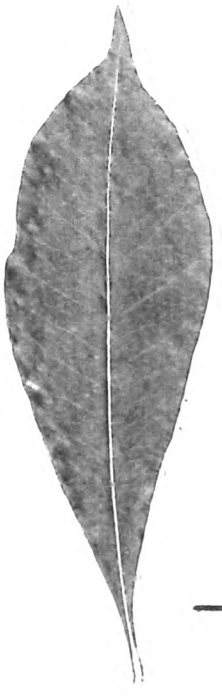
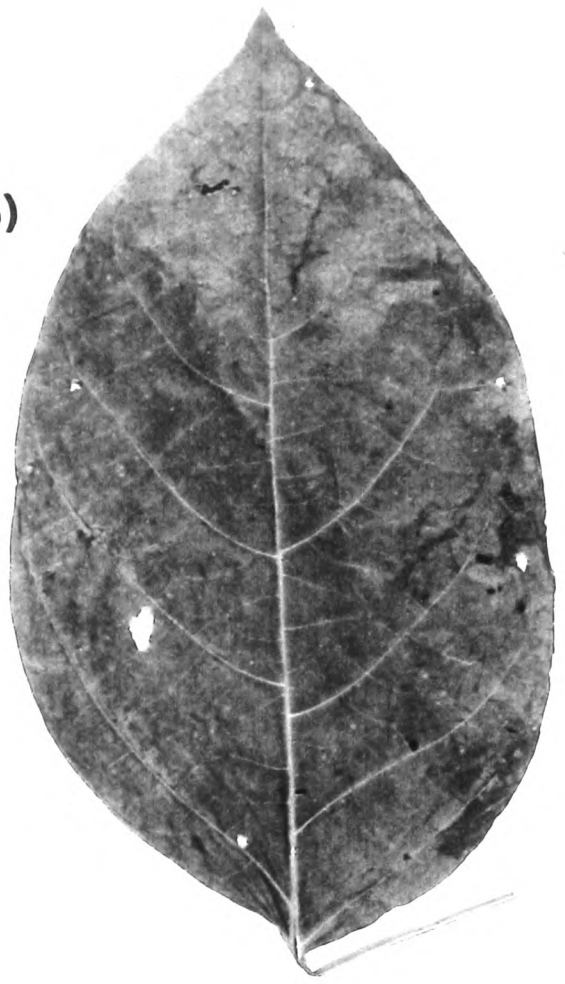


Plate Seven

SYMPLOCACEAE a) *Symplocos cochinchinensis*
VERBENACEAE b) *Clerodendrum* sp.
c) *Faradaya splendida*
XANTHOPHYLLACEAE d) *Xanthophyllum octandrum*
MONIMIACEAE e) *Palmeria scandens*
ANNONACEAE f) *Desmos goeziances*
MENISPERMACEAE g) *Hypserpa decumbens*
APOCYNACEAE h) *Melodinus australis*

a)

b)



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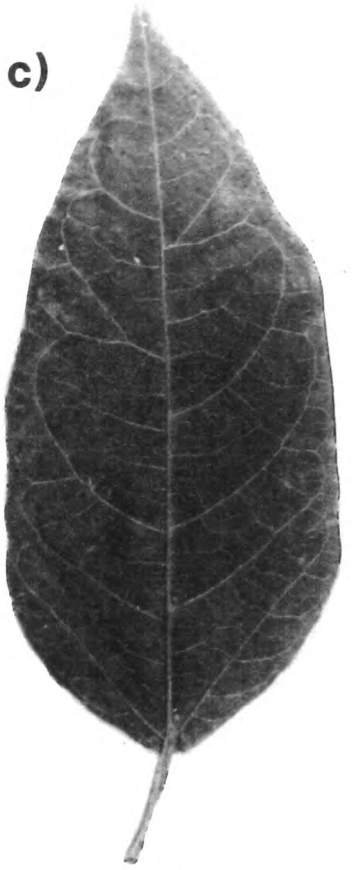

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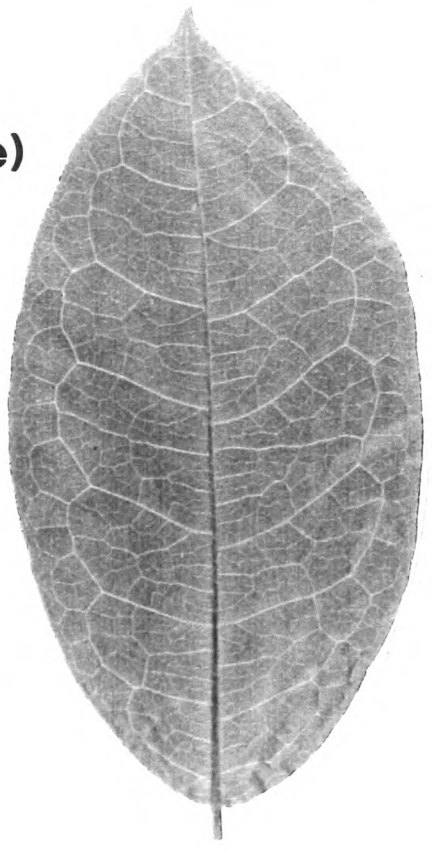

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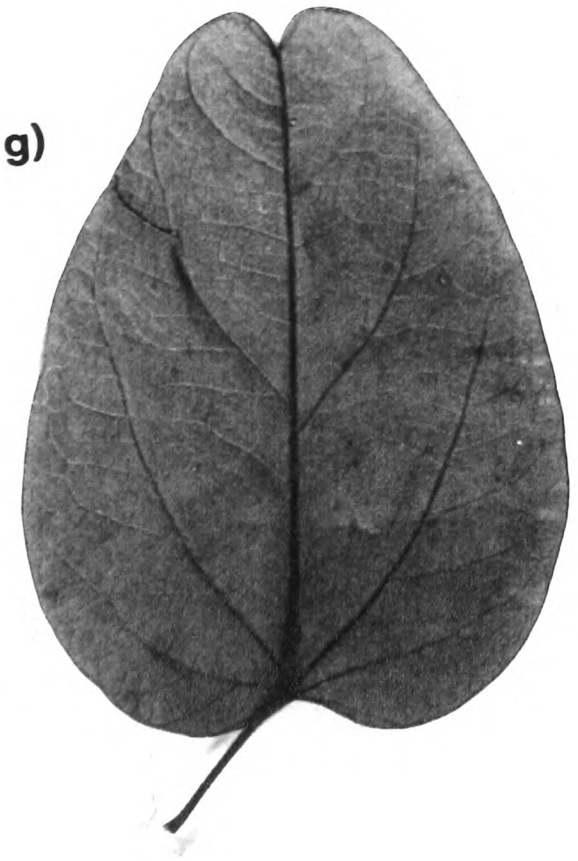
g)



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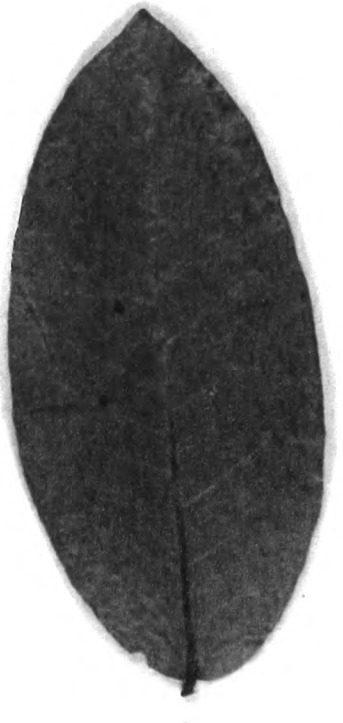


New Zealand species: Plates 8-15
Plate Eight

ALSEUOSMIACEAE a) *Alseuosmia* sp. (unnamed)
APOCYNACEAE b) *Parsonsia capsularis*
c) *Parsonsia heterophylla*
ARALIACEAE d) *Pseudopanax arboreus*
e) *Pseudopanax colensoi* f) *Pseudopanax crassifolius*
(i juvenile ii adult)
g) *Pseudopanax edgerleyi* h) *Pseudopanax linearis*
i) *Pseudopanax simplex* j) *Schefflera digitata*

a)

b)

c)

i

ii

d)

e)

f) i

ii

g)

h)

i)

j)

Plate Nine

CHLORANTHACEAE a) *Ascarina lucida*
ASTERACEAE b) *Brachyglottis bidwillii*
c) *Brachyglottis buchananii* d) *Brachyglottis elaeagnifolia* e) *Brachyglottis repanda*
f) *Brachyglottis rotundifolia* g) *Brachyglottis sciadophila* h) *Celmisia angustifolia* i) *Celmisia* sp. A
j) *Helichrysum aggregatum* k) *Olearia arborescens*
l) *Olearia avicenniaefolia* m) *Olearia colensoi*
n) *Olearia fragrantisima* o) *Olearia ilicifolia*
p) *Olearia lacunosa*

a)

b)

c)

d)

e)

f)

g)

h)

i)

j)

k)

l)

m)

n)

o)

p)

Plate Ten

ASTERACEAE a) *Olearia nummularifolia*
b) *Olearia rani* c) *Olearia* sp A.
CONVOLVULACEAE d) *Calystegia tuguriorum*
CORIARIACEAE e) *Coriaria arborea*
CORNACEAE f) *Griselinia littoralis* g) *Griselinia lucida*
CORNOCARPACEAE h) *Corynocarpus laevigatus*
CUNONIACEAE l) *Weinmannia racemosa*
ELAEOCARPACEAE i) *Aristotelia serrata*
j) *Elaeocarpus dentatus* k) *Elaeocarpus hookerianus*

a)

x5

b)

c)

d)

e)

f)

g)

h)

i)

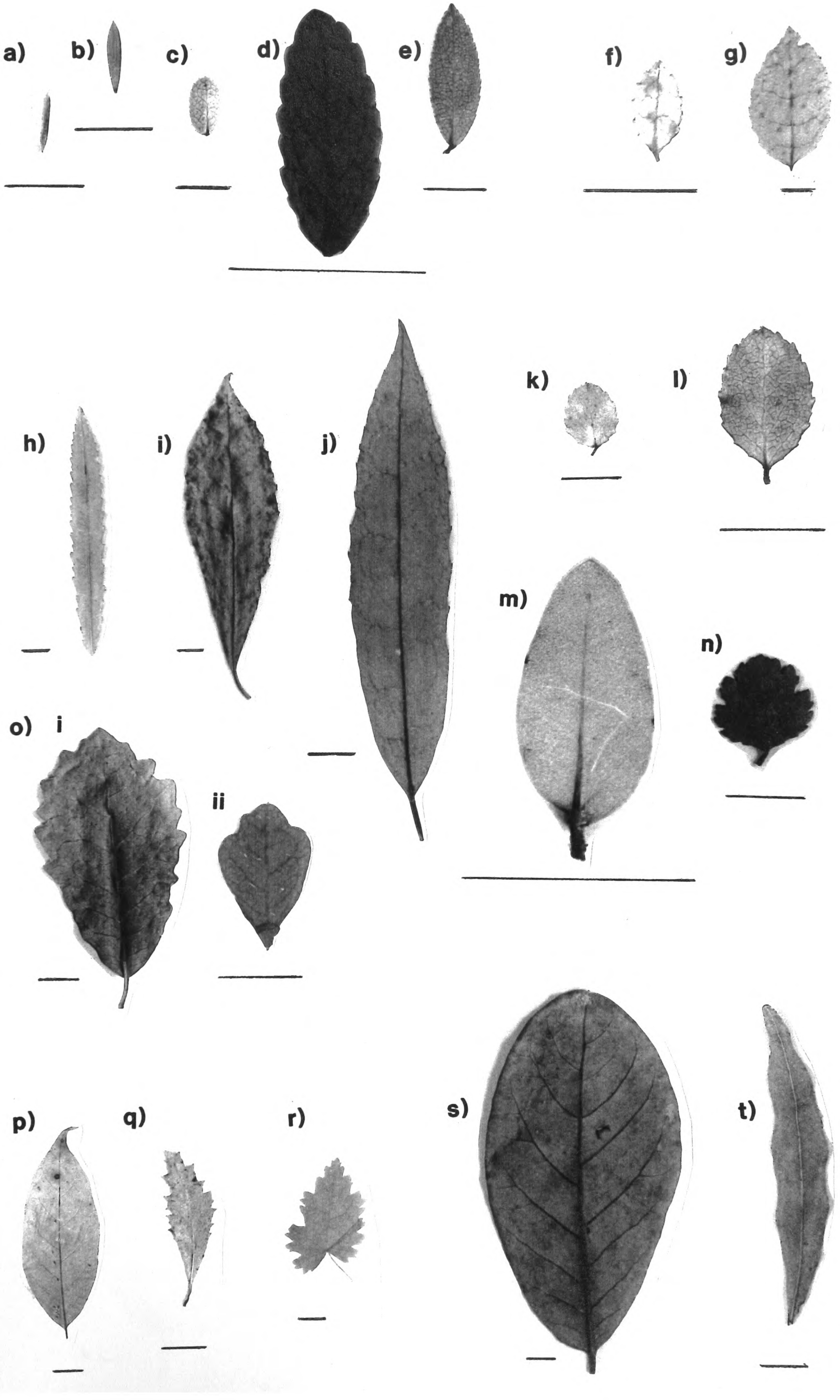
j)

k)

l)

Plate Eleven

EPACRIDACEAE a) *Leucopogon fasciculates*
b) *Leucopogon parviflorus*
ERICACEAE c) *Gaultheria colensoi* d) *Gaultheria crassa*
e) *Gaultheria rupestris* f) *Pernettya alpina*
ESCALLONIACEAE g) *Carpodetus serratus*
h) *Ixerba brexioides* i) *Quintinia acutifolia*
j) *Quintinia serrata*
FAGACEAE k) *Nothofagus fusca* l) *Nothofagus menzeii*
m) *Nothofagus solandri* var. cliffortioides
n) *Nothofagus truncata*
ICACINACEAE o) *Pennantia corymbosa*
LAURACEAE s) *Bilschmiedia tarairi*
t) *Beilschmiedia tawa*
LOGANIACEAE p) *Genistoma rupeste*
MALVACEAE q) *Hoheria angustifolia* r) *Hoheria lyallii*


a)
b)
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i)
j)
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l)
m)
n)
o)
i
ii
p)
q)
r)
s)
t)

Plate Twelve

MONIMIACEAE a) *Hedycarya arborea*
MYRSINACEAE b) *Myrsine australis*
c) *Myrsine chathamica* d) *Myrsine divaricarta* e)
Myrsine salicina f) *Caldcluvia rosaefolia*
g) *Leptospermum ericoides*
h) *Leptospermum scoparium*
i) *Lophomyrtus obcordata*
MYRTACEAE j) *Metrosideros colensoi* k) *Metrosideros diffusa* l) *Metrosideros parkinsonii* m) *Metrosideros robusta* n) *Metrosideros umbellata*
o) *Metrosideros* sp. A p) *Metrosideros* sp. B
q) *Metrosideros* sp. C r) *Neomyrtus pedunculata*
NYCTAGINACEAE s) *Pisonia brunonia*
OLEACEAE t) *Nestegis cunninghamii*
u) *Nestegis lanceolata* v) *Nestegis montana*

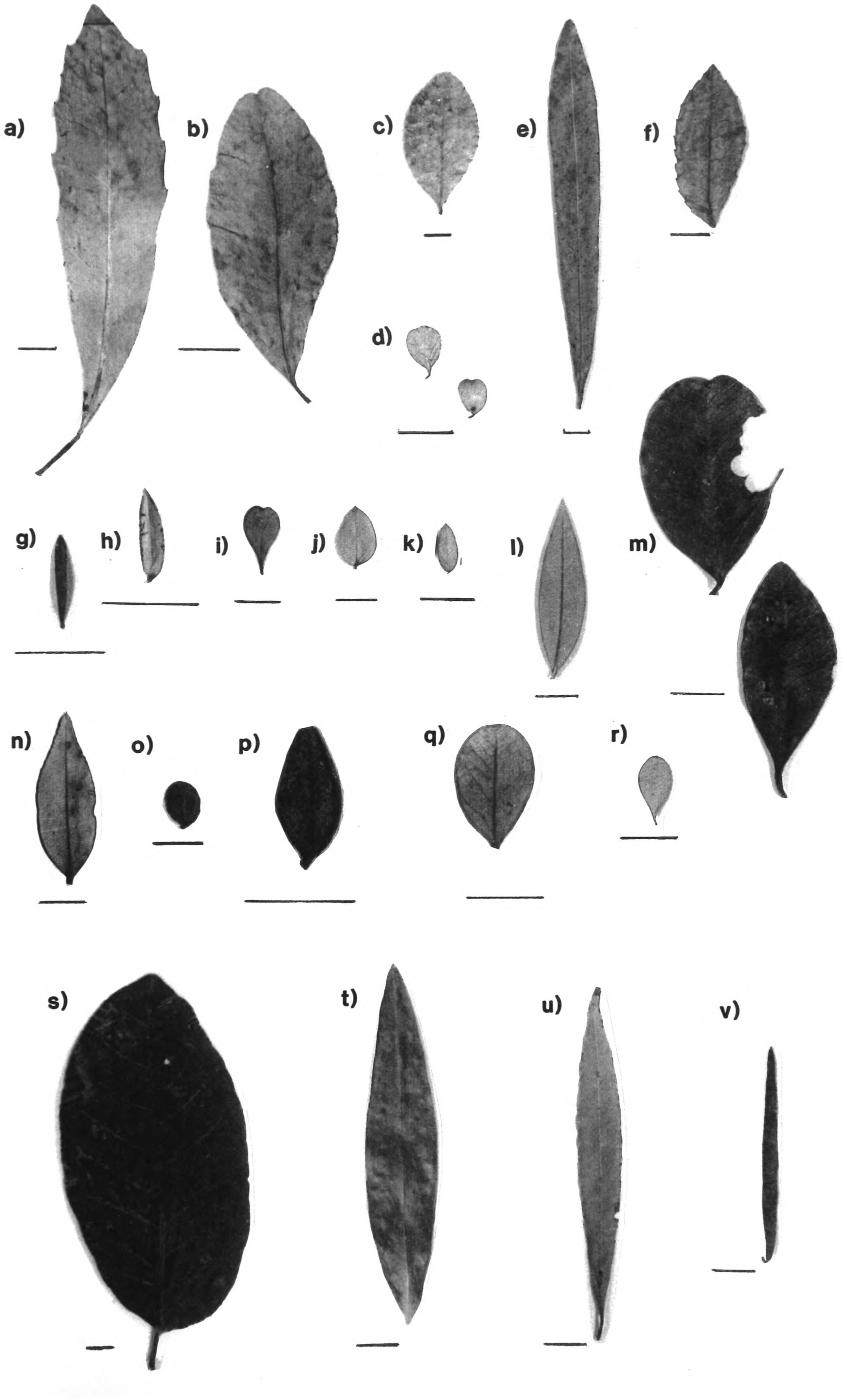

a)
b)
c)
d)
e)
f)
g)
h)
i)
j)
k)
l)
m)
n)
o)
p)
q)
r)
s)
t)
u)
v)

Plate Thirteen

ONAGRACEAE a) *Fuchsia excorticata*
PAPILIONACEAE b) *Sophora microphylla*
PIPERACEAE c) *Macropiper excelsum*
PITTOSPORACEAE d) *Pittosporum colensoi*
e) *Pittosporum eugenioides*
f) *Pittosporum huttonianum*
g) *Pittosporum tenuifolium*
PROTACEAE h) *Knightia excelsa*
RANUNCULACEAE i) *Clematis foetida*
j) *Clematis forsteri*

a)

b)

c)

d)

e)

f)

g)

h)

i)

j)

Plate Fourteen

ROSACEAE a) *Rubus australis* b) *Rubus cissoides*
c) *Rubus parvus* d) *Rubus schmidelioides*
e) *Rubus squarrosus*
RUBIACEAE f) *Coprosma acerosa* g) *Coprosma areolata*
h) *Coprosma cheesmanii* i) *Coprosma cuneata*
j) *Coprosma depressa* k) *Coprosma foetidissima*
l) *Coprosma linariifolia* m) *Coprosma grandifolia*
n) *Coprosma lucida* o) *Coprosma parviflora*
p) *Coprosma propinqua* q) *Coprosma pseudocuneata*
r) *Coprosma rhamnoides* s) *Coprosma rigida*
t) *Coprosma rotundifolia* u) *Coprosma serrulata*
v) *Coprosma spathulata* w) *Coprosma tenuicaulis*
x) *Coprosma tenuifolia* y) *Coprosma* sp. A
z) *Coprosma* sp. C aa) *Coprosma* sp. B

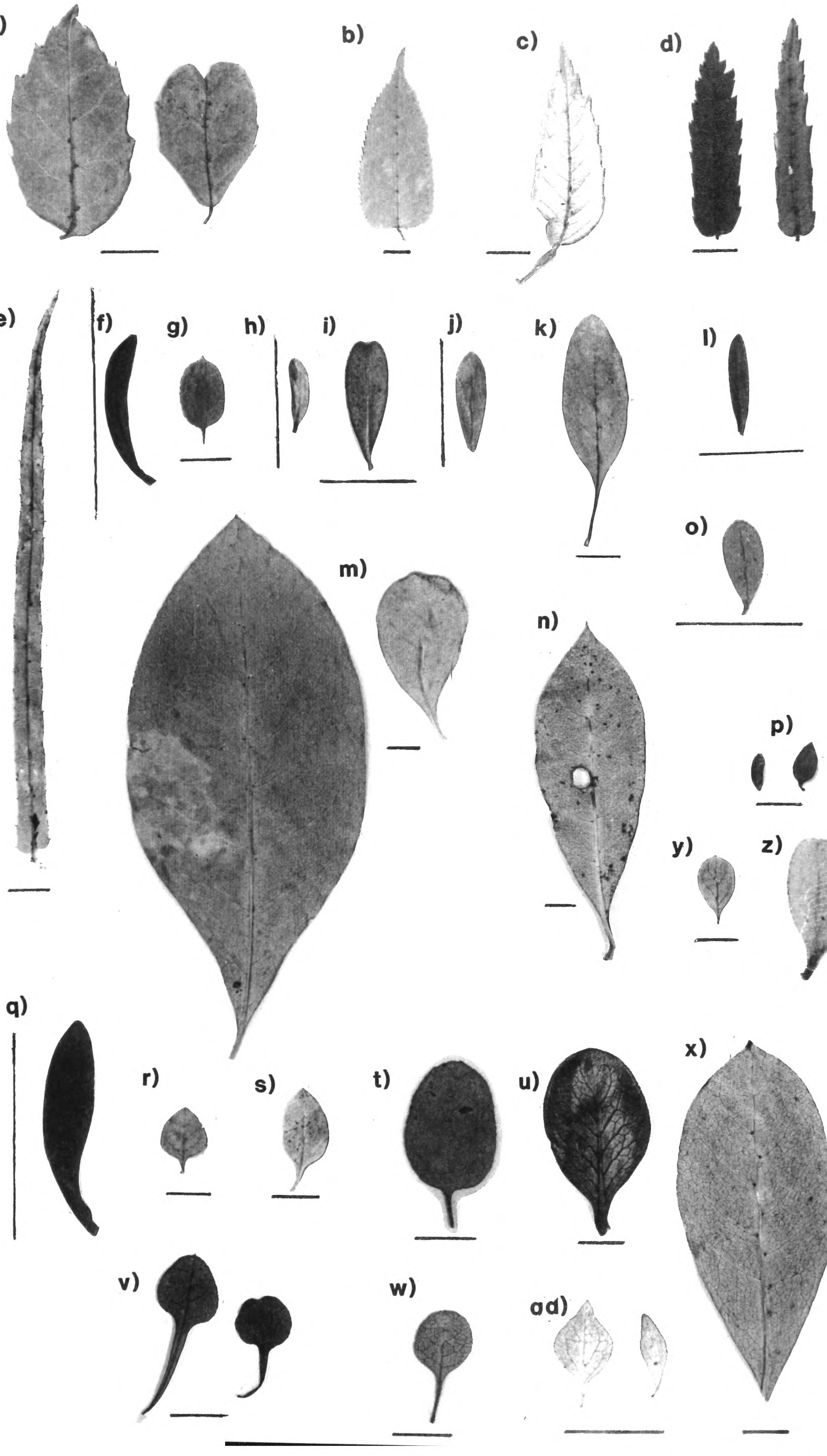

a)
b)
c)
d)
e)
f)
g)
h)
i)
j)
k)
l)
m)
n)
o)
p)
y)
z)
q)
r)
s)
t)
u)
x)
v)
w)
aa)

Plate Fifteen

RUTACEAE a) *Melicope simplex*
SAPINDACEAE b) *Alectryon excelsis*
SCHROPHULARIACEAE c) *Cassinia vauvilliersii*
d) *Hebe macrantha e*) *Hebe odora* f) *Hebe parviflora*
g) *Hebe salicifolia* h) *Hebe stricta* i)*Hebe subalpina*
j) *Hebe* sp. B (T1/12) k) *Hebe* sp A (T1/14)
l) *Hebe* sp. C (AK1/8)
m) *Hebe* sp. D (OG2/19) n) *Pimelea gnidea*
THYMELEACEAE o) *Pimella buxifolia*
p) *Pimella microphylla*
URTICACEAE q) *Urtica ferox*
VIOLACEAE r) *Melicytus macrophyllus*
s) *Melicytus ramiflorus* t) *Hymenanthera alpina*
u) *Hymenanthera angustifolia*
WINTERACEAE v) *Pseudowintera colorata*
MORACEAE w) *Streblus heterophylia*
EPACRIDACEAE x) *Archeria traversii*
z) unidentified OT3/32
y) unidentified T4/7
aa) unidentified LT2/12

a)

b)

c)

d)

e)

f)

g)

h)

i)

j)

x5

k)

x5

l)

m)

n)

o)

p)

x3.5

q)

r)

s)

t)

w)

u)

v)

x)

y)

z)

a a)

Taphonomic samples: Plates 16-18
Plate Sixteen

APOCYNACEAE a) *Parsonsia heterophylla*
ARALIACEAE b) *Pseudopanax crassifolius*
c) *Schefflera digitata*
CORNACEAE d) *Grisselinia littoralis*
CORIARIACEAE e) *Coriaria arborea*
CUNONIACEAE f) *Weinmannia racemosa*
ELAEOCARPACEAE g) *Aristotelia serrata*
h) *Elaeocarpus dentatus*
ESCALLONIACEAE i) *Carpodetus serratus*
j) *Quintinia acutifolia*

a)

b)

c)

d)

e)

f)

g)

h)

i)

j)

Plate Seventeen

ICACINACEAE a) *Pennantia corymbosa*
b) unidentified (site 1 transect 2)
MONIMIACEAE c) *Hedycarya arborea*
MYRSINIACEAE d) *Myrsine australis*
e) *Myrsine salicine*
MYRTACEAE f) *Metrosideros umbellata*
g) *Metrosideros diffusa* h) *Metrosideros colensoi*
i) *Neomyrtus pedunculata*
ONAGRACEAE j) *Fuchsia excorticata*
PITTOSPORACEAE k) *Pittosorum colensoi*
ROSACEAE l) *Rubus schmidelioides*
m) *Rubus australis*
n) *Rubus cissoides*

a)

b)

c)

d)

e)

f)

g)

h)

i)

j)

k)

l)

m)

n)

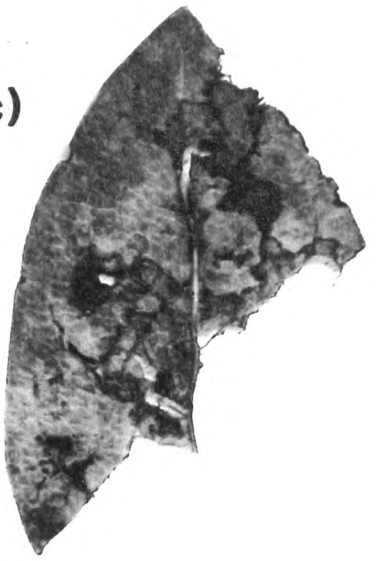
Plate Eighteen

RUBIACEAE a) *Coprosma aereolata*
b) *Coprosma foetidissima* c) *Coprosma lucida*
d) *Coprosma propinqua* e) *Coprosma rhamnoides*
f) *Coprosma rotundifolia* g) *Coprosma spathulata*
h) *Coprosma* sp i (site 5 tranect 1)
i) *Coprosma* sp ii (site 10 transect 1)
SCHROPHULARIACEAE j) *Hebe odora*
k) *Hebe* sp. i (site 10 transect 1)
VIOLACEAE l) *Melycytus ramiflorus*
WINTERACEAE m) *Pseudowintera colorata*

a)

b)

c)



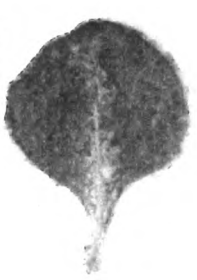
d)

e)

f)

g)

h)



i)

j)

k)

l)

m)

APPENDIX TWO

CLAMP physiognomic character state scores for taphonomic collections from Lady Lake, New Zealand

APPENDIX TWO

FAMILY	SPECIES	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	lepto1	lepto2	micro1	micro2	micro3	meso1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base cordate	base round	base acute	L:W <1:1	1:1-2:1	2:1-3:1	3:1-4:1	<4:1	shape obovate	shape elliptical	shape ovate	total	whole
SITE 1 TRANSECT 2																																
ARALIACEAE	*Pseudopanax arboreus*	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	_	_	_	_	0.0	0.0	1.0	_	_	_	_	_	_	_	_	1	
CORIARIACEAE	*Coriaria arborea*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	0.0	1.0	0.5	0.5	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	8	3
CUNONIACEAE	*Weinmannia racemosa*	0.0	0.0	1.0	0.5	1.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.0	0.0	1.0	0.5	0.5	0.0	0.0	0.5	0.5	0.0	0.3	0.3	0.3	0.0	0.0	0.5	0.5	46	
ESCALLONIACEAE	*Carpodetus serratus*	0.0	0.0	0.0	0.0	0.5	0.5	0.5	0.0	0.0	0.0	1.0	0.0	0.0	0.0	_	_	_	_	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	1	1
ESCALLONIACEAE	*Quintinia acutifolia*	0.0	0.5	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.5	0.5	0.0	0.5	0.5	0.0	6	1
MYRSINACEAE	*Myrsine australis*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	2	0
RUBIACEAE	*Coprosma propinqua*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	_	_	_	_	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	1	
	unidentified (Plate 17-b)	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1	0
	CLAMP SCORE	11.1	50.0	11.1	5.6	16.7	33.3	5.6	11.1	0.0	3.7	64.8	20.3	0.0	0.0	33.3	58.3	8.3	33.3	22.2	61.1	16.7	12.5	22.9	41.6	22.9	0.0	6.3	87.5	6.3	68	6
SITE 2 TRANSECT 2																																
CORIARIACEAE	*Coriaria arborea*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.5	0.5	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.5	0.5	3	0
CORNACEAE	*Griselinia littoralis*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	1	0
CUNONIACEAE	*Weinmannia racemosa*	0.0	0.0	1.0	0.5	1.0	0.0	0.0	0.0	0.3	0.3	0.3	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.5	0.5	0.0	0.5	0.5	0.0	0.0	0.0	1.0	0.0	40	9
ESCALLONIACEAE	*Quintinia acutifolia*	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	1.0	0.0	0.5	0.5	0.0	7	6
MYRSINACEAE	*Myrsine australis*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	2	2
MYRTACEAE	*Metrosideros diffusa*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.5	0.5	4	4
MYRTACEAE	*Metrosideros umbellata*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	4	2
RUBIACEAE	*Coprosma rhamnoides*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	1	1
RUBIACEAE	*Coprosma propinqua*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	1	1
WINTERACEAE	*Pseudowintera colorata*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	_	_	_	_	_	_	_	_	_	_	_	0.0	1.0	0.0	_	_	_	_	_	_	_	_	1	0
	CLAMP SCORE	0.0	80.0	10.0	5.0	10.0	10.0	0.0	16.7	20.3	37.0	25.9	0.0	0.0	0.0	11.1	66.7	22.2	11.1	5.0	65.0	30.0	0.0	16.7	50.0	11.1	22.2	16.7	72.2	11.1	64	3

APPENDIX TWO

SITE 3 TRANSECT 2

FAMILY	SPECIES	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	lepto1	lepto2	micro1	micro2	micro3	meso1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base cordate	base round	base acute	L:W <1:1	1:1-2:1	2:1-3:1	3:1-4:1	<4:1	shape obovate	shape elliptical	shape ovate	total	whole
ARALIACEAE	*Pseudopanax crassifolius*	0.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	_	_	_	_	_	_	_	_	_	_	_	1	0
ARALIACEAE	*Pseudowintera colorata*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	_	_	_	_	0.0	1.0	0.0	_	_	_	_	_	_	_	_	1	0
CORIARIACEAE	*Coriaria arborea*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.3	0.3	0.3	0.0	0.0	0.5	0.5	26	2
CUNONIACEAE	*Weinmannia racemosa*	0.0	0.0	0.5	0.3	1.0	0.0	0.0	0.0	0.3	0.3	0.3	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.5	0.5	0.0	0.5	0.5	0.0	0.0	0.0	0.5	0.5	117	22
ELAEOCARPACEAE	*Elaeocarpus dentatus*	0.0	0.0	0.0	0.0	1.0	0.0	0.5	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	1	0
ESCALLONIACEAE	*Aristotelia serrata*	0.0	0.0	0.0	1.0	0.0	1.0	1.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	0.5	0.5	0.0	1.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	1.0	0.0	3	2
ESCALLONIACEAE	*Carpodetus serratus*	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	2	2
ESCALLONIACEAE	*Quintinia acutifolia*	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.5	0.5	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	9	5
MYRTACEAE	*Metrosideros colensoi*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	1	1
MYRTACEAE	*Metrosideros umbellata*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	5	2
MYRTACEAE	*Metrosideros diffusa*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.5	0.5	4	4
ROSACEAE	*Rubus australis*	0.0	0.0	0.0	0.0	0.0	1.0	0.5	0.0	0.0	1.0	0.0	0.0	0.0	0.0	_	_	_	_	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	2	1
ROSACEAE	*Rubus schmideloides*	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	_	_	_	_	0.0	0.0	1.0	_	_	_	_	_	_	_	_	1	0
RUBIACEAE	*Coprosma areolata*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	1	1
RUBIACEAE	*Coprosma propinqua*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.5	0.5	0.0	0.0	1.0	0.0	3	3
RUBIACEAE	*Coprosma rotundifolia*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	1	1
RUBIACEAE	*Coprosma foetidissima*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	_	_	_	_	_	_	_	_	_	_	_	1	0
RUBIACEAE	*Coprosma tenuicaulis*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.5	0.5	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	1	1
	CLAMP SCORE	0.0	57.9	2.6	6.6	10.5	31.6	15.8	16.7	9.2	42.6	17.6	13.9	0.0	0.0	0.0	53.3	30.0	16.7	5.9	70.6	23.5	0.0	52.4	34.5	13.1	0.0	14.3	60.7	25.0	180	47

APPENDIX TWO

FAMILY	SPECIES	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	lepto1	lepto2	micro1	micro2	micro3	meso1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base cordate	base round	base acute	L:W <1:1	1:1-2:1	2:1-3:1	3:1-4:1	<4:1	shape obovate	shape elliptical	shape ovate	total	whole
SITE 4 TRANSECT 2																																
CORIARIACEAE	*Coriaria arborea*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	11	1
CUNONIACEAE	*Weinmannia racemosa*	0.0	0.0	1.0	0.5	0.0	1.0	0.0	0.0	0.0	0.3	0.3	0.3	0.0	0.0	1.0	0.5	0.5	0.0	0.0	0.5	0.5	0.0	0.3	0.3	0.3	0.0	0.0	0.5	0.5	113	23
ELAEOCARPACEAE	*Aristotelia serrata*	0.0	0.0	1.0	1.0	0.0	1.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	_	_	_	_	0.0	1.0	0.0	_	_	_	_	_	_	_	_	3	0
ELAEOCARPACEAE	*Elaeocarpus dentatus*	0.0	0.0	0.0	0.5	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	1	1
ESCALLONIACEAE	*Carpodetus serratus*	0.0	0.0	0.0	0.0	0.0	1.0	0.5	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	1	1
ESCALLONIACEAE	*Quintinia acutifolia*	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.0	0.5	0.5	0.0	0.0	1.0	0.0	0.0	0.5	0.5	0.0	10	5
MYRSINACEAE	*Myrsine australis*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	1	1
MYRTACEAE	*Metrosideros diffusa*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	2	1
MYRTACEAE	*Metrosideros umbellata*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	1.0	0.0	8	2
ROSACEAE	*Rubus australis*	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	_	_	_	_	0.0	0.5	0.5	_	_	_	_	_	_	_	_	2	0
RUBIACEAE	*Coprosma lucida*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	_	_	_	_	_	_	_	_	_	_	_	_	1	0
RUBIACEAE	*Coprosma propinqua*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.5	0.5	0.0	1.0	0.0	2	2
VIOLACEAE	*Melicytus ramiflorus*	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	1	1
	CLAMP SCORE	0.0	46.2	15.4	15.4	15.4	38.5	11.5	11.5	7.7	21.8	48.7	10.2	0.0	0.0	18.2	34.8	53.0	12.1	0.0	70.8	29.2	0.0	23.3	48.3	23.3	5.0	15.0	80.0	5.0	156	38
SITE 1 TRANSECT 1																																
CORIARIACEAE	*Coriaria arborea*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	3	1
CUNONIACEAE	*Weinmannia racemosa*	0.0	0.0	1.0	0.5	1.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3		0.0	1.0	0.5	0.5	0.0	0.0	0.5	0.5	0.0	0.5	0.5	0.0	0.0	0.0	0.5	0.5	60	6
ELAEOCARPACEAE	*Aristotelia serrata*	0.0	0.0	1.0	1.0	0.0	1.0	1.0	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	1	0
ESCALLONIACEAE	*Carpodetus serratus*	0.0	0.0	0.5	0.0	0.0	1.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	3	2
ESCALLONIACEAE	*Quintinia acutifolia*	0.0	0.5	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.5	0.5	0.0	0.0	0.5	0.5	0.0	0.5	0.5	0.0	11	7
MONIMIACEAE	*Hedycarya arborea*	0.0	0.5	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	_	_	_	_	0.0	0.0	1.0	0.0	0.0	0.5	0.5	0.0	0.5	0.5	0.0	7	0
MYRTACEAE	*Metrosideros diffusa*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	1.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.5	0.5	4	2
MYRTACEAE	*Metrosideros umbellata*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	1.0	0.0	9	2
ROSACEAE	*Rubus australis*	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	_	_	_	_	1.0	0.0	0.0	_	_	_	_	_	_	_	_	1	0
ROSACEAE	*Rubus schmideloides*	0.0	0.0	0.0	0.5	0.5	0.5	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	2	0
RUBIACEAE	*Coprosma propinqua*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	1	1
RUBIACEAE	*Elaeocarpus dentatus*	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	_	_	_	_	_	_	_	_	_	_	_	_	1	1
VIOLACEAE	*Melicytus ramiflorus*	0.0	()	()	()	()	()	()	0.0	0.0	0.0	1.0	0.0	0.0	0.0	_	_	_	_	0.0	1.0	0.0	_	_	_	_	_	_	_	_	1	0
WINTERACEAE	*Pseudowintera colorata*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	1.0	0.0	3	0
	CLAMP SCORE	0.0	50.0	25.0	14.3	21.4	28.6	7.1	2.4	9.5	30.9	41.6	13.1	0.0	0.0	9.1	36.4	45.5	18.2	7.7	76.9	15.4	0.0	22.7	45.5	27.3	4.5	9.1	77.3	13.6	107	22

APPENDIX TWO

SITE 2A TRANSECT 1

FAMILY	SPECIES	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	lepto1	lepto2	micro1	micro2	micro3	meso1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base cordate	base round	base acute	L:W <1:1	1:1-2:1	2:1-3:1	3:1-4:1	<4:1	shape obovate	shape elliptical	shape ovate	total	whole
CORIARIACEAE	*Coriaria arborea*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.5	0.5	8	1
CUNONIACEAE	*Weinmannia racemosa*	0.0	0.0	1.0	0.5	1.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.5	0.5	0.0	0.3	0.3	0.3	0.0	0.0	1.0	0.0	61	5
ELAEOCARPACEAE	*Aristotelia serrata*	0.0	0.0	0.5	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	2	0
ELAEOCARPACEAE	*Elaeocarpus dentatus*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	_	_	_	_	_	_	_	_	_	_	_	0.0	1.0	0.0	_	_	_	_	_	_	_	_	1	0
ESCALLONIACEAE	*Carpodetus serratus*	0.0	0.0	0.5	0.5	0.0	1.0	0.5	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	4	0
ESCALLONIACEAE	*Quintinia acutifolia*	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.5	0.0	0.5	0.0	0.5	0.5	0.0	0.0	1.0	0.0	0.0	0.5	0.5	0.0	8	2
MYRTACEAE	*Metrosideros umbellata*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	1.0	0.0	5	2
ONAGRACEAE	*Fuchsia excorticata*	0.0	0.0	0.5	0.0	0.5	0.5	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	0.0	1.0	0.0	_	_	_	_	_	_	_	_	_	_	_	2	0
PITTOSPORACEAE	*Pittosporum colensoi*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	6	0
ROSACEAE	*Rubus schmideloides*	0.0	0.0	0.0	0.5	0.0	1.0	0.5	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	1	1
RUBIACEAE	*Coprosma propinqua*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	1	1
VIOLACEAE	*Melicytus ramiflorus*	0.0	0.0	0.5	0.5	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	_	_	_	_	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	1	0
WINTERACEAE	*Pseudowintera colorata*	0.0	0.5	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	1.0	0.0	4	0
	CLAMP SCORE	0.0	42.3	23.1	23.1	23.1	34.6	7.7	8.3	2.1	18.8	52.1	18.8	0.0	0.0	0.0	55.0	40.0	5.0	0.0	90.9	9.1	0.0	28.3	48.3	18.3	5.0	5.0	80.0	15.0	104	12

SITE 2B TRANSECT 1

CORIARIACEAE	*Coriaria arborea*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.5	0.5	6	0
CUNONIACEAE	*Weinmannia racemosa*	0.0	0.0	1.0	0.5	1.0	0.0	0.0	0.0	0.3	0.3	0.3	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.5	0.5	0.0	0.3	0.3	0.3	0.0	0.0	0.5	0.5	63	13
ESCALLONIACEAE	*Quintinia acutifolia*	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.5	0.5	0.0	0.5	0.5	0.0	9	2
ESCALLONIACEAE	*Carpodetus serrata*	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	_	_	_	_	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	1	0
MYRTACEAE	*Metrosideros diffusa*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	1	1
MYRTACEAE	*Neomyrtus pedunculata*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	1	1
ROSACEAE	*Rubus australis*	0.0	0.0	0.0	0.5	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	1	0
SCHROPHULARIACEAE	*Hebe salicifolia*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	_	_	_	_	_	_	_	_	_	_	_	0.0	1.0	0.0	_	_	_	_	_	_	_	_	1	0
WINTERACEAE	*Pseudowintera colorata*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	1.0	0.0	3	0
	CLAMP SCORE	0.0	60.0	10.0	10.0	10.0	30.0	0.0	0.0	25.9	25.9	48.1	0.0	0.0	0.0	0.0	68.8	6.3	25.0	0.0	83.3	16.7	0.0	59.2	20.3	20.3	0.0	5.6	72.2	22.2	87	17

APPENDIX TWO

FAMILY	SPECIES	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	lepto1	lepto2	micro1	micro2	micro3	meso1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base cordate	base round	base acute	L:W <1:1	1:1-2:1	2:1-3:1	3:1-4:1	<4:1	shape obovate	shape elliptical	shape ovate	total	whole
SITE 3A TRANSECT 1																																
CORIARIACEAE	Coriaria arborea	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	2	1
ELAEOCARPACEAE	Aristotelia serrata	0.0	0.0	0.0	1.0	0.5	0.5	1.0	_	_	_	_	_	_	_	_	_	_	_	0.0	1.0	0.0	_	_	_	_	_	_	_	_	1	0
MYRTACEAE	Metrosideros diffusa	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.5	0.5	9	6
MYRTACEAE	Neomyrtus pedunculata	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	1	1
CUNONIACEAE	Weinmannia racemosa	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.5	0.5	0.0	0.3	0.3	0.3	0.0	0.0	1.0	0.0	52	13
MYRTACEAE	*Metrosideros umbellata*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	_	_	_	_	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	2	0
ESCALLONIACEAE	Carpodetus serratus	0.0	0.0	0.5	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	_	_	_	_	0.0	1.0	0.0	_	_	_	_	_	0.0	1.0	0.0	2	0
ESCALLONIACEAE	Quintinia acutifolia	0.0	0.5	0.0	0.0	0.0	0.5	0.3	0.0	0.0	0.3	0.3	0.3	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.5	0.5	0.0	0.5	0.5	0.0	0.0	0.5	0.5	0.0	6	2
ROSACEAE	Rubus australis	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	2	1
	CLAMP SCORE	0.0	50.0	16.7	11.1	22.2	27.8	13.9	6.3	12.5	29.1	35.4	4.1	0.0	0.0	0.0	58.3	25.0	16.7	0.0	88.9	11.1	0.0	69.0	26.1	4.7	0.0	6.3	87.5	6.3	77	24
SITE 3B TRANSECT 1																																
ARALIACEAE	*Schefflera digitata*	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	1	1
CORIARIACEAE	*Coriaria arborea*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.5	0.5	2	1
CUNONIACEAE	*Weinmannia racemosa*	0.0	0.0	1.0	0.5	1.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.0	0.0	0.0	0.3	0.3	0.3	0.0	0.5	0.5	0.0	0.3	0.3	0.3	0.0	0.0	0.5	0.5	85	20
ESCALLONIACEAE	*Carpodetus serratus*	0.0	0.0	0.5	0.5	0.0	1.0	0.5	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.5	0.5	3	1
ESCALLONIACEAE	*Quintinia acutifolia*	0.0	0.5	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	0.5	0.0	0.5	0.0	0.5	0.5	0.0	0.0	0.5	0.5	0.0	0.5	0.5	0.0	7	3
MYRSINACEAE	*Myrsine australis*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	1.0	0.0	3	1
MYRTACEAE	*Metrosideros umbellata*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	5	1
MYRTACEAE	*Metrosideros diffusa*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.5	0.5	6	5
PITTOSPORACEAE	*Pittosporum colensoi*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	3	2
ROSACEAE	*Rubus cissoides*	0.0	0.0	1.0	1.0	0.0	1.0	0.5	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	1	0
RUBIACEAE	*Coprosma foetidissima*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	1	1
RUBIACEAE	*Coprosma propinqua*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	1	1
WINTERACEAE	*Pseudowintera colorata*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	_	_	_	_	0.0	1.0	0.0	_	_	_	_	_	_	_	_	1	0
	CLAMP SCORE	0.0	67.9	17.9	14.3	14.3	17.9	7.1	0.0	19.8	35.2	39.1	5.8	0.0	0.0	9.1	43.9	48.5	7.5	0.0	84.6	15.4	0.0	31.9	44.4	15.3	8.3	12.5	70.8	16.7	122	37

APPENDIX TWO

FAMILY	SPECIES	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	lepto1	lepto2	micro1	micro2	micro3	meso1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base cordate	base round	base acute	L:W <1:1	1:1-2:1	2:1-3:1	3:1-4:1	<4:1	shape obovate	shape elliptical	shape ovate	total	whole
SITE 3 TRANSECT 1																																
APOCYNACEAE	*Parsonsia heterophyllus*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	1	0
CORIARIACEAE	*Coriaria arborea*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	1	0
CORNACEAE	*Griselinia littoralis*	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1	0
CUNONIACEAE	*Weinmannia racemosa*	0.0	0.0	1.0	0.5	1.0	0.0	0.0	0.0	0.3	0.3	0.3	0.0	0.0	0.0	1.0	0.5	0.5	0.0	0.0	1.0	0.0	0.0	0.3	0.3	0.3	0.0	0.0	0.5	0.5	72	17
ESCALLONIACEAE	*Quintinia acutifolia*	0.0	0.5	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.3	0.3	0.3	0.0	0.0	1.0	0.5	0.0	0.5	0.0	0.5	0.5	0.0	0.0	1.0	0.0	0.0	0.5	0.5	0.0	2	0
ICACINACEAE	*Pennantia corymbosa*	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	2	1
MYRSINACEAE	*Myrsine australis*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	2	0
MYRTACEAE	*Metrosideros diffusa*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	1.0	0.0	0.0	0.3	0.3	0.3	0.0	0.0	0.5	0.5	24	16
MYRTACEAE	*Metrosideros umbellata*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.5	0.5	0.0	1.0	0.0	7	5
MYRTACEAE	*Neomyrtus pedunculata*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	4	4
RUBIACEAE	*Coprosma propinqua*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	1	1
WINTERACEAE	*Pseudowintera colorata*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	1.0	0.0	_	_	_	_	_	_	_	_	6	0
	CLAMP SCORES	0.0	70.8	8.3	4.2	8.3	20.8	0.0	8.3	23.6	22.2	22.2	2.8	8.3	0.0	41.7	70.8	16.7	12.5	0.0	83.3	16.7	9.1	33.3	42.4	10.5	4.5	22.7	68.2	9.1	123	44
SITE 4 TRANSECT 1																																
CUNONIACEAE	*Weinmannia racemosa*	0.0	0.0	1.0	0.5	1.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.5	0.5	0.0	0.5	0.5	0.0	0.0	0.5	0.5	0.0	31	24
ELAEOCARPACEAE	*Aristotelia serrata*	0.0	0.0	0.5	1.0	0.0	1.0	0.5	0.0	0.0	0.3	0.3	0.3	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.5	0.5	4	1
ESCALLONIACEAE	*Carpodetus serratus*	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	0.5	0.0	0.5	0.0	1.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	1.0	0.0	0	2
ESCALLONIACEAE	*Quintinia acutifolia*	0.0	0.5	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.5	0.5	0.0	0.0	1.0	0.0	0.0	0.5	0.5	0.0	6	4
MONIMIACEAE	*Hedycarya arborea*	0.0	0.5	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.5	0.5	0.0	5	0
MYRSINACEAE	*Myrsine australis*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0	1
MYRTACEAE	*Metrosideros diffusa*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	1.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.5	0.5	1	7
MYRTACEAE	*Metrosideros umbellata*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	_	_	_	_	_	_	_	_	_	_	_	0.0	1.0	0.0	0.0	_	_	_	_	_	_	_	1	0
MYRTACEAE	*Neomyrtus pedunculata*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0	1
RUBIACEAE	*Coprosma foetidissima*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0	1
VIOLACEAE	*Melicytus ramiflorus*	0.0	0.5	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	_	_	_	_	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.5	0.5	0.0	2	0
WINTERACEAE	*Pseudowintera colorata*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	_	_	_	_	0.0	1.0	0.0	0.0	_	_	_	_	0.0	1.0	0.0	2	0
	CLAMP SCORES	0.0	65.4	11.5	11.5	11.5	23.1	3.8	2.8	4.8	20.1	40.9	20.1	0.0	0.0	0.0	60.0	25.0	15.0	0.0	69.2	30.8	0.0	10.0	75.0	15.0	0.0	33.3	58.3	8.3	56	42

APPENDIX TWO

SITE 5 TRANSECT 1

FAMILY	SPECIES	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	lepto1	lepto2	micro1	micro2	micro3	meso1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base cordate	base round	base acute	L:W <1:1	1:1-2:1	2:1-3:1	3:1-4:1	<4:1	shape obovate	shape elliptical	shape ovate	total	whole
ARALIACEAE	*Pseudopanax crassifolius*	0.0	0.0	_	_	0.0	1.0	0.0	_	_	_	_	_	_	_	_	_	_	_	0.0	0.0	1.0	_	_	_	_	_	_	_	_	1	0
ARALIACEAE	*Schefflera digitata*	0.0	0.5	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	_	_	_	_	0.0	0.5	0.5	0.0	0.0	1.0	0.0	0.0	0.5	0.5	0.0	5	0
CUNONIACEAE	*Weinmannia racemosa*	0.0	0.0	1.0	0.5	1.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3	0.0	0.0	1.0	0.3	0.3	0.3	0.0	0.5	0.5	0.0	0.3	0.3	0.3	0.0	0.0	1.0	0.0	157	46
ELAEOCARPACEAE	*Aristotelia serrata*	0.0	0.0	_	0.0	0.0	1.0	_	_	_	_	_	_	_	_	_	_	_	_	1.0	0.0	0.0	_	_	_	_	_	_	_	_	1	0
ELAEOCARPACEAE	*Elaeocarpus dentatus*	0.0	0.0	0.0	0.5	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	5	0
ESCALLONIACEAE	*Carpodetus serratus*	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	1.0	0.0	10	1
ESCALLONIACEAE	*Quintinia acutifolia*	0.0	0.5	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.3	0.3	0.3	0.0	0.0	0.0	0.3	0.3	0.3	0.0	0.5	0.5	0.0	0.0	0.3	0.3	0.3	0.5	0.5	0.0	24	4
ICACINACEAE	*Pennantia corymbosa*	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	1	1
MYRSINACEAE	*Myrsine australis*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	2	1
MYRSINACEAE	*Myrsine salicina*	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	_	_	_	_	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	1	0
MYRTACEAE	*Metrosideros diffusa*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	1.0	9	2
MYRTACEAE	*Metrosideros umbellata*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.5	0.5	0.0	1.0	0.0	3	2
PITTOSPORACEAE	*Coprosma sp i (Plate 16-h)*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	1	1
ROSACEAE	*Rubus australis*	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	2	0
ROSACEAE	*Rubus cissoides*	0.0	0.0	0.5	1.0	0.0	1.0	0.5	0.0	0.0	0.0	0.5	0.5	0.0	0.0	_	0.0	_	_	0.5	0.5	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	4	0
ROSACEAE	*Rubus schmideloides*	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	1	0
RUBIACEAE	*Coprosma areolata*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	2	0
RUBIACEAE	*Coprosma propinqua*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	1	1
WINTERACEAE	*Pseudowintera colorata*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	1.0	0.0	6	1
	CLAMP SCORE	0.0	45.0	8.3	10.5	20.0	35.0	2.6	9.7	2.8	35.2	39.3	8.8	0.0	0.0	21.4	40.4	47.6	11.9	7.5	57.5	35.0	0.0	37.9	34.2	12.0	15.7	22.2	61.1	16.7	244	60

APPENDIX TWO

SITE 6 TRANSECT 1

FAMILY	SPECIES	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	lepto1	lepto2	micro1	micro2	micro3	meso1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base cordate	base round	base acute	L:W <1:1	1:1-2:1	2:1-3:1	3:1-4:1	<4:1	shape obovate	shape elliptical	shape ovate	total	whole
CUNONIACEAE	*Weinmannia racemosa*	0.0	0.0	1.0	0.5	1.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.5	0.5	8	2
ESCALLONIACEAE	*Carpodetus serratus*	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	1	1
ESCALLONIACEAE	*Quintinia acutifolia*	0.0	0.5	0.0	0.0	0.0	0.5	0.3	0.0	0.3	0.3	0.3	0.0	0.0	0.0	_	_	_	_	0.0	0.5	0.5	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	3	1
MYRTACEAE	*Metrosideros diffusa*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	1.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.5	0.5	0	7
WINTERACEAE	*Pseudowintera colorata*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	1	0
	CLAMP SCORE	0.0	50.0	20.0	10.0	40.0	10.0	5.0	10.0	16.6	36.6	36.6	0.0	0.0	0.0	25.0	62.5	37.5	0.0	20.0	70.0	10.0	0.0	60.0	40.0	0.0	0.0	0.0	80.0	0.0	13	11

SITE 7 TRANSECT 1

CORIARIACEAE	*Coriaria arborea*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	_	_	_	_	_	_	_	_	1	0
CORNACEAE	*Griselinia littoralis*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	_	_	_	_	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	2	0
CUNONIACEAE	*Weinmannia racemosa*	0.0	0.0	1.0	0.5	1.0	0.0	0.0	0.0	0.3	0.3	0.3	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	1.0	0.0	0.0	0.3	0.3	0.3	0.0	0.0	0.5	0.5	86	26
ELAEOCARPACEAE	*Elaeocarpus dentatus*	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	1	1
ESCALLONIACEAE	*Quintinia acutifolia*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	1.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.5	0.5	0.0	2	0
MONIMIACEAE	*Hedycarya arborea*	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.5	0.5	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	3	1
MYRTACEAE	*Metrosideros diffusa*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	1.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.5	0.5	27	22
MYRTACEAE	*Neomyrtus pedunculata*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.5	0.5	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	2	2
ROSACEAE	*Rubus australis*	0.0	0.0	0.0	0.5	0.0	1.0	0.5	0.0	0.0	0.0	1.0	0.0	0.0	0.0	_	_	_	_	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	1	0
RUBIACEAE	*Coprosma areolata*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	1	1
RUBIACEAE	*Coprosma propinqua*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.5	0.5	3	2
RUBIACEAE	*Coprosma rotundifolia*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1	0
SCHROPHULARIACEAE	*Hebo odora*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	1	1
VIOLACEAE	*Melicytus ramiflorus*	0.0	0.0	0.0	0.5	1.0	0.0	0.5	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	1	1
WINTERACEAE	*Pseudowintera colorata*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	4	1
CLAMP SCORES		0.0	68.8	6.3	9.4	12.5	18.8	6.3	21.9	8.3	2.1	52.1	6.3	0.0	0.0	14.3	57.1	28.6	14.3	6.3	87.5	6.3	6.7	38.9	45.5	8.9	0.0	16.7	66.7	16.7	138	59

SITE 8 TRANSECT 1																															
FAMILY	SPECIES	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	lepto1	lepto2	micro1	micro2	micro3	meso1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base cordate	base round	base acute	L:W <1:1	1:1-2:1	2:1-3:1	3:1-4:1	<4:1	shape obovate	shape elliptical	shape ovate	total	whole
CUNONIACEAE	*Weinmannia racemosa*	0.0	0.0	1.0	0.5	1.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.3	0.3	0.3	0.0	0.5	0.5	12	1
ICACINACEAE	*Pennantia corymbosa*	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	1	1
MYRTACEAE	*Metrosideros diffusa*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	1.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.5	0.5	15	8
MYRTACEAE	*Neomyrtus pedunculata*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	1	1
RUBIACEAE	*Coprosma rotundifolia*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	1	1
CLAMP SCORE		0.0	0.6	0.2	0.1	0.4	0.0	0.0	0.3	0.3	0.3	0.3	0.0	0.0	0.0	0.0	0.9	0.1	0.0	0.0	0.4	0.6	0.0	0.7	0.2	0.1	0.1	0.2	0.6	0.2	30	12
SITE 9 TRANSECT 1																															
APOCYNACEAE	*Parsonsia heterophylla*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1	1
CORIARIACEAE	*Coriaria arborea*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	1	0
CUNONIACEAE	*Weinmannia racemosa*	0.0	0.0	1.0	0.5	1.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.5	0.5	27	10
ELAEOCARPACEAE	*Aristotelia serrata*	0.0	0.0	1.0	1.0	0.0	1.0	0.0	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_		1	0
ESCALLONIACEAE	*Quintinia acutifolia*	0.0	_	_	_	_	_	_	_	_	_	_	1.0	_	_	_	_	_	_	0.0	0.0	1.0	_	_	_	_	_	_	_		1	0
ICACINACEAE	*Pennantia corymbosa*	0.0	0.0	0.0	0.0	1.0	0.0	0.5	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	1	0
MYRTACEAE	*Metrosideros diffusa*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	1.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.5	0.5	33	23
MYRTACEAE	*Neomyrtus pedunculata*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.5	0.5	0.0	0.5	0.5	0.0	4	3
RUBIACEAE	*Coprosma areolata*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	1	1
RUBIACEAE	*Coprosma foetidissima*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0					0.0	1.0	0.0						0.0	1.0	0.0	1	0
RUBIACEAE	*Coprosma tenuicaulis*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1	1
VIOLACEAE	*Melicytus ramiflorus*	0.0	_	_	_	_	_	_	_	_	_	1.0	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_		1	0
WINTERACEAE	*Pseudowintera colorata*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_		1	0
	unidentified	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	1	1
CLAMP SCORE		0.0	75.0	16.7	12.5	16.7	8.3	4.2	40.3	11.1	4.2	20.8	8.3	0.0	0.0	22.2	72.2	16.7	11.1	18.2	72.7	9.1	22.2	33.3	38.9	5.6	0.0	5.0	75.0	20.0	75	40

APPENDIX TWO

FAMILY	SPECIES	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	lepto1	lepto2	micro1	micro2	micro3	meso1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base cordate	base round	base acute	L:W <1:1	1:1-2:1	2:1-3:1	3:1-4:1	<4:1	shape obovate	shape elliptical	shape ovate	total	whole
SITE 10 TRANSECT 1																																
CUNONIACEAE	*Weinmannia racemosa*	0.0	0.0	1.0	0.5	1.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	1.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.5	0.5	27	10
ELAEOCARPACEAE	*Aristotelia serrata*	0.0	0.0	1.0	1.0	0.0	1.0	1.0	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	_	2	0
MYRTACEAE	*Metrosideros umbellata*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	_	_	_	_	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	2	1
MYRTACEAE	*Metrosideros diffusa*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.0	1.0	0.0	0.0	0.3	0.3	0.3	0.0	0.0	0.5	0.5	8	6
RUBIACEAE	*Coprosma sp ii (Plate 18-i)*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	1	1
SCHROPHULARIACEAE	*Hebe sp. i (Plate 18-k)*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	1	1
WINTERACEAE	*Pseudowintera colorata*	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	_	_	_	_	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	_	_	_	1	0
	CLAMP SCORE	0.0	0.7	0.3	0.2	0.1	0.1	0.1	0.3	0.3	0.1	0.3	0.0	0.0	0.0	0.3	0.9	0.1	0.0	0.0	0.8	0.2	0.0	0.6	0.1	0.2	0.0	0.0	0.8	0.2	42	19

APPENDIX THREE

CLAMP physiognomic character state scores for modern vegetation collections from Australia and New Zealand

APPENDIX THREE

ALEX KNOB 300-350m, SOUTH ISLAND, NEW ZEALAND

family	species name	specimen number	lobed	no. teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	lepto1	lepto 2	micro1	micro2	micro 3	meso 1	meso 2	apex emarginate	apex round	apex acute	apex attenuate	base cordate	base round	base acute	L:W<1:1	L:W 1-2:1	L:W 2-3:1	L:W 3-4:1	L:W >4:1	shape obovate	shape elliptical	shape ovate
ARALIACEAE	*Scheffiera digitata* *	AK5/1	0	0	1	1/2	0	1	1/2	0	0	1/3	1/3	1/3	0	0	0	0	1/2	1/2	0	1	0	0	0	1	0	0	1/2	1/2	0
ARALIACEAE	*Pseudopanax colensoi* *	AK5/19	0	0	0	1/2	1/2	1/2	1/2	0	0	0	0	1/3	1/3	1/3	0	0	1/2	1/2	0	0	1	0	1/2	1/2	0	0	0	1	0
ARALIACEAE	*Pseudopanax edgerleyi* *	AK5/22	1/2	1/2	1/4	1/2	1/4	1/4	1/4	0	0	0	1/2	1/2	0	0	0	0	1/2	1/2	0	0	1	0	0	1/2	1/2	0	0	1	0
ARALIACEAE	*Pseudopanax simplex* *	AK5/24	0	0	0	1/2	0	1/2	1/2	1/4	1/4	1/4	1/4	0	0	0	0	0	1	0	1/3	1/3	1/3	0	0	1	0	0	0	1	0
CHLORANTHACEAE	*Ascarina lucida*	AK5/20	0	0	1	1	0	1/2	1/2	0	1/3	1/3	1/3	0	0	0	0	1	0	0	0	1	0	0	1/2	1/2	0	0	0	1	0
CORNACEAE	*Griselinia littoralis* *	AK5/4	0	1	0	0	0	0	0	0	0	0	1/3	1/3	1/3	0	1	1	0	0	0	1	0	0	1	0	0	0	0	1	0
CUNONIACEAE	*Weinmannia racemosa* *	AK5/23	0	0	1	1	1/2	1/2	1/2	0	1/3	1/3	1/3	0	0	0	0	0	1	0	0	1/2	1/2	0	1/2	1/2	0	0	0	1	0
ESCALLONIACEAE	*Carpodetus serratus* *	AK5/7	0	1	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	1	0
ICACINACEAE	*Pennantia corymbosa* *	AK5/25	0	1/2	0	0	0	1/2	0	1/2	1/2	0	0	0	0	0	0	0	1/2	1/2	0	0	1	0	1/2	1/2	0	0	0	0	1	0
MALVACEAE	*Hoheria lyallii* *	AK5/5	0	0	0	1	1	0	1	0	0	1/2	1/2	0	0	0	0	1/2	1/2	0	1	0	0	0	0	1	0	0	0	0	1
MONIMIACEAE	*Hedycarya arborea* *	AK5/13	0	1/2	0	0	1/4	1/4	0	0	0	0	0	1	0	0	0	1/2	1/2	0	0	0	1	0	0	0	1	0	1/2	1/2	0
MYRSINACEAE	*Myrsine australis* *	AK5/21	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	0	1	1	0	0	0	1/2	1/2	0	0	1	0	0	0	1	0
MYRTACEAE	*Metrosideros sp. C* *	AK5/9	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	1	0	0	0	0	1	0
MYRTACEAE	*Metrosideros diffusa* *	AK5/10	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	0	0	0	1	0
ONAGRACEAE	*Fuchsia excorticata* *	AK5/3	0	0	0	0	0	1	0	0	0	1/3	1/3	1/3	0	0	0	0	1/2	1/2	0	1	0	0	0	1	0	0	0	1	0
RUBIACEAE	*Coprosma lucida* *	AK5/6	0	1	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	1/2	1/2	0	1/2	1/2	0	0	1	0	0	1/2	1/2	0
RUBIACEAE	*Coprosma rigida*	AK5/8	0	1	0	0	0	0	0	0	1/2	1/2	0	0	0	0	1	1	0	0	0	0	1	0	1/2	1/2	0	0	0	1	0
RUBIACEAE	*Coprosma foetidissima* *	AK5/11	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0	1	0
RUBIACEAE	*Coprosma grandifolia* *	AK5/18	0	1	0	0	0	0	0	0	0	1/5	1/5	1/5	1/5	1/5	0	1/3	1/3	1/3	0	0	1	0	1/3	1/3	1/3	0	0	1	0
SCHROPHULARIACEAE	*Hebe salicifolia* *	AK5/15		0	0	0	1	0	1/2	0	0	0	1	0	0	0	0	0	0	1/2	1/2	0	1	0	0	0	0	0	1	0	1	0
VIOLACEAE	*Melicytus ramiflorus* *	AK5/17+ 14	0	0	1	1/2	1	0	0	0	0	1/3	1/3	1/3	0	0	0	1/3	1/3	1/3	0	1	0	0	0	1/3	1/3	1/3	1/2	1/2	0
WINTERACEAE	*Pseudowintera colorata* *	AK5/2	0	1	0	0	0	0	0	0	0	0	1/2	1/2	0	0	1	1	0	0	0	1	0	0	0	1	0	0	0	1	0
PITTOSPORACEAE	*Pittosporum tenuifolium*	AK5/12	0	1	0	0	1/2	1/2	0	1/3	1/3	1/3	0	0	0	0	0	1	0	0	0	1/2	1/2	0	1/2	1/2	0	0	1/2	1/2	0
	CLAMP SCORE		2.3	54.3	18.5	23.9	21.7	23.9	18.5	6.9	17.7	22.1	28.7	18.2	3.7	2.3	17.4	44.2	39.8	15.9	5.8	53.6	40.6	2.2	27.5	55.0	9.4	5.8	10.9	84.8	4.3

APPENDIX THREE

ALEX KNOB 600-650m, SOUTH ISLAND, NEW ZEALAND

family	species name	specimen number	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	lepto1	lepto 2	micro1	micro2	micro 3	meso 1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base Cordate	base round	base acute	L:W<1:1	1-2:1	2-3:1	3-4:1	>4:1	shape obovate	shape elliptical	shape ovate
ARALIACEAE	*Pseudopanax colensoi*	AK4/5	0	0	1/2	1/2	1/2	1/2	0	0	0	0	0	1/3	1/3	1/3	0	0	1	0	0	1/2	1/2	0	0	1	0	0	0	1	0
ARALIACEAE	*Pseudopanax crassifolius*	AK4/8	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	1	0	0	0	0	1/2	1/2	0	1	0
ARALIACEAE	*Pseudopanax simplex*	AK4/14	0	0	0	1	0	1	1/2	0	1/4	1/4	1/4	1/4	0	0	0	1/2	1/2	0	0	1	0	0	1/2	1/2	0	0	0	1/2	1/2
CORNACEAE	*Griselinia littoralis*	AK4/10	0	1	0	0	0	0	0	0	0	0	0	1/2	1/2	0	1	1	0	0	0	1	0	0	1	0	0	0	1/2	1/2	0
CUNONIACEAE	*Weinmannia racemosa*	AK4/15	0	0	1	1	1	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	1	0	1/2	1/2	0	0	0	1	0
ESCALLONIACEAE	*Carpodetus serratus*	AK4/12	0	0	1/2	1/2	1	0	1/2	1/4	1/4	1/4	1/4	0	0	0	0	1/2	1/2	0	1	0	0	0	1	0	0	0	0	1/2	1/2
MYRTACEAE	*Metrosideros diffusa*	AK4/1	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	1	0	0	1/2	1/2	0	0	0	1	0
MYRTACEAE	*Metrosideros umbellata*	AK4/11	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1	0	0	1/2	1/2	0	0	0	1/2	1/2	0	1	0
ROSACEAE	*Rubus schmideloides*	AK4/7	0	0	1/2	1	0	1	1	0	0	0	1/2	1/2	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	1
RUBIACEAE	*Coprosma rhamnoides*	AK4/2	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	1	0
RUBIACEAE	*Coprosma parviflora*	AK4/3	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	1/2	1/2	0
RUBIACEAE	*Coprosma lucida*	AK4/4	0	1	0	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	1/3	1/3	1/3	0	0	1	0	0	1	0	0	1/2	1/2	0
RUBIACEAE	*Coprosma foetidissima*	AK4/13	0	1	0	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1/2	1/2	0	0	0	1	0	0	1/2	1/2	0	0	1	0
WINTERACEAE	*Pseudowintera colorata*	AK4/6	0	1	0	0	0	0	0	0	0	0	1/2	1/2	0	0	1	1	0	0	0	1	0	0	1/2	1/2	0	0	0	1	0
	CLAMP SCORE		0.0	57.1	17.9	28.6	25.0	17.9	14.3	12.5	21.4	14.3	23.8	17.2	8.3	2.4	14.3	48.8	41.6	9.5	14.3	50.0	35.7	0.0	35.7	46.4	10.7	7.1	10.7	75.0	14.3

APPENDIX THREE

ALEX KNOB 810-860m, SOUTH ISLAND, NEW ZEALAND

family	species name	specimen number	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	lepto1	lepto 2	micro1	micro2	micro 3	meso 1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base Cordate	base round	base acute	L:W<1:1	1-2:1	2-3:1	3-4:1	>4:1	shape obovate	shape elliptical	shape ovate
ARALIACEAE	*Pseudopanax crassifolius*	AK3/3	0	0	1/2	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	1	0
ARALIACEAE	*Pseudopanax simplex*	AK3/5	0	0	0	1/2	1/2	1/2	1/2	0	1/4	1/4	1/4	1/4	0	0	0	0	1	0	0	1/2	1/2	0	0	1/2	1/2	0	0	1	0
ARALIACEAE	*Pseudopanax colensoi*	AK3/17	0	0	0	1/2	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0	1	0	0	0	1	0
COMPOSITAE	*Brachyglottis elaeagnifolia* *	AK3/6	0	1	0	0	0	0	0	0	1/3	0	1/3	1/3	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	1	0
COMPOSITAE	*Olearia arborescens* *	AK3/12	0	0	0	0	1	0	0	0	0	1/3	1/3	1/3	0	0	0	1/3	1/3	1/3	0	1	0	0	1	0	0	0	0	1	0
COMPOSITAE	*Olearia ilicifolia* *	AK3/14	0	0	1/2	1	0	1	1/2	0	0	0	1/2	1/2	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	1	0
COMPOSITAE	*Olearia colensoi* *	AK3/15	0	0	1	1	0	1	1	0	1/5	1/5	1/5	1/5	1/5	0	0	1/2	1/2	0	0	1/2	1/2	0	1/2	1/2	0	0	1/2	1/2	0
CORNACEAE	*Griselinia littoralis*	AK3/13	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	1	1	0	0	0	1	0	0	1	0	0	0	0	1	0
MYRTACEAE	*Metrosideros umbellata* *	AK3/9	0	1	0	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	1/2	1/2	0	0	1/2	1/2	0	0	1	0
RUBIACEAE	*Coprosma parviflora*	AK3/2	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1/2	1/2	0	0	1/2	1/2	1/2	1/2	0	0	0	0	1	0
RUBIACEAE	*Coprosma foetidissima*	AK3/4	0	1	0	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1	0	0	0	1/2	1/2	0	0	1	0	0	0	1	0
RUBIACEAE	*Coprosma linariifolia* *	AK3/7	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1/2	1/2	0	0	0	1	0	0	0	1/2	1/2	0	1	0
RUBIACEAE	*Coprosma propinqua*	AK3/8	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0	1/3	1/3	1/3	1/2	1/2	0
SCHROPHULARIACEAE	*Hebe salicifolia*	AK3/1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0	1	0
WINTERACEAE	*Pseudowintera colorata*	AK3/10	0	1	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	1	0	0	0	1/2	1/2	0	1/2	1/2	0	0	0	1	0
	CLAMP SCORE		0.0	53.3	13.3	20.0	30.0	16.7	13.3	13.3	18.5	14.1	29.6	22.9	1.3	0.0	13.3	45.5	45.5	8.9	0.0	53.3	46.7	3.3	30.0	28.9	12.2	25.5	6.7	93.3	0.0

APPENDIX THREE

ALEX KNOB 1020-1070m, SOUTH ISLAND, NEW ZEALAND

family	species name	specimen number	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	iepto1	iepto 2	micro1	micro2	micro 3	meso 1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base Cordate	base round	base acute	L:W<1:1	1-2:1	2-3:1	3-4:1	>4:1	shape obovate	shape elliptical	shape ovate
COMPOSITAE	*Brachyglottis bidwillii*	AK2/2	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	1	0
COMPOSITAE	*Olearia lacunosa* *	AK2/8	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	1	0
COMPOSITAE	*Olearia colensoi*	AK2/12	0	0	1	1	0	1	1	0	0	0	1/2	1/2	0	0	0	0	1	0	0	1	0	0	0	1/2	1/2	0	0	1	0
COMPOSITAE	*Olearia sp A**	AK2/6	0	0	0	0	1	0	0	0	0	1/2	1/2	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	1	0
ERICACEAE	*Gaultheria rupestris* *	AK2/11	0	0	1	1/2	0	1	1/2	0	1/2	1/2	0	0	0	0	0	0	1	0	0	1	0	0	0	1/2	1/2	0	0	1	0
MYRTACEAE	*Myrsine divaricata*	AK2/7	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1	1	0	0	0	1	0	1/2	1/2	0	0	0	0	1	0
PITTOSPORACEAE	*Pittosporum colensoi*	AK2/3	0	0	0	1/2	1	0	1/2	0	0	0	1/2	1/2	0	0	0	0	1	0	0	1/2	1/2	0	0	1	0	0	0	1	0
RUBIACEAE	*Coprosma linariifolia*	AK2/1	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1/2	1/2	0	0	1	0	0	0	0	1	0	0	1	0
RUBIACEAE	*Coprosma serrulata*	AK2/10	0	0	0	1	1	0	0	0	0	1/3	1/3	1/3	0	0	0	1	0	0	0	1/2	1/2	0	1	0	0	0	0	1	0
RUBIACEAE	*Coprosma pseudocuneata*	AK2/13	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1/2	1/2	0	0	1	0	0	0	1	0
SCHROPHULARIACEAE	*Pimelea gnidia* *	AK2/9	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1/2	1/2	0	0	1	0	0	0	1/2	1/2	0	0	1	0
	CLAMP SCORE		0.0	45.5	18.2	27.3	36.4	18.2	18.2	22.7	18.2	16.6	30.3	12.1	0.0	0.0	9.1	45.5	54.5	0.0	0.0	86.4	13.6	4.5	22.7	31.8	22.7	18.2	0.0	100.0	0.0

APPENDIX THREE

ALEX KNOB 1160-1285m, SOUTH ISLAND, NEW ZEALAND

family	species name	specimen number	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	lepto1	lepto 2	micro1	micro2	micro 3	meso 1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base Cordate	base round	base acute	L:W<1:1	1-2:1	2-3:1	3-4:1	>4:1	shape obovate	shape elliptical	shape ovate
ARALIACEAE	*Pseudopanax colensoi*	AK1/4	0	0	0	1/2	1	0	1/2	0	0	1/3	1/3	1/3	0	0	0	1/2	1/2	0	0	1/2	1/2	0	1/2	1/2	0	0	0	1	0
COMPOSITAE	*Olearia colensoi*	AK1/5	0	0	1	1	0	1	1	0	0	1/3	1/3	1/3	0	0	0	1/2	1/2	0	0	1/2	1/2	0	0	1/2	1/2	0	1/2	1/2	0
COMPOSITAE	*Olearia lacunosa*	AK1/7	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	1	0
COMPOSITAE	*Celmisia angustifolia*	AK1/10	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1/2	1/2	0	1	0
ERICACEAE	*Pernettya alpina* *	AK1/9	0	0	1	1	1	0	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	1	0	0	1	0	0	0	0	1	0
RUBIACEAE	*Coprosma parviflora*	AK1/2	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	1/2	1/2	0	0	0	1/2	1/2	0	1	0
RUBIACEAE	*Coprosma pseudocuneata*	AK1/3	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	1/2	1/2	1/2	1/2	0
RUBIACEAE	*Coprosma serrulata*	AK1/1	0	0	0	1	1	0	0	0	1/3	1/3	1/3	0	0	0	0	1	0	0	0	0	1	0	1/2	1/2	0	0	1/3	1/3	1/3
RUBIACEAE	*Coprosma linariifolia*	AK1/15	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1/2	1/2	0	0	0	1	0	0	0	1/2	1/2	1/2	1/2	0
RUBIACEAE	*Gaultheria rupestris*	AK1/6	0	0	1/2	0	1	0	0	0	1/2	1/2	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	1	0
SCROPHULARIACEAE	*Hebe macrantha* *	AK1/11	0	0	0	1	1	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	1	0	1/2	1/2	0	0	0	1	0
SCROPHULARIACEAE	*Hebe sp. C (8l)*	AK1/8	0	1	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	0	1/2	1/2	0	0	1	0	0	0	0	1	0	0	1	0
VIOLACEAE	*Hymenanthera alpina* *	AK1/12	0	1/2	0	1/2	1/2	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1/2	1/2	0	1	0	0	0	1/2	1/2	0
	CLAMP SCORE		0.0	50.0	19.2	38.5	42.3	7.7	11.5	37.2	24.3	21.7	11.5	5.1	0.0	0.0	7.7	61.5	38.5	0.0	0.0	53.8	46.2	0.0	34.6	15.4	26.9	23.1	17.9	79.5	2.5

APPENDIX THREE

FLAGGY CREEK, RIPARIAN, QUEENSLAND, AUSTRALIA

family	species name	specimen number	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	lepto1	lepto 2	micro1	micro2	micro 3	meso 1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base Cordate	base round	base acute	L:W<1:1	1-2:1	2-3:1	3-4:1	>4:1	shape obovate	shape elliptical	shape ovate
CLUSIACEAE	*Garcinia warrenii* *	FKR/40	0	1	0	0	0	0	0	0	0	0	0	0	1/2	1/2	1	1	0	0	0	1	0	0	1	0	0	0	0	1	0
CONNARACEAE	*Connarus conchocarpus* *	FKR/27	0	1	0	0	0	0	0	0	0	0	0	0	1/2	1/2	-	-	-	-	0	1	0	0	0	1	0	0	0	1	0
DILLENIACEAE	*Tetracera nordtiana* *	FKR/26	0	1/2	0	0	1/4	1/4	0	0	0	1/3	1/3	1/3	0	0	0	0	1/2	1/2	0	1/2	1/2	0	0	1	0	0	0	1	0
ELAEOCARPACEAE	*Aceratium megalospermum* *	FKR/38	0	1	0	0	0	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0	1	0
ELAEOCARPACEAE	*Sloanea langii* *	FKR/16	0	1/2	0	0	1/2	0	0	0	0	0	0	1/3	1/3	1/3	0	0	1/2	1/2	0	1	0	0	0	1	0	0	0	1	0
EUPHORBIACEAE	*Aleurites moluccana var. rockingha*	FKR/11	0	1	0	0	0	0	0	0	0	0	0	0	1/2	1/2	0	0	0	1	1/2	1/2	0	0	1	0	0	0	0	1	0
EUPHORBIACEAE	*Breynia stipitata* *	FKR/33	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	0	1	0	1	0	0	1	0	0	1	0	0	0	0	1/2	1/2
EUPHORBIACEAE	*Glochidion sumatranum* *	FKR/8	0	1	0	0	0	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1	0	1	0	0	1/2	1/2	0	0	0	1	0
EUPHORBIACEAE	*Rockinghamia angustifolia* *	FKR/39	0	0	0	0	1	0	0	0	0	0	1/4	1/4	1/4	1/4	0	0	0	1	0	1	0	0	0	1/3	1/3	1/3	0	1	0
FABACEAE	*Castanospermum australe* *	FKR/10	0	1	0	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	1/2	1/2	0	1	0	0	0	1/2	1/2	0	1/3	1/3	1/3
LAURACEAE	*Beilschmiedia obtusifolia* *	FKR/12	0	1	0	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	1/2	1/2	0	0	0	1	0	0	1/2	1/2	0	0	1	0
LAURACEAE	*Cryptocarya mackinnoniana* *	FKR/1a	0	1	0	0	0	0	0	0	0	0	0	0	1/2	1/2	0	0	1	0	0	1	0	0	0	1/2	1/2	0	1/2	1/2	0
LAURACEAE	*Cryptocarya murrayi* *	FKR/1	0	1	0	0	0	0	0	0	0	0	1/4	1/4	1/4	1/4	1	1/2	0	1/2	0	1/2	1/2	0	1/3	1/3	1/3	0	0	1	0
MELIACEAE	*Dysoxylum oppositifolium* *	FKR/5	0	1	0	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	1	0	1/2	1/2	0	1/2	1/2	0	0	0	1	0
MONIMIACEAE	*Doryphora aromatica* *	FKR/2	0	0	0	0	1	0	0	0	0	1/3	1/3	1/3	0	0	1	0	1/2	1/2	0	1/2	1/2	0	0	1	0	0	0	1	0
MONIMIACEAE	*Hedycarya loxocarya* *	FKR/21	0	1	0	0	0	0	0	0	0	0	0	1/2	1/2	0	0	1/3	1/3	1/3	0	1/2	1/2	0	0	1	0	0	0	1/2	1/2
MONIMIACEAE	*Tetrasynandra laxiflora* *	FKR/18	0	1	0	0	0	0	0	0	0	0	0	1/2	1/2	0	0	0	0	1	0	1/2	1/2	0	0	1	0	0	0	1	0
MORACEAE	*Ficus leptoclada* *	FKR/19	0	1	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	0	1	0	1	0	0	1/2	1/2	0	0	0	1	0
MYRSINACEAE	*Maesa muelleni* *	FKR/25	0	0	0	0	0	1	0	0	0	0	1/3	1/3	1/3	0	0	0	1	0	1	0	0	0	1/2	1/2	0	0	0	1	0
MYRTACEAE	*Austromyrtus sp.* *	FKR/6	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0	1	0
MYRTACEAE	*Rhodamnia spongiosa* *	FKR/29	0	1	0	0	0	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1	0	1	0	0	1/2	1/2	0	0	0	1/2	1/2
MYRTACEAE	*Rhodomyrtus macrocarpa* *	FKR/7	0	1	0	0	0	0	0	0	0	0	0	0	1/2	1/2	0	1/2	0	1/2	0	0	1	0	1/2	1/2	0	0	0	1	0
MYRTACEAE	*Syzygium tierneyanum* *	FKR/3	0	1	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	1/2	0	1/2	0	1	0	0	1/2	1/2	0	0	0	1	0
PROTEACEAE	*Helicia nortoiana* *	FKR/30	0	0	1/2	1	0	1	1/2	0	0	0	0	1/3	1/3	1/3	0	0	1/2	1/2	0	0	1	0	0	0	1/2	1/2	1	0	0
RUBIACEAE	*Guettardella tenuiflora* *	FKR/13	0	1	0	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	1/2	1/2	0	0	1	0	0	1/2	1/2	0	0	1	0
RUTACEAE	*Flindersia iffliana* *	FKR/14	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1/2	1/2	0	0	1	0	0	0	1/2	1/2	0	0	0	1

APPENDIX THREE

family	species name	specimen number	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	lepto1	lepto 2	micro1	micro2	micro 3	meso 1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base Cordate	base round	base acute	L:W<1:1	1-2:1	2-3:1	3-4:1	>4:1	shape obovate	shape elliptical	shape ovate
RUTACEAE	*Melicope elleryana* *	FKR/4	0	1	0	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	1	0	1	0	0	0	1	0	0	0	1	0
SAPINDACEAE	*Cupaniopsis foveolata* *	FKR/22	0	0	0	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0	1/2	1/2
SAPINDACEAE	*Mischocarpus lachnocarpus* *	FKR/23	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1/2	1/2	0	1	0	0	1/2	1/2	0	0	0	1	0
SAPINDACEAE	*Neolitsea dealbata* *	FKR/9	0	1	0	0	0	0	0	0	0	0	0	1/2	1/2	0	0	0	0	1	0	1/2	1/2	0	0	1	0	0	0	1	0
SYMPLOCACEAE	*Symplocos cochinchinensis* *	FKR/28	0	1/2	0	0	1/4	1/4	0	0	0	0	1/3	1/3	1/3	0	0	0	0	1	0	0	1	0	0	1/3	1/3	1/3	1/2	1/2	0
FABACEAE	*Austrosteenisia stipularis* *	FKR/32	0	1	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	1/2	1/2	0	0	1	0	0	0	1/2	1/2	0	1	0	0
VERBENACEAE	*Faradaya splendida* *	FKR/36	0	1	0	0	0	0	0	0	0	0	1/4	1/4	1/4	1/4	0	0	0	1	0	1	0	0	1/3	1/3	1/3	0	0	1/2	1/2
APOCYNACEAE	*Melodinus australis* *	FKR/34	0	1	0	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	1/2	1/2	0	1	0	0	0	1	0	0	0	1	0
	CLAMP SCORE		0.0	80.9	1.5	2.9	11.8	7.4	1.5	0.0	1.0	6.3	28.1	29.0	23.7	11.5	12.1	11.7	24.2	64.2	5.0	65.0	30.0	0.0	16.7	60.8	13.3	9.2	12.5	72.5	15.0

APPENDIX THREE

FLAGGY CREEK, NON-RIPARIAN, QUEENSLAND, AUSTRALIA

family	species name	specimen number	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	leptol	lepto 2	microl	micro2	micro 3	meso 1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base Cordate	base round	base acute	L:W<1:1	1-2:1	2-3:1	3-4:1	>4:1	shape obovate	shape elliptical	shape ovate
RHAMNACEAE	*Alphitonia whitei*	FCNR/32A	0	1	0	0	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	1/2	1/2	0	0	1	0	0	1	0	0	0	1	0
APOCYNACEAE	*Alstonia muelleriana*	FCNR/6A	0	1	0	0	0	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1	0	0	1	0	0	1/2	1/2	0	0	1	0
PROTEACEAE	*Carnarvonia araliifolia*	FCNR/15A	0	0	0	1/2	1/2	1/2	0	0	0	0	1/4	1/4	1/4	1/4	0	1/3	1/3	1/3	0	1/2	1/2	0	1/2	1/2	0	0	1/2	1/2	0
EUPHORBIACEAE	*Cleistanthus discolor*	FCNR/18A	0	1	0	0	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	1	0	1	0	0	0	1	0	0	0	1	0
VERBENACEAE	*Clerodendrum sp.*	FCNR/29A	0	1	0	0	0	0	0	0	0	0	1/4	1/4	1/4	1/4	0	0	1/2	1/2	0	1	0	0	1	0	0	0	0	1	0
MYRTACEAE	*Decaspermum humile*	FCNR/5A	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	1	0	0	1/2	1/2	0	0	0	1/2	1/2
MORACEAE	*Ficus destruens*	FCNR/17A	0	1	0	0	0	0	0	0	0	0	0	1/2	1/2	0	0	1/3	1/3	1/3	0	0	1	0	0	0	1	0	0	1	0
RUTACEAE	*Flindersia acuminata*	FCNR/33A	0	1	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	0	1	0	1	0	0	0	1/2	1/2	0	0	1/2	1/2
RUBIACEAE	*Gardenia ovularis*	FCNR/39A	0	1	0	0	0	0	0	0	0	0	1/4	1/4	1/4	1/4	0	0	0	1	0	1/2	1/2	0	0	1/2	1/2	0	0	1	0
EUPHORBIACEAE	*Glochidion sumatranum*	FCNR/20A	0	1	0	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	1	0	1	0	0	0	1/2	1/2	0	0	1/2	1/2
CELASTACEAE	*Hedraianthera porphyropetala*	FCNR/7A	0	1	0	0	0	0	0	0	0	0	1/2	1/2	0	0	1	1/2	1/2	0	0	0	1	0	0	1	0	0	0	1	0
MENISPERMACEAE	*Hypserpa decumbens*	FCNR/35A	0	1	0	0	0	0	0	0	0	0	0	1/3	1/3	1/3	1	1/2	0	1/2	1	0	0	0	1	0	0	0	0	1/2	1/2
EUPHORBIACEAE	*Macaranga subdentata*	FCNR/24A	0	1	0	0	0	0	0	0	0	0	0	1/2	0	1/2	0	0	0	1	0	1	0	0	0	0	1	0	0	1	0
PROTEACEAE	*Musgravea heterophylla*	FCNR/34A	0	1	0	0	0	0	0	0	0	0	0	1/3	1/3	1/3	0	1/2	1/2	0	0	1/2	1/2	0	0	1/2	1/2	0	1/2	1/2	0
LAURACEAE	*Neolitsea dealbata*	FCNR/37A	0	1	0	0	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	1/2	1/2	0	1/2	1/2	0	0	1	0	0	0	1	0
MONIMIACEAE	*Palmeria scandens*	FCNR/10A	0	1	0	0	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	1	0	1	0	0	1	0	0	0	0	1	0
BIGNONIACEAE	*Pandorea pandorana*	FCNR/12A/2	0	1/2	0	1/4	1/4	1/4	0	0	0	0	1/2	1/2	0	0	0	1/3	1/3	1/3	0	1/2	1/2	0	1/3	1/3	1/3	0	1/2	1/2	0
PASSIFLORACEAE	*Passiflora sp.*	FCNR/9A	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1/2	0	1/2	0	1	0	0	1/2	1/2	0	0	1/2	1/2	0
ARALIACEAE	*Polyscias australiana*	FCNR/14A	0	1	0	0	0	0	0	0	0	0	0	0	1/2	1/2	0	0	0	1	0	1/2	1/2	0	0	1	0	0	0	1/2	1/2
ARALIACEAE	*Polyscias elegans*	FCNR/3A	0	1	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	0	1	0	1/2	1/2	0	1/2	1/2	0	0	0	1	0
SAPOTACEAE	*Pouteria chartacea*	FCNR/11A	0	1	0	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	1	0	0	1	0	0	1/2	1/2	0	0	1	0
MYRTACEAE	*Rhodomyrtus pervagata*	FCNR/16A	0	1	0	0	0	0	0	0	0	1/4	1/4	1/4	1/4	0	0	0	0	1	0	1	0	0	0	1	0	0	0	1/2	1/2

APPENDIX THREE

family	species name	specimen number	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	teeth	lepto1	lepto 2	micro1	micro2	micro 3	meso 1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base Cordate	base round	base acute	L:W<1:1	1-2:1	2-3:1	3-4:1	>4:1	shape obovate	shape elliptical	shape ovate
H	*Salacia disepala*	FCNR/8A	0	1	0	0	0	0	0	0	0	0	0	0	1/3	1/3	1/3	1	0	1	0	0	1	0	0	0	1	0	0	0	1	0
ELAEOCARPACEAE	*Sloanea langii*	FCNR/1A	0	1/2	0	0	0	1/2	0	0	0	0	0	0	1/2	0	1/2	0	0	0	1	1	0	0	0	0	1	0	0	0	1	0
MYRTACEAE	*Syzygium kuranda*	FCNR/36A	0	1	0	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	1	0	1/2	1/2	0	0	1/3	1/3	1/3	1/2	1/2	0
DILLENIACEAE	*Tetracera nordtiana*	FCNR/21A	0	1/2	0	1/4	1/2	0	0	0	0	0	1/3	1/3	1/3	0	0	1/2	1/2	0	0	1	0	0	1/2	1/2	0	0	0	1	0
XANTHOPHYLLACEAE	*Xanthophyllum octandrum*	FCNR/4A	0	1	0	0	0	0	0	0	0	1/4	1/4	1/4	1/4	0	0	1/2	1/2	0	0	1	0	0	1/2	1/2	0	0	0	1	0
ARISTOLOCHIACEAE	*Aristolochia deltantha*	FCNR/12A	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1	0	0	0	0	0	0	1/2	1/2	1	0	0
EUPHORBIACEAE	*Breynia stipulata*	FCNR/26A	0	1	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	1/2	1/2	0	0	1	0	0	1/2	1/2	0	0	0	1/2	1/2
FLACOURTIACEAE	*Casearia sp.*	FCNR/2A	0	1	0	0	0	0	0	0	0	0	1/2	1/2	0	0	1	0	0	1	0	1	0	0	0	1	0	0	0	1	0
LAURACEAE	*Cryptocarya sp*	FCNR/40A	0	1	0	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	1	0	1/2	1/2	0	0	1/2	1/2	0	0	1	0
ANNONACEAE	*Desmos goeziances*	FCNR/25A	0	1	0	0	0	0	0	0	0	0	1/4	1/4	1/4	1/4	0	0	1/2	1/2	0	1/2	1/2	0	0	0	1/2	1/2	0	1/2	1/2
APOCYNACEAE	*Melodinus australis*	FCNR/23A	0	1	0	0	0	0	0	0	1/4	1/4	1/4	1/4	0	0	0	0	1/2	1/2	0	1	0	0	1/3	1/3	1/3	0	0	1	0
SAPINDACEAE	*Mischocarpus lachnocarpus*	FCNR/22A	0	1	0	0	0	0	0	0	0	0	1/4	1/4	1/4	1/4	0	0	0	1	0	1	0	0	0	1	0	0	0	1	0
PROTEACEAE	*Placospermum coriaceum*	FCNR/27A	1/2	1	0	0	0	0	0	0	0	1/5	1/5	1/5	1/5	1/5	0	1	0	0	0	0	1	0	0	1/3	1/3	1/3	1/2	1/2	0
	CLAMP SCORE		1.4	92.9	0.0	2.9	3.6	3.6	0.0	0.0	0.7	7.0	21.0	33.3	22.6	15.0	11.4	15.7	22.8	61.4	8.6	60.0	31.4	0.0	20.5	52.3	22.3	4.7	11.4	77.1	11.4

APPENDIX THREE

MOUNT FYFFE, KAIKOURA, SOUTH ISLAND, NEW ZEALAND

family	species name	specimen number	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	lepto 1	lepto 2	micro1	micro2	micro 3	meso 1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base Cordate	base round	base acute	L:W<1:1	1-2:1	2-3:1	3-4:1	>4:1	shape obovate	shape elliptical	shape ovate
ARALIACEAE	*Pseudopanax arboreus*	MF/1	0	0	0	1/2	1/2	1/2	0	0	0	1/4	1/4	1/4	1/4	0	0	1/2	1/2	0	0	1	0	0	1/2	1/2	0	0	0	1	0
ARALIACEAE	*Rubus cissoides*	MF/4	0	0	0	1/2	0	1	0	0	0	0	1	0	0	0	0	0	1	0	1/2	1/2	0	0	0	1	0	0	0	1/2	1/2
COMPOSITAE	*Helichrysum aggregatum*	MF/19	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	1/2	1/2	0	1	0	0	0	0	1	0
ELAEOCARPACEAE	*Aristotelia serrata*	MF/9	0	0	1/2	1	0	1	1	0	0	1/4	1/4	1/4	1/4	0	0	1/2	0	1/2	1/2	1/2	0	0	1/2	1/2	0	0	0	1/2	1/2
ELAEOCARPACEAE	*Elaeocarpus dentatus*	MF/13	0	0	0	1/2	1	0	0	0	0	1/2	1/2	0	0	0	0	1/2	0	1/2	0	1/2	1/2	0	0	0	1/2	1/2	1/2	1/2	0
ESCALLONIACEAE	*Carpodetus serratus*	MF/6+7	0	0	1/2	1/2	1/2	1/2	1/2	0	1/3	1/3	1/3	0	0	0	0	1/2	1/2	0	0	1	0	0	1	0	0	0	0	1	0
MONIMIACEAE	*Hedycarya arborea*	MF/2	0	0	1/2	0	0	1	0	0	0	0	1/2	1/2	0	0	0	1/2	1/2	0	0	1/2	1/2	0	0	1	0	0	0	1	0
MYRSINACEAE	*Myrsine australis*	MF/12	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	0	1	1	0	0	0	1	0	0	0	1	0	0	0	1	0
MYRTACEAE	*Leptospermum scoparium*	MF/23	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	1	0	0	1/2	1/2	0	0	0	1	0
MYRTACEAE	*Leptospermum ericoides*	MF/22	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	1	0	0	0	0	0	1	0	1	0
PAPILIONACEAE	*Sophora microphylla*	MF/17	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	1	0	0	1	0	0	0	1/2	1/2	0
PIPERACEAE	*Macropiper excelsum*	MF/10	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1/2	0	1/2	1	0	0	1/2	1/2	0	0	0	0	1	0
RANUNCULACEAE	*Clematis foetida*	MF/8	0	1	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	1/2	0	1/2	1/2	1/2	0	0	1	0	0	0	0	1	0
RUBIACEAE	*Coprosma rotundifolia*	MF/20	0	1	0	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1	0	0	1/2	1/2	0	1/2	1/2	0	0	0	0	1	0
RUBIACEAE	*Coprosma sp. A*	MF/18	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	0	1	0	1/4	1/4	1/4	1/4	0	1	0
RUBIACEAE	*Rubus schmideloides*	MF/5	0	0	1/2	1	0	1	0	0	0	0	1	0	0	0	0	0	1/2	1/2	1/2	1/2	0	0	0	1	0	0	0	0	1
URTICACEAE	*Urtica ferox*	MF/15	0	0	1	1	0	1	0	0	1/3	1/3	1/3	0	0	0	0	0	1	0	1	0	0	0	0	1/2	1/2	0	0	0	1
VIOLACEAE	*Melicytus ramiflorus*	MF/16	0	0	1	1/2	1	0	0	0	0	0	1/3	1/3	1/3	0	0	1/2	0	1/2	0	1	0	0	1/3	1/3	1/3	0	1/2	1/2	0
RANUNCULACEAE	*Clematis foetida*	MF/21	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	0	1	0	0	0	0	1/2	1/2
	CLAMP SCORE		0.0	52.6	21.1	28.9	15.8	31.6	7.9	21.1	18.4	15.7	28.0	7.0	9.6	0.0	10.5	57.9	26.3	15.8	28.9	57.9	13.2	5.3	42.5	34.6	8.3	9.2	7.9	73.7	18.4

APPENDIX THREE

BLUE DUCK RESERVE, KAIKOURA, SOUTH ISLAND, NEW ZEALAND

family	species name	specimen number	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	lepto1	lepto 2	micro1	micro2	micro 3	meso 1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base Cordate	base round	base acute	L:W<1:1	1-2:1	2-3:1	3-4:1	>4:1	shape obovate	shape elliptical	shape ovate
APOCYNACEAE	*Parsonsia heterophylla*	BDR/5	1/2	1	0	0	0	0	0	0	0	1/2	1/2	0	0	0	0	1/2	1/2	0	0	1/2	1/2	0	0	1/3	1/3	1/3	0	1	0
ARALIACEAE	*Schefflera digitata*	BDR/15	0	0	1	1/2	0	1	0	0	0	0	1/3	1/3	1/3	0	0	0	0	1	0	1/2	1/2	0	0	1/2	1/2	0	0	1	0
ARALIACEAE	*Pseudopanax arboreus*	BDR/4	0	0	0	1/2	0	1	0	0	1/6	1/6	1/6	1/6	1/6	1/6	0	1/2	1/2	0	0	1	0	0	1/2	1/2	0	0	0	1	0
ARALIACEAE	*Pseudopanax crassifolius*	BDR/24	0	0	0	0	0	1	1/2	0	0	0	1/2	1/2	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	1	0
MYRTACEAE	*Metrosideros sp. A*	BDR/32	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	1/2	1/2	0	1/2	1/2	0	0	0	0	1	0
CORIARIACEAE	*Coriaria arborea*	BDR/22	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0
ELAEOCARPACEAE	*Elaeocarpus hookerianus* *	BDR/1+18	0	0	0	1/2	1	0	0	0	0	1/2	1/2	0	0	0	0	1/2	1/2	0	0	1/2	1/2	0	0	1/2	1/2	0	0	1	0
ELAEOCARPACEAE	*Elaeocarpus dentatus*	BDR/16+17	0	0	1/2	1/2	1/2	1/2	1/2	0	0	0	1/2	1/2	0	0	0	0	1/2	1/2	0	1	0	0	0	0	1/2	1/2	1/2	1/2	0
ELAEOCARPACEAE	*Aristotelia serrata*	BDR/23	0	0	1	1	0	1	1	0	0	1/5	1/5	1/5	1/5	1/5	0	0	1/2	1/2	1	0	0	0	1	0	0	0	0	1/2	1/2
ESCALLONIACEAE	*Carpodetus serratus*	BDR/12+19	0	0	1/2	1/2	0	1	1/2	1/4	1/4	1/4	1/4	0	0	0	0	1/2	1/2	0	0	1	0	0	1	0	0	0	0	1	0
FAGACEAE	*Nothofagus solandri*	BDR/25+27	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	1	0	0	1/2	1/2	0	0	0	1/2	1/2
ICACINACEAE	*Pennantia corymbosa*	BDR/3	0	1/2	0	1/2	1/2	0	1/2	1/4	1/4	1/4	1/4	0	0	0	0	1	0	0	0	1/2	1/2	0	1	0	0	0	1/2	1/2	0
MONIMIACEAE	*Hedycarya arborea*	BDR/6	0	0	0	0	1/2	1/2	0	0	0	0	1/3	1/3	1/3	0	0	-1/2	1/2	0	0	0	1	0	0	1/3	1/3	1/3	1/2	1/2	0
MYRTACEAE	*Metrosideros diffusa*	BDR/26	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	1	0	0	1/2	1/2	0	0	0	1/2	1/2
MYRTACEAE	*Metrosideros sp. B* *	BDR/33	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0
MYRTACEAE	*Leptospermum scoparium*	BDR/34	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	1	0
MYRTACEAE	*Metrosideros colensoi*	BDR/35	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1/2	1/2	0	0	1	0	0	1/2	1/2	0	0	0	1/2	1/2
ONAGRACEAE	*Fuchsia excorticata*	BDR/14	0	0	0	0	1	0	0	0	1/3	1/3	1/3	0	0	0	0	0	1	0	0	1	0	0	0	1	0	0	0	1/2	1/2
PIPERACEAE	*Macropiper excelsum*	BDR/11	0	1	0	0	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	1	1	0	0	0	1	0	0	0	0	0	1
PITTOSPORACEAE	*Pittosporum eugenioides*	BDR/13	0	1	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	1	0
ROSACEAE	*Rubus cissoides*	BDR/2	0	0	1/2	1/2	0	1	1/2	0	1/4	1/4	1/4	1/4	0	0	0	0	1/2	1/2	1/2	1/2	0	0	1/2	1/2	0	0	0	0	1
RUBIACEAE	*Coprosma grandifolia*	BDR/9	0	1	0	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	1/2	1/2	0	0	1	0	0	1/2	1/2	0	0	0	1	0
RUBIACEAE	*Coprosma robusta*	BDR/20	0	1	0	0	0	0	0	0	1/4	1/4	1/4	1/4	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	1	0
RUBIACEAE	*Coprosma rhamnoides*	BDR/28	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	1/2	1/2
RUBIACEAE	*Coprosma linariifolia*	BDR/29	0	1	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	1	0

APPENDIX THREE

family	species name	specimen number	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	lepto1	lepto 2	micro1	micro2	micro 3	meso 1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base Cordate	base round	base acute	L:W<1:1	1-2:1	2-3:1	3-4:1	>4:1	shape obovate	shape elliptical	shape ovate
RUBIACEAE	*Coprosma tenuicaulis*	BDR/31	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1/2	1/2	0	0	1	0	0	1	0	0	0	0	1	0
URTICACEAE	*Urtica ferox*	BDR/8	0	0	1	1	0	1	0	0	0	1/3	1/3	1/3	0	0	0	0	1	0	1	0	0	0	0	1	0	0	0	0	1
VIOLACEAE	*Melicytus ramiflorus*	BDR/7	0	0	1/2	1/2	1	0	0	0	1/5	1/5	1/5	1/5	1/5	0	0	1/3	1/3	1/3	0	1/2	1/2	0	0	1/2	1/2	0	0	1	0
WINTERACEAE	*Pseudowintera colorata*	BDR/21	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	0	1	1	0	0	0	0	1	0	1/2	1/2	0	0	0	1	0
RANUNCULACEAE	*Clematis foetida*	BDR/30	1/2	1	0	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1	0	0	1/2	1/2	0	1/2	1/2	0	0	0	0	1/2	1/2
VIOLACEAE	*Hymenanthera angustifolia*	BDR/38	1/2	1/2	0	1/2	1/2	0	1/4	0	1/2	1/2	0	0	0	0	1	1	0	0	0	0	1	0	1/4	1/4	1/4	1/4	1/2	1/2	0
MYRTACEAE	*Leptospermum ericoides*	BDR/39	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	1/2	1/2	0
	CLAMP SCORE		4.7	59.4	15.6	20.3	15.6	25.0	11.7	18.2	22.0	18.4	20.5	12.6	5.9	2.2	9.4	47.9	40.1	12.0	14.1	59.4	26.6	3.1	36.7	34.1	12.2	13.8	7.8	71.9	20.3

APPENDIX THREE

PUHI PUHI RESERVE, KAIKOURA, SOUTH ISLAND, NEW ZEALAND

family	species name	specimen number	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	leptol	lepto 2	microl	micro2	micro 3	meso 1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base Cordate	base round	base acute	L:W<1:1	1-2:1	2-3:1	3-4:1	>4:1	shape obovate	shape elliptical	shape ovate
APOCYNACEAE	*Parsonsia heterophylla*	PP/17	0	1/2	0	0	1/2	0	0	1/3	1/3	1/3	0	0	0	0	0	1/2	1/2	0	0	1	0	1/3	1/3	0	0	1/3	0	1/2	1/2
ARALIACEAE	*Pseudopanax arboreus*	PP/28	0	0	0	1/2	1/2	1/2	1/2	0	0	0	1/2	1/2	0	0	0	0	1	0	0	1	0	0	0	1	0	0	0	1	0
CORNACEAE	*Corokia cotoneaster*	PP/3	0	1	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	1	1	0	0	0	0	1	1/2	1/2	0	0	0	0	1	0
CORNACEAE	*Griselinia littoralis*	PP/26	0	1	0	0	0	0	0	0	0	0	1/2	1/2	0	0	0	1	0	0	0	1/2	1/2	0	1	0	0	0	0	1	0
ELAEOCARPACEAE	*Elaeocarpus dentatus*	PP/21	0	0	1/2	1/2	1/2	1/2	0	0	0	0	1/2	1/2	0	0	0	0	1/2	1/2	0	1	0	0	0	0	0	1	1/2	1/2	0
ICACINACEAE	*Pennantia corymbosa* *	PP/36	0	0	0	1/2	1	0	1/2	0	0	1/2	1/2	0	0	0	0	1	0	0	0	1	0	0	1/2	1/2	0	0	1/2	1/2	0
MONIMIACEAE	*Hedycarya arborea*	PP/20	0	0	0	0	1/2	1/2	0	0	0	0	1/2	1/2	0	0	0	1/2	1/2	0	0	1/2	1/2	0	0	1/3	1/3	1/3	0	1	0
MYRSINACEAE	*Myrsine divaricata*	PP/12	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1	1	0	0	0	0	1	0	1	0	0	0	0	1	0
MYRSINACEAE	*Myrsine australis*	PP/32	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	0	0	1	0	0	0	1/2	1/2	0	0	1	0	0	0	1	0
MYRTACEAE	*Metrosideros diffusa*	PP/4	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	0	1	0	0	1	0	0	1/2	1/2	0	0	0	1/2	1/2
MYRTACEAE	*Metrosideros colensoi* *	PP/6	0	1	0	0	0	0	0	1/3	1/3	1/2	0	0	0	0	0	1/2	1/2	0	1/2	1/2	0	0	1/2	1/2	0	0	0	1/2	1/2
MYRTACEAE	*Metrosideros diffusa*	PP/7	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	1	0	0	1/2	1/2	0	0	0	1	0
MYRTACEAE	*Neomyrtus pedunculata*	PP/13	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	1/2	1/2	0	0	0	1	0
ONAGRACEAE	*Fuchsia excorticata*	PP/33	0	0	0	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	1/2	1/2	0	1	0	0	0	1	0	0	0	1	0
PAPILIONACEAE	*Sophora microphylla*	PP/16	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1/2	1/2	0	1	0	0	0	1/2	1/2	0
PIPERACEAE	*Macropiper excelsum*	PP/24	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1/2	1/2	1	0	0	0	1	0	0	0	0	1	0
PITTOSPORACEAE	*Pittosporum eugenioides*	PP/25	0	1	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	1/2	1/2	0	0	1	0	0	0	1/2	1/2	0	0	1	0
RANUNCULACEAE	*Clematis forsteri* *	PP/9	0	1/2	0	0	1/2	0	0	0	0	1/2	1/2	0	0	0	1	1/2	1/2	0	1/2	1/2	0	0	1	0	0	0	0	0	1
RUBIACEAE	*Coprosma areolata*	PP/8	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	1/2	1/2	0	0	1	0	0	1	0	0	0	0	1	0
RUBIACEAE	*Coprosma tenuicaulis*	PP/11	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1/2	1/2	0	1	0	0	0	1	0	0	0	0	1	0
RUBIACEAE	*Coprosma linariifolia*	PP/18	0	1	0	0	0	0	0	1/2	1/4	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1/2	1/2	0	0	1	0
RUBIACEAE	*Coprosma parviflora*	PP/19	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0
RUBIACEAE	*Coprosma robusta*	PP/29	0	1	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	1	0	0	0	1	0	0	1/2	1/2	0	0	1/2	1/2	0
RUBIACEAE	*Coprosma grandifolia*	PP/30	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1/2	0	1/2	0	1	0	0	1	0	0	0	0	1	0
SAPINDACEAE	*Alectryon excelsis*	PP/22	0	0	1/2	1/2	0	1	0	0	1/3	1/3	1/3	0	0	0	0	0	1	0	0	1/2	0	0	1/3	1/3	1/3	0	0	1	0
SCHROPHULARIACEAE	*Hebe parviflora* *	PP/23	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	1/2	1/2	0	1/2	1	0	0	0	0	0	1	0	1	0

APPENDIX THREE

family	species name	specimen number	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	lepto1	lepto 2	micro1	micro2	micro 3	meso 1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base Cordate	base round	base acute	L:W<1:1	1-2:1	2-3:1	3-4:1	>4:1	shape obovate	shape elliptical	shape ovate
SCHROPHULARIACEAE	*Hebe salicifolia*	PP/27	0	1/2	0	0	1/2	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	1	0
VIOLACEAE	*Melicytus ramiflorus*	PP/35	0	0	1	1/2	1	0	0	0	0	0	1/4	1/4	1/4	1/4	0	0	1/2	1/2	0	1	0	0	0	1/2	1/2	0	0	1	0
MORACEAE	*Streblus heterophyllus*	PP/2	1/2	0	0	1	1/2	1/2	0	0	1/2	1/2	0	0	0	0	1	1	0	0	0	1/2	1/2	0	1	0	0	0	0	1	0
CONVOLVULACEAE	*Calystegia tuguriorum* *	PP/9.b	0	1	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	0	1/2	1/2	1/2	1/2	0	0	1	0	0	0	0	0	1
RUTACEAE	*Melicope simplex* *	PP/10	0	0	0	0	1	0	0	1/2	1/2	0	0	0	0	0	1	1	0	0	0	1	0	1/2	1/2	0	0	0	0	1	0
MALVACEAE	*Hoheria angustifolia* *	PP/14	0	0	0	1/2	0	1	1/2	1/3	1/3	1/3	0	0	0	0	0	1/2	1/2	0	0	0	1	0	1/4	1/4	1/4	1/4	0	1	0
	CLAMP SCORE		1.6	64.1	6.3	12.5	23.4	12.5	4.7	19.8	19.5	21.3	20.5	13.8	3.9	0.8	15.6	59.4	31.3	9.4	12.5	64.1	23.4	4.2	46.6	29.4	7.5	12.2	6.3	82.8	10.9

APPENDIX THREE

LADY LAKE, SOUTH ISLAND, NEW ZEALAND

family	species name	specimen number	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	lepto1	lepto 2	micro1	micro2	micro 3	meso 1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base Cordate	base round	base acute	L:W<1:1	1-2:1	2-3:1	3-4:1	>4:1	shape obovate	shape elliptical	shape ovate
APOCYNACEAE	*Parsonsia heterophylla* *	LL/10	1/2	1	0	0	0	0	0	0	0	1	0	0	0	0	0	1/2	1/2	0	1/2	1/2	0	0	1/4	1/4	1/4	1/4	0	1/2	1/2
ARALIACAEA	*Pseudopanax crassifolius* *	LL/15	0	0	0	0	0	1	1/2	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	0	1	0	1	0
ARALIACAEA	*Schefflera digitata*	LL/35	0	0	1	0	1/2	1/2	1	0	0	1/4	1/4	1/4	1/4	0	0	1/3	1/3	1/3	0	1/2	1/2	1/3	1/3	1/3	0	0	1/2	1/2	0
COMPOSITAE	*Olearia arborescens*	LL/18	0	0	0	0	1	0	0	0	0	1/3	1/3	1/3	0	0	1	0	1	0	0	1	0	0	1/3	1/3	1/3	0	0	1	0
CORIARIACEAE	*Coriaria arborea* *	LL/3	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	1	0	0	1/2	1/2	0	0	0	1	0
CORNACEAE	*Griselinia littoralis*	LL/5	0	1	0	0	0	0	0	0	0	1/4	1/4	1/4	1/4	0	1	1	0	0	0	1	0	0	1/2	1/2	0	0	0	1/2	0
CUNONIACEAE	*Weinmannia racemosa*	LL/23	0	0	1	1/2	1/2	1/2	0	0	0	1/4	1/4	1/4	1/4	0	0	1/2	1/2	0	0	1/2	1/2	0	1/3	1/3	1/3	0	0	1/2	1/2
ELAEOCARPACEAE	*Aristotelia serrata* *	LL/24	0	0	1	1	0	1	1	0	0	1/5	1/5	1/5	1/5	1/5	0	0	1/2	1/2	1/2	1/2	0	0	1/2	1/2	0	0	0	1/2	1/2
ELAEOCARPACEAE	*Elaeocarpus dentatus* *	LL/7	0	0	1/2	0	0	1	1/2	0	0	0	1/2	1/2	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0	1	0
ESCALLONIACEAE	*Carpodetus serratus* *	LL/12	0	0	1/2	0	1/2	1/2	1/2	0	0	1/2	1/2	0	0	0	0	1/2	1/2	0	0	1	0	0	1/2	1/2	0	0	0	1	0
ESCALLONIACEAE	*Quintinia acutifolia* *	LL/1	0	1/2	0	0	0	1/2	0	0	0	0	1/3	1/3	1/3	0	0	0	1/2	1/2	0	0	1	0	0	0	1	0	1/2	1/2	0
ICACINACEAE	*Pennantia corymbosa*	LL/34	0	1/2	0	1/4	1	0	0	1/2	1/2	0	0	0	0	0	1	1	0	0	0	1	0	1/2	1/2	0	0	0	1/2	1/2	0
MALVACEAE	*Hoheria lyallii*	LL/6	1/2	0	1	1	1	0	1	0	0	1/2	1/2	0	0	0	0	1/2	1/2	0	1	0	0	0	1	0	0	0	0	0	1
MYRSINACEAE	*Myrsine australis*	LL/8	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0	1	0	0	1/2	1/2	0	0	0	1	0
MYRSINACEAE	*Myrsine salicina* *	LL/4	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	1	0	0	0	0	0	1	1/2	1/2	0
MYRTACEAE	*Metrosideros diffusa*	LL/14	0	1	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	0	0	1	0	0	1	0	0	1/2	1/2	0	0	0	1/2	1/2
MYRTACEAE	*Neomyrtus pedunculata* *	LL/25	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	1/2	1/2	0	1	0	0	0	0	1	0
ONAGRACEAE	*Fuchsia excorticata*	LL/11	0	0	0	0	0	1	0	0	0	1/2	1/2	0	0	0	0	0	1/2	1/2	0	1	0	0	1/3	2/7	1/3	0	0	1/2	1/2
PITTOSPORACEAE	*Pittosporum colensoi* *	LL/13	0	1	0	0	0	0	0	0	0	0	1/2	1/2	0	0	1	1/2	1/2	0	0	1	0	0	1/2	1/2	0	0	1/2	1/2	0
ROSACEAE	*Rubus australis* *	LL/20	0	0	0	0	0	1	1/2	0	0	1/2	1/2	0	0	0	1	0	1	0	0	1	0	0	1	0	0	0	0	1	0
ROSACEAE	*Rubus cissoides* *	LL/21	0	0	1	1	0	1	1/2	0	0	0	1/2	1/2	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	1
ROSACEAE	*Rubus schmidelioides* *	LL/19	0	0	0	0	0	1	0	0	0	1/2	1/2	0	0	0	0	0	1	0	0	1	0	0	0	1/2	1/2	0	0	0	1
RUBIACEAE	*Coprosma areolata* *	LL/27	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	1/3	1/3	1/3
RUBIACEAE	*Coprosma rotundifolia* *	LL/28	0	1	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	0	1/2	1/2	0	0	1	0	0	1/2	1/2	0	0	0	1/2	1/2
RUBIACEAE	*Coprosma lucida* *	LL/29	0	1	0	0	0	0	0	0	1/5	1/5	1/5	1/5	1/5	0	0	1/2	1/2	0	0	1/2	1/2	0	0	1/2	1/2	0	0	1	0
RUBIACEAE	*Coprosma rhamnoides*	LL/30	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	1/2	1/2	0	1/3	1/3	1/3	0	1/2	1/2	0

APPENDIX THREE

family	species name	specimen number	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	lepto1	lepto 2	micro1	micro2	micro 3	meso 1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base Cordate	base round	base acute	L:W<1:1	1-2:1	2-3:1	3-4:1	>4:1	shape obovate	shape elliptical	shape ovate
RUBIACEAE	*Coprosma propinqua* *	LL/31	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1/2	1/2	0	0	1	0	0	1/2	1/2	0	0	0	1	0
RUBIACEAE	*Coprosma foetidissima*	LL/32	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0	1/2	0
RUBIACEAE	*Coprosma tenuicaulis* *	LL/33	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	1/2	1/2	1/2	1/2	0	0	0	0	1	0
SCROPHULARIACEAE	*Hebe salicifolia*	LL/22	0	1/2	0	0	1/2	0	0	0	0	1/2	1/2	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	1	0
VIOLACEAE	*Melicytus ramiflorus*	LL/2	0	0	1	1/2	1	0	0	0	0	1/4	1/4	1/4	1/4	0	1	0	0	1	0	1	0	0	1/3	1/3	1/3	0	0	1	0
WINTERACEAE	*Pseudowintera colorata*	LL/16	0	1	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	1	1	0	0	0	1	0	0	1	0	0	0	1/2	1/2	0
MORACEAE	*Strebius heterophylla* *	LL/9	1/2	0	0	1/2	1	0	0	1/2	1/2	0	0	0	0	0	1	1	0	0	0	1/2	1/2	0	1	0	0	0	1/2	1/2	0
	CLAMP SCORE		4.5	53.0	21.2	14.4	21.2	27.3	16.7	12.6	13.2	23.4	26.9	14.8	8.3	0.6	30.3	43.4	38.9	17.7	9.1	74.2	16.7	4.0	41.6	29.4	11.8	12.9	13.1	64.6	19.2

APPENDIX THREE

LAKE MARY, SOUTH ISLAND, NEW ZEALAND

family	species name	specimen number	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	lepto1	lepto 2	micro1	micro2	micro 3	meso 1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base Cordate	base round	base acute	L:W<1:1	1-2:1	2-3:1	3-4:1	>4:1	shape obovate	shape elliptical	shape ovate
ARALIACAEA	*Pseudopanax colensoi*	LM/18	0	0	0	1/2	0	1	1/2	0	0	1/5	1/5	1/5	1/5	1/5	0	1/2	1/2	0	0	1/2	1/2	0	1/2	1/2	0	0	0	1	0
ARALIACAEA	*Pseudopanax crassifolius*	LM/22	0	0	1/2	1/2	0	1	0	0	0	0	0	1	0	0	0	1/2	1/2	0	0	0	1	0	0	0	0	1	1/2	1/2	0
CHLORANTHACEAE	*Ascarina lucida* *	LM/23	0	0	1	1	1/2	1/2	0	0	0	1/2	1/2	0	0	0	0	1/2	1/2	0	0	1/2	1/2	0	1/2	1/2	0	0	0	1	0
CORNACEAE	*Griselinia littoralis*	LM/19	0	1	0	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	1	0	0	0	1	0	0	1	0	0	0	0	1	0
CUNONIACEAE	*Weinmannia racemosa*	LM/24	0	0	1/2	1	1/2	1/2	1/2	0	1/3	1/3	1/3	0	0	0	0	1/2	1/2	0	0	1/2	1/2	0	1/2	1/2	0	0	0	1	0
ESCALLONIACEAE	*Carpodetus serratus*	LM/3	0	0	1	1	1/2	1/2	1	0	1/2	1/2	0	0	0	0	0	0	1	0	0	1	0	1/3	1/3	1/3	0	0	0	1	0
FAGACEAE	*Nothofagus solandri* *	LM/1	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	1	0	0	1/2	1/2	0	0	0	1/2	1/2
FAGACEAE	*Nothofagus truncata* *	LM/2	0	0	1/2	1	1	0	1	2/7	2/7	2/7	0	0	0	0	0	1	0	0	0	0	1	0	1	0	0	0	0	1	0
MYRSINACEAE	*Myrsine divaricarta* *	LM/13	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1	1	0	0	0	1/2	1/2	0	1	0	0	0	1/2	1/2	0
MYRSINACEAE	*Myrsine australis*	LM/17	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	0	1	1	0	0	0	0	1	0	1/2	1/2	0	0	0	1	0
MYRTACEAE	*Leptospermum scoparium* *	LM/4	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	0	0	0	1	0
MYRTACEAE	*Metrosideros diffusa*	LM/6+7	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1/2	1/2	0	0	1	0	1/2	1/2	0	0	0	0	1	0
MYRTACEAE	*Neomyrtus pedunculata*	LM/11	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	1	0
MYRTACEAE	*Metrosideros sp. A*	LM/14	0	1	0	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1	0	0	0	1	0	1/2	1/2	0	0	0	0	1	0
MYRTACEAE	*Metrosideros umbellata*	LM/25	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1	0	0	1	0	0	0	0	1/2	1/2	0	1	0
MYRTACEAE	*Metrosideros parkinsonii* *	LM/26	0	1	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	1/2	1/2	0	0	1/2	1/2	0	0	1	0	0	0	1	0
ONAGRACEAE	*Fuchsia excorticata*	LM/20	0	0	1/2	0	0	1	0	0	0	1/3	1/3	1/3	0	0	0	0	0	1	0	0	1	0	0	1/3	1/3	1/3	0	1	0
ROSACEAE	*Rubus schmidelioides*	LM/21	0	0	1	1	0	1	1/2	0	0	0	1/2	1/2	0	0	0	0	1/2	1/2	1	0	0	0	0	1	0	0	0	0	1
RUBIACEAE	*Coprosma parviflora* *	LM/9	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	1	0
RUBIACEAE	*Coprosma rigida* *	LM/10	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1/2	1/2	0	1/2	1/2	0	0	1/2	1/2	0
RUBIACEAE	*Coprosma foetidissima*	LM/12	0	1	0	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1	0	0	0	0	1	0	1/2	1/2	0	0	0	1	0
RUBIACEAE	*Coprosma lucida*	LM/16	0	1	0	0	0	0	0	0	0	0	1/2	1/2	0	0	0	1/2	1/2	0	0	1/2	1/2	0	1/2	1/2	0	0	0	1	0
RUBIACEAE	*Coprosma propinqua*	LM/8	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	1/2	1/2	0	1/2	1/2	0	0	1/2	1/2	0
RUTACEAE	*Melicope simplex*	LM/5	0	0	0	0	1	0	0	1/2	1/2	0	0	0	0	0	1	1	0	0	0	0	1	0	1	0	0	0	1/2	1/2	0
	CLAMP SCORE		0.0	62.5	20.8	25.0	14.6	22.9	14.6	26.3	21.4	18.7	16.8	13.3	2.2	0.8	12.5	64.6	29.2	6.3	4.2	54.2	41.7	5.5	49.3	34.0	3.5	7.6	10.4	83.3	6.3

APPENDIX THREE

LE CHATEAUX, NORTH ISLAND, NEW ZEALAND

family	species name	specimen number	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	lepto1	lepto 2	micro1	micro2	micro 3	meso 1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base Cordate	base round	base acute	L:W<1:1	1-2:1	2-3:1	3-4:1	>4:1	shape obovate	shape elliptical	shape ovate
MYRSINACEAE	*Myrsine divaricata*	LC/1	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1	1	0	0	0	1	0	0	1	0	0	0	1/2	1/2	0
RUBIACEAE	*Coprosma foetidissima*	LC/2	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1/2	1/2	0	0	0	1	0
MYRTACEAE	*Leptospermum ericoides*	LC/3	0	1	0	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	1	0
RUBIACEAE	*Coprosma rigida*	LC/4	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	1/2	1/2	0	1/2	1/2	0	0	0	1/2	1/2
RUBIACEAE	*Coprosma pseudocuneata*	LC/5	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	1/2	1/2	0
RUBIACEAE	*Coprosma sp. C*	LC/6	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	1	0	0	1/2	1/2	0	0	0	1	0
EPACRIDACEAE	*Leucopogon fasciculatus* *	LC/7	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	1/2	1/2	0	1	0
FAGACEAE	*Nothofagus solandri*	LC/8	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	0	1
EPACRIDACEAE	*Leucopogon parviflorus* *	LC/9	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	1	0
RUBIACEAE	*Coprosma propinqua*	LC/10	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	1	0	0	0	0	1/2	1/2	0	1	0
FAGACEAE	*Nothofagus fuchsia* *	LC/11	0	0	1	1/2	1	0	0	0	1/2	1/2	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	1	0
RUBIACEAE	*Coprosma parviflora*	LC/12	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	1	0	0	0	0	0	1	0	1	0
MYRTACEAE	*Neomyrtus pedunculata*	LC/13	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	0	1	0	1/2	1/2	0	0	1/2	1/2	0
RUBIACEAE	*Coprosma linarifolia*	LC/14	0	1	0	0	0	0	0	0	1/4	1/4	1/4	1/4	0	0	0	0	1	0	0	1	0	0	1/2	1/2	0	0	0	1	0
Pittosporaceae	*Pittosporum tenuifolium*	LC/15	0	1	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	1	0	0	1	0	0	0	1	0	0	0	1	0
Schrophulariaceae	*Hebe stricta*	LC/16	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	1/2	1/2
Cornaceae	*Griselinia littoralis*	LC/17	0	1	0	0	0	0	0	0	0	0	1/2	1/2	0	0	1	1	0	0	0	1	0	0	0	1	0	0	0	1	0
Araliaceae	*Pseudopanax colensoi*	LC/18	0	0	0	0	1/2	1/2	1/2	0	0	1/4	1/4	1/4	1/4	0	0	0	1	0	0	1	0	0	0	1	0	0	0	1	0
Compositae	*Olearia arborescens*	LC/19	0	1	0	0	0	0	0	1/4	1/4	1/4	1/4	0	0	0	0	0	1/2	1/2	0	1	0	0	0	1	0	0	0	1	0
Rubiaceae	*Coprosma tenuifolia*	LC/20	0	0	0	0	1	0	0	0	1/3	1/3	1/3	0	0	0	0	1	0	0	0	1	0	1/2	1/2	0	0	0	0	1	0
Rosaceae	*Rubus cissoides*	LC/21	0	0	1	0	0	1	1/2	0	0	0	1	0	0	0	0	0	1	0	1/2	1/2	0	0	0	0	0	1	0	0	1
	CLAMP SCORE		0.0	81.0	9.5	2.4	11.9	7.1	4.8	36.9	25.4	13.9	16.2	6.3	1.2	0.0	14.3	57.1	40.5	2.4	2.4	85.7	11.9	2.4	33.3	35.7	4.8	23.8	7.1	78.6	14.3

APPENDIX THREE

LINK TRACK 1120-1165m, NORTH ISLAND, NEW ZEALAND

family	species name	specimen number	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	lepto1	lepto 2	micro1	micro2	micro 3	meso 1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base Cordate	base round	base acute	L:W<1:1	1-2:1	2-3:1	3-4:1	>4:1	shape obovate	shape elliptical	shape ovate
RUBIACEAE	*Coprosma parviflora*	LT/1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	1	0
Araliaceae	*Pseudopanax colensoi*	LT/2	0	0	0	1/2	1/2	1/2	0	0	0	0	1/2	1/2	0	0	0	0	1	0	0	1	0	0	0	1/2	1/2	0	0	1	0
Araliaceae	*Pseudopanax simplex*	LT/3	0	0	0	1/2	0	1	0	0	1/3	1/3	1/3	0	0	0	0	0	1	0	0	1/2	1/2	0	1/2	1/2	0	0	0	1	0
Fagaceae	*Nothofagus menziesii*	LT/4	0	0	1	1	1	0	0	1/2	1/2	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	1	0
Ericaceae	*Gaultheria colensoi*	LT/5	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	1/2	1/2	0
Compositae	*Cassinia vauvilliersii*	LT/6	0	0	1	1/2	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	1	0
Rubiaceae	*Coprosma foetidissima*	LT/7	0	1	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	1	1	0	0	0	0	1	0	1/2	1/2	0	0	0	1	0
Schrophulariaceae	*Hebe stricta*	LT/8	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	1	0
Rubiaceae	*Coprosma rhamnoides*	LT/9	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	1/2	1/2	0	1	0	0	0	0	1	0
Compositae	*Olearia arborescens*	LT/10	0	1	0	0	0	0	0	1/4	1/4	1/4	1/4	0	0	0	0	1/2	1/2	0	0	1	0	0	1	0	0	0	0	1	0
Myrsinaceae	*Myrsine divaricata*	LT/11	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1	1	0	0	0	1	0	1/2	1/2	0	0	0	0	1	0
Cornaceae	*Griselinia littoralis*	LT/12	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	0	1	1	0	0	0	1	0	0	1/2	1/2	0	0	0	1	0
Compositae	*Olearia ilicifolia*	LT/13	0	0	1	1	0	1	0	0	0	1/2	1/2	0	0	0	0	0	1	0	1/2	1/2	0	0	0	0	0	1	0	1/2	1/2
Compositae	*Olearia rani* *	LT/14	0	0	1/2	1/2	1/2	1/2	0	0	0	1/2	1/2	0	0	0	0	0	1	0	1/2	1/2	0	0	0	1	0	0	0	1	0
Rubiaceae	*Coprosma rigida*	LT/15	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1/2	1/2	0	0	1	0	0	1/2	1/2	0
Epacridaceae	*Leucopogon fasciculatus*	LT/16	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	1/2	1/2	0
	CLAMP SCORE		0.0	62.5	21.9	25.0	18.8	18.8	0.0	44.3	15.1	21.3	16.1	3.1	0.0	0.0	18.8	59.4	40.6	0.0	6.3	71.9	21.9	3.1	37.5	37.5	3.1	18.8	9.4	87.5	3.1

APPENDIX THREE

LINK TRACK 1050-1065m, NORTH ISLAND, NEW ZEALAND

family	species name	specimen number	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	leptol	lepto 2	microl	micro2	micro 3	meso 1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base Cordate	base round	base acute	L:W<1:1	1-2:1	2-3:1	3-4:1	>4:1	shape obovate	shape elliptical	shape ovate
ROSACEAE	*Rubus cissoides*	LT2/1	0	0	1	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0	0	1
ESCALLONIACEAE	*Quintinia acutifolia*	LT2/2	0	1	0	0	0	0	0	0	0	0	1/2	1/2	0	0	1	1/2	1/2	0	0	1	0	0	1/3	1/3	1/3	0	0	1	0
ARALIACEAE	*Pseudopanax colensoi*	LT2/3	0	0	0	1/2	1/2	1/2	1/2	0	0	0	1/2	1/2	0	0	0	0	1	0	0	0	1	0	0	1/2	1/2	0	0	1	0
FAGACEAE	*Nothofagus menziesii**	LT2/4	0	0	1/2	0	1	0	0	1/2	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	1	0
CUNONIACEAE	*Weinmannia racemosa*	LT2/5	0	0	1/2	1/2	1/2	1/2	0	0	1/2	1/2	1/2	0	0	0	0	0	1	0	0	1/2	1/2	0	1/2	1/2	0	0	0	1	0
RUBIACEAE	*Coprosma foetidissima*	LT2/6	0	1	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0	1	0
ARALIACEAE	*Pseudopanax simplex*	LT2/7	0	0	0	1/2	0	1	1/2	0	0	1/2	1/2	0	0	0	0	0	1	0	0	1	0	0	1/2	1/2	0	0	0	1	0
WINTERACEAE	*Pseudowintera colorata*	LT2/8	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	0	1	1	0	0	0	1	0	0	1/2	1/2	0	0	0	1	0
MYRTACEAE	*Neomyrtus pedunculata*	LT2/9	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1/2	1/2	0	1	0	0	0	0	1	0
MYRSINACEAE	*Myrsine divaricata*	LT2/10	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1	1	0	0	0	1/2	1/2	0	1	0	0	0	1/2	1/2	0
ARALIACEAE	*Pseudopanax simplex*	LT2/11	0	0	0	0	1/2	1/2	0	0	1/3	1/3	1/3	0	0	0	0	0	1	0	0	1/2	1/2	0	0	1/2	1/2	0	0	1	0
	unidentified 8sa	LT2/12	0	0	1	0	0	1	0	0	1/3	1/3	1/3	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	1	0
CORNACEAE	*Griselinia littoralis*	LT2/13	0	1	0	0	0	0	0	0	0	0	1/2	1/2	0	0	1	1	0	0	1	0	0	0	1/2	1/2	0	0	0	1	0
RUBIACEAE	*Coprosma parviflora*	LT2/14	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	0	1	0	1/2	1/2	0	0	1/2	1/2	0
	CLAMP SCORES		0.0	50.0	21.4	10.7	17.9	32.1	7.1	20.2	17.8	17.8	26.1	17.9	0.0	0.0	28.6	53.6	46.4	0.0	14.3	50.0	35.7	0.0	41.6	34.5	9.5	14.3	7.1	85.7	7.1

APPENDIX THREE

LINK TRACK 950-1050m, NORTH ISLAND, NEW ZEALAND

family	species name	specimen number	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	lepto1	lepto 2	micro1	micro2	micro 3	meso 1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base Cordate	base round	base acute	L:W<1:1	1-2:1	2-3:1	3-4:1	>4:1	shape obovate	shape elliptical	shape ovate
VIOLACEAE	*Hymenanthera angustifolia*	LT3/1	1/2	1/2	1/4	1/4	1/2	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	1/2	1/2	0	1/4	1/4	1/4	1/4	1/2	1/2	0
RUBIACEAE	*Coprosma foetidissima*	LT3/2	0	1	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	1	1	0	0	0	0	1	0	0	1	0	0	0	1	0
RUBIACEAE	*Coprosma parviflora*	LT3/3	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	0	1	0	1/2	1/2	0	0	1/2	1/2	0
ESCALLONIACEAE	*Quintinia acutifolia*	LT3/4	0	1	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	1/2	1/2	0	1	0	0	1/3	1/3	1/3	0	0	1	0
ROSACEAE	*Rubus parvus*	LT3/5	0	0	0	0	0	1	1/2	0	0	0	1	0	0	0	0	0	1	0	1/2	1/2	0	0	0	0	0	1	0	0	1
RUBIACEAE	*Coprosma grandifolia*	LT3/6	0	1	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	1/2	1/2	0	0	1/2	1/2	0	0	1	0	0	0	1	0
MYRTACEAE	*Neomyrtus pedunculata*	LT3/7	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	1/2	1/2	0	1/2	1/2	0	0	1/2	1/2	0
MYRSINACEAE	*Myrsine salicina*	LT3/8	0	1	0	0	0	0	0	0	0	0	1/2	1/2	0	0	0	1	0	0	0	1	0	0	0	0	0	1	1	0	0
ESCALLONIACEAE	*Carpodetus serratus*	LT3/9	0	1/2	1/4	1/4	0	1/2	1/4	1/3	1/3	1/3	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	1	0
CORNACEAE	*Griselinia lucida*	LT3/10	0	1	0	0	0	0	0	0	0	0	1/2	1/2	0	0	1	1	0	0	0	1	0	0	1/2	1/2	0	0	0	1	0
MYRSINACEAE	*Myrsine divaricata*	LT3/11	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1	1	0	0	0	1/2	1/2	0	1	0	0	0	1/2	1/2	0
RUTACEAE	*Melicope simplex*	LT3/12	0	1/2	0	0	1/2	0	0	1/2	1/2	0	0	0	0	0	1	1	0	0	0	1	0	1/3	1/3	1/3	0	0	0	1	0
WINTERACEAE	*Pseudowintera colorata*	LT3/13	0	1	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	1	0	0	0	1	0	0	0	1/2	1/2	0	0	1	0
CUNONIACEAE	*Weinmannia racemosa*	LT3/14	0	0	1	1	1	0	0	0	0	1/3	1/3	1/3	0	0	0	1/2	1/2	0	0	1	0	0	1/2	1/2	0	0	0	1	0
ARALIACEAE	*Pseudopanax edgerleyi*	LT3/15	0	0	0	1/2	0	1	1/2	0	0	1/3	1/3	1/3	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	1	0
	CLAMP SCORES		3.3	70.0	10.0	13.3	13.3	16.7	8.3	21.1	21.1	15.4	24.3	17.7	0.0	0.0	26.7	66.7	30.0	3.3	3.3	63.3	33.3	2.2	32.7	42.7	7.2	15.0	20.0	73.3	6.7

APPENDIX THREE

LINK TRACK 800-850m, NORTH ISLAND,NEW ZEALAND

family	species name	specimen number	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	leptot	lepto 2	microt	micro2	micro 3	meso 1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base Cordate	base round	base acute	L:W<1:1	1-2:1	2-3:1	3-4:1	>4:1	shape obovate	shape elliptical	shape Ovate
MYRTACEAE	*Metrosideros diffusa*	LT4/1	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1/2	1/2	0	0	1	0	0	1/2	1/2	0	0	0	1	0
MYRTACEAE	*Neomyrtus pedunculata*	LT4/2	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1/2	1/2	0	0	0	1	0	1/3	1/3	1/3	0	0	1	0
ARALIACEAE	*Pseudopanax crassifolius*	LT4/3	0	0	1/2	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	1/2	1/2	0	0	1	0	0	0	0	1	1/2	1/2	0
ARALIACEAE	*Beilschmiedia tawa* *	LT4/4	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1/2	1/2	0	0	1	0	0	0	0	1	0	1	0
VIOLACEAE	*Hymenanthera alpina*	LT4/5	0	0	0	1/2	1	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	0	1	0	1/4	1/4	1/4	1/4	1/2	1/2	0
APOCYNACEAE	*Parsonsia capsularis* *	LT4/6	0	1/2	0	0	1/2	0	0	0	0	1/2	1/2	0	0	0	0	0	1	0	0	1/2	1/2	0	0	0	0	1	0	1	0
RUBIACEAE	*Coprosma grandifolia*	LT4/7	0	1	0	0	0	0	0	0	0	0	0	0	1/2	1/2	0	0	1/2	1/2	0	1	0	0	1/2	1/2	0	0	0	1	0
COMPOSITAE	*Brachyglottis repanda*	LT4/8	0	0	0	1/2	1	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	1	0	0	0	0	1	0
ARALIACEAE	*Pseudopanax edgerleyi*	LT4/9+25	1/2	1/2	0	0	1/2	0	0	0	0	0	1/3	1/3	1/3	0	1	1/3	1/3	1/3	0	1/2	1/2	0	0	1/2	1/2	0	0	1	0
ESCALLONIACEAE	*Quintinia acutifolia*	LT4/10	0	1/2	0	0	1/2	0	0	0	0	1/3	1/3	1/3	0	0	0	1/3	1/3	1/3	0	1/2	1/2	0	1/3	1/3	1/3	0	0	1	0
CUNONIACEAE	*Weinmannia racemosa*	LT4/11	0	0	1	1/2	1/2	1/2	1/2	0	1/4	1/4	1/4	1/4	0	0	0	0	1	0	0	1/2	1/2	0	1/3	1/3	1/3	0	0	1/2	1/2
ONAGRACEAE	*Fuchsia excorticata*	LT4/12	0	0	0	0	1	0	0	0	0	1/3	1/3	1/3	0	0	0	0	1/2	1/2	0	1	0	0	1/2	1/2	0	0	0	1	0
ARALIACEAE	*Pseudopanax linearis*	LT4/13	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	1	0
ROSACEAE	*Rubus cissoides*	LT4/14	0	0	0	0	1/2	1/2	0	0	0	0	0	1/2	1/2	0	0	0	1	0	1	0	0	0	0	1/2	1/2	0	0	0	1
ESCALLONIACEAE	*Carpodetus serratus*	LT4/15	0	1/2	0	1/4	1/4	1/4	0	0	1/2	1/2	0	0	0	0	0	1/2	1/2	0	0	1	0	0	1	0	0	0	0	1	0
ARALIACEAE	*Scheffiera digitata*	LT4/16	0	0	1	1/2	0	1	0	0	0	0	1/4	1/4	1/4	1/4	0	0	1/2	1/2	0	1	0	0	0	1/2	1/2	0	1/2	1/2	0
ELAEOCARPACEAE	*Aristotelia serrata*	LT4/17	0	0	1	1	0	1	1	0	0	1/3	1/3	1/3	0	0	0	0	1/2	1/2	1/2	1/2	0	0	1/2	1/2	0	0	0	1/2	1/2
WINTERACEAE	*Pseudowintera colorata*	LT4/18	0	1	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	1	0	0	0	1	0	0	1/3	1/3	1/3	0	0	1	0
RUBIACEAE	*Coprosma rigida*	LT4/19	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	0	1	0	1/3	1/3	1/3	0	1/2	1/2	0
RUBIACEAE	*Coprosma parviflora*	LT4/20	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	0	1	0	1/2	1/2	0	0	1/2	1/2	0
RUBIACEAE	*Coprosma foetidissima*	LT4/21	0	1	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	1	1	0	0	0	0	1	0	0	1	0	0	0	1	0
MYRSINACEAE	*Myrsine salicina*	LT4/22	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	1	0
PITTOSPORACEAE	*Pittosporum tenuifolium*	LT4/23	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	1	0	0	0	1	0	0	0	1	0
CORNACEAE	*Griselinia littoralis*	LT4/24	0	1	0	0	0	0	0	0	0	0	1/3	1/3	1/3	0	1	1	0	0	0	1	0	0	1/2	1/2	0	0	0	1	0
RUBIACEAE	*Coprosma robusta*	LT4/26	0	1	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	1/2	1/2	0	0	0	1	0	0	1/2	1/2	0	0	1	0
	CLAMP SCORES		2.0	56.0	14.0	13.0	31.0	13.0	6.0	11.3	14.3	14.9	25.2	19.2	7.6	7.0	12.0	38.6	46.6	14.6	10.0	42.0	48.0	0.0	27.6	35.6	15.6	21.0	10.0	82.0	8.0

APPENDIX THREE

OKARITO GLACIAL MORAINE, SOUTH ISLAND, NEW ZEALAND

family	species name	specimen number	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	lepto1	lepto 2	micro1	micro2	micro 3	meso 1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base Cordate	base round	base acute	L:W<1:1	1-2:1	2-3:1	3-4:1	>4:1	shape obovate	shape elliptical	shape ovate
ARALIACEAE	*Pseudopanax crassifolius*	OKG/9	0	0	1/2	0	0	1	0	0	0	0	1/2	1/2	0	0	0	0	1/2	1/2	0	1/2	1/2	0	0	0	1/2	1/2	0	1	0
CORNACEAE	*Griselinia littoralis*	OKG/4	0	1	0	0	0	0	0	0	0	0	1/4	1/4	1/4	1/4	0	1	0	0	0	1	0	0	1/2	1/2	0	0	0	1	0
CUNONIACEAE	*Weinmannia racemosa*	OKG/15	0	0	1	1	1/2	1/2	0	0	0	1/2	1/2	0	0	0	0	1/2	1/2	0	0	1	0	0	1/2	1/2	0	0	0	1	0
ESCALLONIACEAE	*Quintinia acutifolia*	OKG/3	0	1/2	0	0	1/2	0	0	0	0	0	1/2	1/2	0	0	1	1/2	0	1/2	0	1/2	1/2	0	0	1	0	0	1	0	0
MONIMIACEAE	*Hedycarya arborea*	OKG/2	0	0	0	0	1	0	0	0	0	0	1/2	1/2	0	0	1	1/2	1/2	0	0	1/2	1/2	0	0	1	0	0	0	1	0
MYRSINIACEAE	*Myrsine australis*	OKG/14	0	1	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	1	1	0	0	0	1/2	1/2	0	1/2	1/2	0	0	0	1	0
MYRTACEAE	*Metrosideros umbellata*	OKG/1	0	1	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	0	1/2	1/2	0	1/2	1/2	0	0	0	1	0	0	1	0
MYRTACEAE	*Neomyrtus pedunculata*	OKG/8	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1	1	0	0	0	1	0	0	1/2	1/2	0	0	1/3	1/3	1/3
MYRTACEAE	*Metrosideros parkinsonii*	OKG/16	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	0	0	1	0	0	0	1	0	0	1/2	1/2	0	0	0	1	0
RUBIACEAE	*Coprosma lucida*	OKG/5	0	1	0	0	0	0	0	0	0	1/4	1/4	1/4	1/4	0	0	1/3	1/3	1/3	0	1/2	1/2	0	0	1	0	0	1/2	1/2	0
RUBIACEAE	*Coprosma parviflora*	OKG/10	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1/2	1/2	0	0	1/2	1/2	0
RUBIACEAE	*Coprosma diffusa*	OKG/12	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	1	0	0	1/2	1/2	0	0	0	1	0
RUBIACEAE	*Coprosma foetidissima*	OKG/13	0	1	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0	1	0
VIOLACEAE	*Hymenanthera angustifolia*	OKG/11	1/2	1/2	0	0	1/2	0	0	1/2	1/2	0	0	0	0	0	0	1	1	0	0	0	0	1	0	1/4	1/4	1/4	1/4	1/2	1/2	0
		OKG/7	0	1/2	0	0	0	1/2	0	0	1/4	1/4	1/4	1/4	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	1	0
	CLAMP SCORE		3.1	65.6	9.4	6.3	15.6	12.5	0.0	15.6	17.1	15.6	26.5	14.1	3.1	1.6	31.3	61.4	20.8	11.4	0.0	50.0	43.8	0.0	23.4	48.4	10.9	10.9	17.7	73.9	2.1

APPENDIX THREE

OKARITO RIVER TERRACE, SOUTH ISLAND, NEW ZEALAND

family	species name	specimen number	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	lepto1	lepto 2	micro1	micro2	micro 3	meso 1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base Cordate	base round	base acute	L:W<1:1	1-2:1	2-3:1	3-4:1	>4:1	shape obovate	shape elliptical	shape ovate
VIOLACEAE	*Hymenanthera angustifolia*	OKT/1	1/2	1/2	1/4	1/4	1/2	0	0	1/2	1/2	0	0	0	0	0	1	1	0	0	0	0	1	0	1/4	1/4	1/4	1/4	1/2	1/2	0
MYRTACEAE	*Metrosideros diffusa*	OKT/2	0	1	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	0	1/2	1/2	0	0	1	0	0	1/3	1/3	1/3	0	0	0	1
RUBIACEAE	*Coprosma foetidissima*	OKT/3	0	1	0	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1	0	0	0	1/2	1/2	0	1/2	1/2	0	0	0	1	0
RUBIACEAE	*Coprosma propinqua*	OKT/4	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1/2	1/2	0	0	1	0
MYRSINACEAE	*Myrsine divaricata*	OKT/5	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1	1	0	0	0	0	1	0	1	0	0	0	1/2	1/2	0
MYRTACEAE	*Neomyrtus pedunculata*	OKT/6	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	1/2	1/2	0	1	0	0	0	0	1	0
MYRTACEAE	*Metrosideros parkinsonii*	OKT/7	0	1	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	0	1	0	0	0	0	1	0	1	0	0	0	0	1	0
CUNONIACEAE	*Weinmannia racemosa*	OKT/8	0	0	1	1/2	1/2	1/2	0	0	0	1/2	1/2	0	0	0	0	1/3	1/3	1/3	0	1/2	1/2	0	1/2	1/2	0	0	0	1	0
MYRTACEAE	*Metrosideros umbellata*	OKT/9	0	1	0	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	1	0
MYRSINACEAE	*Myrsine australis*	OKT/10	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	0	1	1	0	0	0	1	0	0	1/2	1/2	0	0	0	1	0
ROSACEAE	*Rubus cissoides*	OKT/11	0	0	1	1	0	1	1/2	0	0	0	1/2	1/2	0	0	0	0	0	1	1/2	1/2	0	0	0	1/2	1/2	0	0	0	1
ROSACEAE	*Rubus australis*	OKT/12	0	0	1	1	0	1	1/2	0	0	1/2	1/2	0	0	0	0	0	1	0	1/2	1/2	0	0	1	0	0	0	0	1	0
ARALIACEAE	*Pseudopanax crassifolius*	OKT/13	0	0	1/2	0	0	1	0	0	0	0	1/2	1/2	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	1	0
WINTERACEAE	*Pseudowintera colorata*	OKT/15	0	1	0	0	0	0	0	0	0	0	1/2	1/2	0	0	1	1	0	0	0	1	0	0	1/2	1/2	0	0	0	1	0
CORNACEAE	*Griselinia littoralis*	OKT/16	0	1	0	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	1	0	0	0	1	0	1/2	1/2	0	0	0	0	1	0
ESCALLONIACEAE	*Quintinia acutifolia*	OKT/17	0	1	0	0	0	0	0	0	0	0	1/2	1/2	0	0	1	0	1/2	1/2	0	0	1	0	0	1/2	1/2	0	1/2	1/2	0
	CLAMP SCORE		3.1	71.9	23.4	17.2	6.3	21.9	6.3	19.8	19.8	19.8	23.9	14.6	2.1	0.0	31.3	61.4	27.1	11.4	6.3	53.1	40.6	3.1	44.3	25.5	13.0	14.1	9.4	78.1	12.5

APPENDIX THREE

OTIRA GORGE 940-950m, SOUTH ISLAND, NEW ZEALAND

family	species name	specimen number	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	lepto1	lepto 2	micro1	micro2	micro 3	meso 1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base Cordate	base round	base acute	L:W<1:1	1-2:1	2-3:1	3-4:1	>4:1	shape obovate	shape elliptical	shape ovate
ARALIACEAE	*Pseudopanax simplex*	OG1/8	0	0	0	1/2	1/2	1/2	1/2	0	1/3	1/3	1/3	0	0	0	0	0	1	0	0	1/2	1/2	0	0	1	0	0	0	1	0
ARALIACEAE	*Pseudopanax colensoi*	OG1/6	0	0	0	1/2	1/2	1/2	1/2	0	0	1/3	1/3	1/3	0	0	0	1/2	1/2	0	0	1/2	1/2	0	1/2	1/2	0	0	0	1	0
COMPOSITAE	*Brachyglottis buchananii* *	OG1/7	0	1	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	1	0	0	0	1	0	0	1/2	1/2	0	0	1/2	1/2	0
COMPOSITAE	*Brachyglottis elaeagnifolia* *	OG1/19	0	1	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	1	0	0	0	1	0	0	1/2	1/2	0	0	0	1	0
COMPOSITAE	*Olearia avicenniaefolia* *	OG1/1	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	0	0	1/2	1/2	0	0	1	0	0	0	1	0	0	0	1	0
COMPOSITAE	*Olearia colensoi* *	OG1/4	0	0	1	1	0	1	1	0	1/3	1/3	1/3	0	0	0	0	1/2	1/2	0	0	0	1	0	0	1	0	0	0	1	0
COMPOSITAE	*Olearia ilicifolia*	OG1/14	0	0	0	1	0	1	1/2	0	0	1/2	1/2	0	0	0	0	0	1	0	1/2	1/2	0	0	0	0	0	1	0	0	1
COMPOSITAE	*Olearia nummularifolia*	OG1/13	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	1	0
COMPOSITAE	*Olearia arborescens*	OG1/2	0	1/2	0	0	1/2	0	0	0	0	1/2	1/2	0	0	0	0	1/3	1/3	1/3	0	1	0	0	1/2	1/2	0	0	0	1	0
ERICACEAE	*Gaultheria crassa*	OG1/9	0	0	1	1	1	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0
RUBIACEAE	*Coprosma acerosa*	OG1/11	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	0	1	0	0	0	0	1	1	0	0
RUBIACEAE	*Coprosma cuneata*	OG1/5	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0	1/2	1/2	0	0	1/2	1/2
RUBIACEAE	*Coprosma parviflora*	OG1/10	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1/2	1/2	0	0	0	1	0
RUBIACEAE	*Coprosma pseudocuneata*	OG1/17	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1/2	1/2	0	1	0
RUBIACEAE	*Coprosma serrulata*	OG1/3	0	0	1	1	1	0	0	0	1/3	1/3	1/3	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	1	0
SCROPHULARIACEAE	*Hebe odora*	OG1/18	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	1	0	0	1/2	1/2	0	0	0	1	0
SCROPHULARIACEAE	*Hebe subalpina*	OG1/16	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1/2	1/2	0	0	1	0	0	0	1	0	0	0	1	0
SCROPHULARIACEAE	*Cassinia vauvilliersii*	OG1/15	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1/2	1/2	0	0	1	0	0	0	1	0
	CLAMP SCORE		0.0	63.9	16.7	27.8	19.4	16.7	13.9	36.1	23.1	19.3	19.3	1.8	0.0	0.0	5.6	71.3	26.8	1.8	2.8	66.7	30.6	0.0	27.8	52.8	5.6	13.9	8.3	83.3	8.3

APPENDIX THREE

OTIRA GORGE 840m, WESTLAND, SOUTH ISLAND, NEW ZEALAND

family	species name	specimen number	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	lepto1	lepto 2	micro1	micro2	micro 3	meso 1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base Cordate	base round	base acute	L:W<1:1	1-2:1	2-3:1	3-4:1	>4:1	shape obovate	shape elliptical	shape ovate
VIOLACEAE	*Hymenanthera angusstifolia*	OG2/1	0	0	0	0	1	0	0	1/2	1/2	0	0	0	0	0	0	1/2	1/2	0	0	0	1	0	1/2	1/2	0	0	0	1	0
VIOLACEAE	*Hymenanthera alpina* *	OG2/2	0	1/2	0	1/2	1/2	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	1	0	1/4	1/4	1/4	1/4	0	0	1	0
RUBIACEAE	*Coprosma parvflos*	OG2/3	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	0	1	0	1	0	0	0	0	1	0
RUBIACEAE	*Coprosma tenuicaulis*	OG2/4	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1/2	1/2	0	0	1	0	0	1/2	1/2	0
RUBIACEAE	*Coprosma foetidissima*	OG2/5	0	1	0	0	0	0	0	0	1/2	1/2	0	0	0	0	1	1	0	0	0	0	1	0	1/2	1/2	0	0	0	1	0
ARALIACEAE	*Pseudopanax crassifolius* *	OG2/6	0	0	0	0	1	0	0	0	0	1/2	1/2	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	1	0
ARALIACEAE	*Pseudopanax simplex*	OG2/7	0	0	0	1/2	1/2	1/2	0	0	1/3	1/3	1/3	0	0	0	0	0	1	0	0	1/2	1/2	0	0	1	0	0	0	1	0
COMPOSITAE	*Olearia avicenniaefolia*	OG2/8	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1	0	0	1/2	1/2	0	0	1	0	0	0	1	0
RUBIACEAE	*Coprosma acerosa*	OG2/9	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	1	0
CORNACEAE	*Griselinia littoralis*	OG2/10	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0	1/2	1/2	0	0	0	1	0
MYRTACEAE	*Leptospermum scoparium* *	OG2/11	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	1	0	0	0	0	0	1	0	1	0
ARALIACEAE	*not identified 8z*	OG2/12	0	0	0	0	1	0	1/2	0	0	1/2	1/2	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	1	0
RUBIACEAE	*Coprosma linarifolia* *	OG2/13	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1/2	1/2	0	0	1	0	0	0	0	1/2	1/2	0	1	0
COMPOSITAE	*Olearia arborescens*	OG2/14	0	0	0	0	1	0	0	0	1/3	1/3	1/3	0	0	0	0	0	1	0	0	1	0	0	1/2	1/2	0	0	0	1	0
COMPOSITAE	*Brachyglottis elaeagnifolia*	OG2/15	0	1	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	1	0	0	0	1/2	1/2	0	1/2	1/2	0	0	0	1	0
ARALIACEAE	*Pseudopanax colensoi*	OG2/17	0	0	0	1	0	1	1/2	0	0	0	1/3	1/3	1/3	0	0	1/2	1/2	0	0	1	0	0	1	0	0	0	0	1	0
SCROPHULARIACEAE	*Hebe sp. D (8m)*	OG2/19	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1/2	1/2	0	0	1	0	0	0	0	1/2	1/2	1/2	1/2	0
RUBIACEAE	*Coprosma serrulata*	OG2/20	0	0	0	1	1	0	0	0	1/3	1/3	1/3	0	0	0	0	1	0	0	0	0	1	0	1/2	1/2	0	0	0	1	0
SCROPHULARIACEAE	*Hebe salicifolia*	OG2/21	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	1/2	1/2	0	1/2	1/2	0	0	0	0	1	0	1	0
SCROPHULARIACEAE	*Hebe subalpina**	OG2/22	0	1	0	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1/2	1/2	0	0	1	0	0	0	0	0	1	0	1	0
ERICACEAE	*Gaultheria crassa*	OG2/23	0	0	1	1/2	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	1	0	0	1/2	1/2	0	0	0	1	0
EPACRIDACEAE	*Archeria traversii* *	OG2/24	1	1/2	0	0	0	1/2	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	0	1	0	1/2	1/2	0	0	0	1	0
MYRSINACEAE	*Myrsine divaricata*	OG2/25	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1	1	0	0	0	1/2	1/2	1/2	1/2	0	0	0	0	1	0
COMPOSITAE	*Olearia ilicifolia*	OG2/26	0	0	1	1	0	1	1/2	0	0	1/2	1/2	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	1/2	1/2
	CLAMP SCORE		4.2	54.2	8.3	18.8	29.2	16.7	6.3	25.0	29.1	18.0	23.5	2.8	1.4	0.0	8.3	54.2	43.8	2.1	0.0	62.5	37.5	3.1	28.1	30.2	9.4	29.2	4.2	93.8	2.1

APPENDIX THREE

OTIRA GORGE 700m, WESTLAND, SOUTH ISLAND, NEW ZEALAND

family	species name	specimen number	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	lepto1	lepto 2	micro1	micro2	micro 3	meso 1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base Cordate	base round	base acute	L:W<1:1	1-2:1	2-3:1	3-4:1	>4:1	shape obovate	shape elliptical	shape ovate
VIOLACEAE	*Hymenanthera angustifolia*	OG/19	1/2	1/2	0	1/4	1/2	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	1	0	0	1/3	1/3	1/3	0	0	1	0
EPACRIDACEAE	*Archeria traversia*	OG/1	1	1/2	0	0	1/4	1/4	0	0	1/3	1/3	1/3	0	0	0	0	1/2	1/2	0	0	0	1	0	0	1	0	0	0	0	0	1
ELAEOCARPACEAE	*Aristotelia serrata*	OG/8	0	0	1	1	0	1	0	0	0	1/4	1/4	1/4	1/4	0	0	0	1/2	1/2	1	0	0	0	1	0	0	0	0	1	0
RUBIACEAE	*Coprosma foetidisima*	OG/15	0	1	0	0	0	0	0	0	1/2	1/2	0	0	0	0	1	1	0	0	0	0	1	0	1/2	1/2	0	0	0	1	0
RUBIACEAE	*Coprosma linariifolia*	OG/9	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	1/2	1/2	0	0	1/3	1/3	1/3	0	1/2	1/2
RUBIACEAE	*Coprosma rigida*	OG/16	0	1	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	1	1/2	1/2	0	0	1/2	1/2	0	1/2	1/2	0	0	1/2	1/2	0
RUBIACEAE	*Coprosma rigida*	OG/4	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	1/2	1/2	0	1/2	1/2	0	0	0	1	0
RUBIACEAE	*Coprosma lucida*	OG/5	0	1	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	1/2	1/2	0	0	0	1	0	0	1	0	0	1/2	1/2	0
CORNACEAE	*Griselinia littoralis*	OG/11	0	1	0	0	0	0	0	0	0	0	1/3	1/3	1/3	0	1	1	0	0	0	1	0	0	1	0	0	0	0	1	0
MYRSINACEAE	*Leptospermum scoparium*	OG/10	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	0	1
MYRTACEAE	*Metrosideros umbellata*	OG/13	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1/2	1/2	0	1/2	1/2	0	0	1/2	1/2	0	0	1	0
MYRSINACEAE	*Myrsine divaricata*	OG/3	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1	1	0	0	0	1/2	1/2	1/2	1/2	0	0	0	1/2	1/2	0
COMPOSITAE	*Olearia arborescens*	OG/2	0	0	0	0	1	0	0	0	1/4	1/4	1/4	1/4	0	0	0	0	0	1	0	1/2	1/2	0	1	0	0	0	0	1	0
	unidentified (6z)	OG/12	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1/2	1/2	0	0	1	0	0	0	0	1/2	1/2	0	1	0
ARALIACEAE	*Pseudopanax colensoi*	OG/17	0	0	0	1/2	1/2	1/2	1/2	0	1/3	1/3	1/3	0	0	0	0	0	1	0	0	1/2	1/2	0	0	1/2	1/2	0	0	1	0
ARALIACEAE	*Pseudopanax linnearis*	OG/18	0	0	1/2	0	1	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	1	0
ARALIACEAE	*Pseudopanax simplex*	OG/20	0	0	0	0	1/2	1/2	0	0	0	1/4	1/4	1/4	1/4	0	1	0	1	0	0	1/2	1/2	0	0	1	0	0	0	1	0
WINTERACEAE	*Pseudowintera colerata*	OG/6	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0	1/2	1/2	0	0	0	1	0
ROSACEAE	*Rubus schmideloides*	OG/7	0	0	1/2	1/2	0	1	1/2	0	0	0	1/2	1/2	0	0	0	0	0	1	1/2	1/2	0	0	0	1	0	0	0	1/2	1/2
CUNONIACEAE	*Weinmannia racemosa*	OG/14	0	0	1	1/2	1	0	0	0	1/3	1/3	1/3	0	0	0	0	1/2	1/2	0	0	1/2	1/2	0	1/3	1/3	1/3	0	0	1/2	1/2
	CLAMP SCORE		7.5	55.0	15.0	13.8	28.8	16.3	5.0	16.7	20.4	17.0	27.0	14.6	4.2	0.0	25.0	52.5	32.5	15.0	7.5	50.0	42.5	2.5	30.8	40.0	12.5	14.2	7.5	75.0	17.5

APPENDIX THREE

OTIRA GORGE 550m, WESTLAND, SOUTH ISLAND, NEW ZEALAND

family	species name	specimen number	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	lepto1	lepto 2	micro1	micro2	micro 3	meso 1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base Cordate	base round	base acute	L:W<1:1	1-2:1	2-3:1	3-4:1	>4:1	shape obovate	shape elliptical	shape ovate
ARALIACEAE	*Schefflera digitata*	OG4/16	0	0	1	1/2	0	1	0	0	0	1/4	1/4	1/4	1/4	0	0	0	0	1	0	0	1	0	1/2	1/2	0	0	0	1	0
CONVOLVULACEAE	*Calystegia tuguriorum*	OG4/15	0	1	0	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0	1
CORNACEAE	*Griselinia littoralis*	OG4/13	0	1	0	0	0	0	0	0	0	1/4	1/4	1/4	1/4	0	1	1	0	0	0	1	0	0	1	0	0	0	0	1	0
CUNONIACEAE	*Weinmannia racemosa*	OG4/11	0	0	1	1	1	0	0	1/5	1/5	1/5	1/5	1/5	0	0	0	1/2	1/2	0	0	1/2	1/2	0	1/2	1/2	0	0	0	1	0
ELAEOCARPACEAE	*Aristotelia serrata*	OG4/1	0	0	0	1	0	1	1	0	0	1/5	1/5	1/5	1/5	1/5	0	0	1/2	1/2	1/2	1/2	0	0	1/2	1/2	0	0	0	1/2	1/2
ESCALLONIACEAE	*Quintinia acutifolia*	OG4/3	0	0	0	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	1/2	1/2	0	1/2	1/2	0	0	1/2	1/2	0	1/2	1/2	0
ESCALLONIACEAE	*Carpodetus serratus*	OG4/10	0	1	0	1/2	0	0	0	0	0	1/3	1/3	1/3	0	0	0	1/2	1/2	0	0	1	0	0	1/2	1/2	0	0	0	1	0
ICACINACEAE	*Pennantia corymbosa*	OG4/8	0	1/2	0	1/4	1/2	0	0	1/3	1/3	1/3	0	0	0	0	0	1	0	0	0	0	1	0	1	0	0	0	1/2	1/2	0
MYRTACEAE	*Metrosideros diffusa*	OG4/6	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1/2	1/2	0	0	0	1	0
MYRTACEAE	*Metrosideros umbellata*	OG4/17	0	1	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	0	0	1	0	0	1	0	0	0	1/2	1/2	0	0	1	0
ONAGRACEAE	*Fuchsia excorticata*	OG4/12	0	0	0	0	1	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1/2	1/2	0	1	0	0	1/2	1/2	0	0	0	1	0
PITTOSPORACEAE	*Pittosporum eugenioides*	OG4/9	0	1	0	0	0	0	0	0	0	0	1/2	1/2	0	0	0	0	1	0	0	1	0	0	0	1/2	1/2	0	0	1	0
ROSACEAE	*Rubus schmideliioides*	OG4/4	0	0	1/2	1	0	1	0	0	0	0	1/2	1/2	0	0	0	0	0	1	1/2	1/2	0	0	1/2	1/2	0	0	1/2	1/2	0
RUBIACEAE	*Coprosma sp. A*	OG4/2	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	1/2	1/2	0	1/3	1/3	1/3	0	0	1	0
RUBIACEAE	*Coprosma foetidissima*	OG4/5	0	1	0	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1/2	1/2	0	0	0	1	0	0	1/2	1/2	0	0	1	0
RUBIACEAE	*Coprosma parviflora*	OG4/7	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	0	1	0	1	0	0	0	0	1	0
VIOLACEAE	*Melicytus ramiflorus*	OG4/14	0	0	1	0	1	0	0	0	0	0	1/4	1/4	1/4	1/4	0	0	1/2	1/2	0	1	0	0	1/2	1/2	0	0	0	1	0
WINTERACEAE	*Pseudowintera colorata*	OG4/18	0	1	0	0	0	0	0	0	0	0	1/2	1/2	0	0	1	1	0	0	0	1	0	0	1/2	1/2	0	0	0	1	0
	CLAMP SCORE		0.0	58.3	19.4	23.6	25.0	16.7	5.6	15.9	15.9	18.8	22.1	19.3	5.3	2.5	11.1	36.1	41.7	22.2	11.1	58.3	30.6	0.0	49.1	37.9	12.9	0.0	8.3	83.3	8.3

APPENDIX THREE

OTIRA GORGE 400, WESTLAND, SOUTH ISLAND, NEW ZEALAND

family	species name	specimen number	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	lepto1	lepto 2	micro1	micro2	micro 3	meso 1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base Cordate	base round	base acute	L:W<1:1	1-2:1	2-3:1	3-4:1	>4:1	shape obovate	shape elipical	shape ovate
ARALIACEAE	*Schefflera digitata*	OG5/12	0	0	1	1/2	0	1	0	0	0	1/4	1/4	1/4	1/4	0	0	0	0	1	0	0	1	0	0	1	0	0	0	1/2	1/2
ARALIACEAE	*Pseudopanax crassifolius*	OG5/22	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	1	0
ARALIACEAE	*Pseudopanax simplex*	OG5/31	0	0	0	1/2	0	1	1/2	1/6	1/6	1/6	1/6	1/6	1/6	0	0	0	1	0	0	0	1	0	1/3	1/3	1/3	0	0	1	0
COMPOSITAE	*Olearia avicenniaefolia*	OG5/24	0	1	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	1/2	1/2	0	0	1	0	0	0	1/2	1/2	0	0	1	0
CORNACEAE	*Griselinia littoralis*	OG5/20	0	1	0	0	0	0	0	0	0	1/4	1/4	1/4	1/4	0	1	1	0	0	1/2	1/2	0	0	1	0	0	0	0	1	0
CUNONIACEAE	*Weinmannia racemosa*	OG5/11	0	0	1	1	1/2	1/2	1/2	1/5	1/5	1/5	1/5	1/5	0	0	0	0	1	0	0	1/2	1/2	0	1/2	1/2	0	0	0	1	0
ELAEOCARPACEAE	*Aristotelia serrata*	OT6/14	0	0	1/2	1	1/2	1/2	1/2	0	0	1/5	1/5	1/5	1/5	1/5	0	0	1/2	1/2	1/2	1/2	0	0	1/2	1/2	0	0	0	1/2	1/2
ELAEOCARPACEAE	*Aristotelia serrata*	OG5/27	0	0	0	1	1/2	1/2	1/2	0	0	1/3	1/3	1/3	0	0	0	0	1	0	0	1	0	0	1/2	1/2	0	0	0	1	0
ESCALLONIACEAE	*Coprosma areolata*	OG5/4	0	1	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	1	0
ESCALLONIACEAE	*Carpodetus serratus*	OG5/1	0	0	0	1	1/2	1/2	0	0	1/3	1/3	1/3	0	0	0	0	0	1	0	0	1	0	0	1/2	1/2	0	0	0	1	0
ESCALLONIACEAE	*Quintinia acutifolia*	OG5/25	0	1/2	0	0	1/2	0	0	0	0	1/3	1/3	1/3	0	0	0	0	1/2	1/2	0	0	1	0	0	1/2	1/2	0	1/2	1/2	0
ICACINACEAE	*Pennantia corymbosa*	OG5/6	0	1/2	1/4	1/2	1/2	0	0	1/3	1/3	1/3	0	0	0	0	0	1	0	0	0	0	1	0	1	0	0	0	1/2	1/2	0
MALVACEAE	*Hoheria lyallii*	OTG5/19	0	0	1/2	1	1	0	1	0	0	1/3	1/3	1/3	0	0	0	1/2	1/2	0	1	0	0	0	1	0	0	0	0	0	1
MYRSINACEAE	*Myrsine divaricata*	OG5/5	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1	1	0	0	0	1/2	1/2	1/2	1/2	0	0	0	1/2	1/2	0
MYRTACEAE	*Neomyrtus pedunculata*	OT5/7	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	1	0
MYRTACEAE	*Leptospermum scoparium*	OG5/9	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	1	0
MYRTACEAE	*Metrosideros diffusa*	OG5/16	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1/2	1/2	0	0	1	0	0	1/3	1/3	1/3	0	0	1/2	1/2
MYRTACEAE	*Metrosideros umbellata*	G5/18	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1/2	1/2	0	0	1	0	0	0	1/2	1/2	0	1	0
ONAGRACEAE	*Fuchsia excorticata*	OG5/2	0	0	0	0	1	0	0	1/4	1/4	1/4	1/4	0	0	0	0	0	1/2	1/2	0	1	0	0	1/2	1/2	0	0	0	1	0
PITTOSPORACEAE	*Pittosporum eugenioides*	OG5/15	0	1	0	0	0	0	0	0	0	0	1/2	1/2	0	0	0	1/2	1/2	0	0	1	0	0	1/2	1/2	0	0	0	1	0
ROSACEAE	*Rubus schmideloides* *	OG5/23	0	0	0	1/2	1/2	1/2	0	0	0	1/2	1/2	0	0	0	0	1/2	1/2	0	1/2	1/2	0	0	0	1	0	0	0	1/2	1/2
ROSACEAE	*Rubus parvus* *	OG5/30	0	0	1/2	1/2	0	1	1/2	1/3	1/3	1/3	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0	0	1
RUBIACEAE	*Coprosma linariifolia*	OG5/3	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1/2	1/2	0	0	0	1	0	0	0	1/2	1/2	0	1	0
RUBIACEAE	*Coprosma propinqua*	OG5/10	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1/2	1/2	0	0	0	1	0	0	1	0	0	0	1	0
RUBIACEAE	*Coprosma foetidissima*	OG5/17	0	0	0	0	1	0	0	0	1/3	1/3	1/3	0	0	0	0	1	0	0	0	0	1	0	1/3	1/3	1/3	0	0	1	0
RUBIACEAE	*Coprosma lucida*	OG5/26	0	1	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	1/3	1/3	1/3	0	0	1	0	0	1/2	1/2	0	1/2	1/2	0

APPENDIX THREE

family	species name	specimen number	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	lepto1	lepto 2	micro1	micro2	micro 3	meso 1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base Cordate	base round	base acute	L:W<1:1	1-2:1	2-3:1	3-4:1	>4:1	shape obovate	shape elliptical	shape ovate
RUBIACEAE	*Coprosma parviflora*	OG5/28	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1/2	1/2	0	0	1	0	0	1/2	1/2	0
SCROPHULARIACEAE	*Hebe salicifolia*	OG5/29	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1	1/2	1/2	0
VIOLACEAE	*Melicytus ramiflorus*	OG5/13	0	0	1/2	1/2	1	0	0	0	0	0	1/3	1/3	1/3	0	0	1/2	0	1/2	0	1/2	1/2	0	1/3	1/3	1/3	0	0	1	0
WINTERACEAE	*Pseudowintera colorata*	OG5/21	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0	1	0	1/2	1/2	0	0	0	0	1	0
	CLAMP SCORE		0.0	48.4	13.7	25.8	27.4	21.0	11.3	19.7	16.4	18.1	24.1	13.6	3.9	0.6	9.7	39.8	41.4	15.6	11.3	40.3	45.2	3.2	33.3	31.7	12.3	16.1	9.7	74.2	12.9

APPENDIX THREE

OTIRA GORGE 120-160, WESTLAND, SOUTH ISLAND, NEW ZEALAND

family	species name	specimen number	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	lepto1	lepto 2	micro1	micro2	micro 3	meso 1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base Cordate	base round	base acute	L:W<1:1	1-2:1	2-3:1	3-4:1	>4:1	shape obovate	shape elliptical	shape ovate
ARALIACAEA	*Pseudopanax simplex*	OG6/8	0	0	0	0	0	1	1/2	0	1/4	1/4	1/4	1/4	0	0	0	1/2	1/2	0	0	1	0	0	1/2	1/2	0	0	0	1	0
ARALIACAEA	*Pseudopanax crassifolius*	OG6/16	0	0	1/2	0	0	1	0	0	0	0	0	0	1/2	1/2	0	0	1	0	0	0	1	0	0	0	0	1	0	1	0
CUNONIACEAE	*Weinmannia racemosa*	OG6/11	0	0	1	1/2	1/2	1/2	1/2	0	1/3	1/3	1/3	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	1	0
ELAEOCARPACEAE	*Elaeocarpus dentatus*	OG6/10	0	0	1/2	1/2	1	0	1/2	0	0	0	1/2	1/2	0	0	0	0	1/2	1/2	0	1	0	0	0	0	0	1	0	1	0
ELAEOCARPACEAE	*Aristotelia serrata*	OG6/15	0	0	1	1	0	1	1	0	0	1/4	1/4	1/4	1/4	0	0	0	1/2	1/2	1	0	0	0	1	0	0	0	0	1/2	1/2
ESCALLONIACEAE	*Quintinia acutifolia*	OG6/2	0	0	0	0	1	0	0	0	0	0	1/2	1/2	0	0	0	1/2	1/2	0	0	0	1	0	0	1	0	0	1/2	1/2	0
ESCALLONIACEAE	*Carpodetus serratus*	OG6/12+13	0	1/2	1/4	1/4	1/4	1/4	0	0	1/3	1/3	1/3	0	0	0	0	1/2	1/2	0	0	1	0	0	1	0	0	0	0	1/2	1/2
MONIMIACEAE	*Hedycarya arborea*	OG6/4	0	0	0	1/2	0	1	1/2	0	0	0	1/2	1/2	0	0	0	1/2	1/2	0	0	0	1	0	0	1/2	1/2	0	1/2	1/2	0
MYRSINACEAE	*Myrsine australis*	OG6/6	0	1	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	1	1	0	0	0	0	1	0	0	1	0	0	0	1	0
MYRSINACEAE	*Myrsine salicina*	OG6/9	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	1/2	0	1/2	0	1/2	1/2	0	0	0	0	1	0	1	0
MYRTACEAE	*Metrosideros diffusa*	OG6/17	0	1	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	0	1/2	1/2	0	0	1	0	0	1/2	1/2	0	0	0	1	0
MYRTACEAE	*Neomyrtus pedunculata*	OG6/19	0	1	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	1	1	0	0	0	0	1	0	1/3	1/3	1/3	0	0	1	0
RUBIACEAE	*Coprosma lucida*	OG6/7	0	1	0	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	1/2	1/2	0	0	1	0	0	1/2	1/2	0	0	1	0
RUBIACEAE	*Coprosma propinqua*	OG6/18	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1/2	1/2	0	1	0	0
RUBIACEAE	*Coprosma foetidissima*	OG6/20	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	0	1	0	1	0	0	0	0	1	0
RUBIACEAE	*Coprosma tenuicaulis*	OG6/21	0	1	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	0	1	0	0	0	1/2	1/2	0	1	0	0	0	0	1	0
VIOLACEAE	*Melicytus ramiflorus*	OG6/5	0	0	1/2	1	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0	1	0
WINTERACEAE	*Pseudowintera colorata*	OG6/14	0	1	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	1	1	0	0	0	1	0	0	1/2	1/2	0	0	0	1	0
ESCALLONIACEAE	*Quintinia serrata*	OG6/3	0	1/2	0	0	0	1/2	0	0	0	1/3	1/3	1/3	0	0	1	0	1	0	0	1	0	0	0	1	0	0	0	1	0
	CLAMP SCORE		0.0	52.6	19.7	19.7	19.7	27.6	15.8	8.7	17.0	16.5	25.3	23.6	5.7	2.6	26.3	47.4	36.8	15.8	5.3	42.1	52.6	0.0	30.7	43.8	9.6	15.8	10.5	84.2	5.3

APPENDIX THREE

PERAKI SADDLE SCENIC RESERVE, CANTERBURY, SOUTH ISLAND, NEW ZEALAND

family	species name	specimen number	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	tepto1	tepto 2	micro1	micro2	micro 3	meso 1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base Cordate	base round	base acute	L:W<1:1	1-2:1	2-3:1	3-4:1	>4:1	shape obovate	shape elliptical	shape ovate
APOCYNACEAE	*Parsonsia heterophylla* *	PS/25	1/2	1	0	0	0	0	0	0	0	1/2	1/2	0	0	0	1	1	0	0	0	0	1	0	1/3	1/3	0	1/3	0	1/2	1/2
ARALIACEAE	*Pseudopanax arboreus* *	PS/18	0	0	0	0	0	1	1/2	0	0	1/4	1/4	1/4	1/4	0	0	1/2	1/2	0	0	1	0	0	1	0	0	0	0	1	0
ARALIACEAE	*Pseudopanax crassifolius*	PS/21	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	1	0
ARALIACEAE	*Schefflera digitata*	PS/22	0	0	1	1/2	0	1	0	0	0	1/4	1/4	1/4	1/4	0	0	1/2	0	1/2	0	1/2	1/2	0	0	1	0	0	1/2	1/2	0
COMPOSITAE	*Helichrysum aggregatum* *	PS/26	0	1	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	1	1	0	0	0	0	1	0	1	0	0	0	0	1	0
CONVOLVULACEAE	*Calystegia tuguriorum* *	PS/17	0	1/2	0	0	1/2	0	0	0	1/2	1/2	0	0	0	0	0	1	0	0	1	0	0	1/2	1/2	0	0	0	0	0	1
CORNACEAE	*Griselinia littoralis*	PS/12	0	1	0	0	0	0	0	0	0	1/4	1/4	1/4	1/4	0	0	1	0	0	0	1	0	0	1	0	0	0	0	1	0
ESCALLONIACEAE	*Carpodetus serratus*	PS/24	0	1/2	0	0	0	1/2	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	1	0
ICACINACEAE	*Pennantia corymbosa*	PS/3	0	0	0	1/2	1	0	0	1/3	1/3	1/3	0	0	0	0	0	1	0	0	0	1/2	1/2	0	1	0	0	0	1/2	1/2	0
MONIMIACEAE	*Hedycarya arborea*	PS/27	0	0	0	0	0	1	0	0	0	0	1/2	1/2	0	0	0	0	1	0	0	1/2	1/2	0	0	1/2	1/2	0	0	1	0
MYRSINACEAE	*Myrsine australis*	PS/28	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0	1	0
MYRTACEAE	*Leptospermum ericoides* *	PS/5	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	0	1	0	0	0	0	1	0	1	0
MYRTACEAE	*Metrosideros diffusa*	PS/8	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	1	0	0	1/2	1/2	0	0	0	1/2	1/2
MYRTACEAE	*Lophomyrtus obcordata* *	PS/15	0	1	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	1	1	0	0	0	0	1	0	1	0	0	0	1	0	0
ONAGRACEAE	*Fuchsia excorticata*	PS/29	0	0	0	0	1	0	0	0	0	1/3	1/3	1/3	0	0	0	0	1	0	0	1	0	0	1/2	1/2	0	0	0	1	0
PAPILIONACEAE	*Sophora microphylla* *	PS/23	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	1	0	0	1	0	0	0	0	1	0
PIPE-RACK	*Macropiper excelsum* *	PS/7	0	1	0	0	0	0	0	0	0	0	0	1/2	1/2	0	0	0	0	1	1	0	0	0	1	0	0	0	0	1/2	1/2
PITTOSPORACEAE	*Pittosporum eugenioides* *	PS/6	0	1	0	0	0	0	0	0	0	0	1/2	1/2	0	0	0	1/2	1/2	0	0	1	0	0	0	1/2	1/2	0	0	1	0
ROSACEAE	*Rubus cissoides*	PS/13	0	0	1/2	1/2	0	1	1/2	0	0	1/2	1/2	0	0	0	0	0	1	0	1	0	0	0	1/2	1/2	0	0	0	0	1
RUBIACEAE	*Coprosma robusta*	PS/2	0	1	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	1/2	1/2	0	0	1/2	1/2	0	1/2	1/2	0	0	0	1	0
RUBIACEAE	*Coprosma rhamnoides* *	PS/9	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	1/2	1/2	0	1/2	1/2	0	0	0	1	0
RUBIACEAE	*Coprosma tenuicaulis*	PS/10	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1/2	1/2	0	0	1	0	0	1	0	0	0	0	1/2	1/2
RUBIACEAE	*Coprosma rotundifolia*	PS/14	0	1	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	0	1	0	0	1/2	1/2	0	1/2	1/2	0	0	0	0	1/2	1/2
RUBIACEAE	*Coprosma linariifolia*	PS/16	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	1	0
URTICACEAE	*Urtica ferox* *	PS/20	0	0	1	1	0	1	0	0	0	1/2	1/2	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0	1
VIOLACEAE	*Melicytus ramiflorus*	PS/4	0	0	0	1/2	1	0	1/2	0	1/5	1/5	1/5	1/5	1/5	0	0	1/3	1/3	1/3	0	1/2	1/2	0	1/4	1/4	1/4	1/4	1/2	1/2	0
WINTERACEAE	*Pseudowintera colorata*	PS/1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0	1	0	0	1/2	1/2	0	0	0	1	0
	CLAMP SCORE		1.9	63.0	9.3	11.1	13.0	24.1	5.6	19.7	16.7	22.0	24.5	11.5	5.4	0.0	18.5	56.8	36.4	6.8	16.7	50.0	33.3	3.7	54.0	24.4	4.6	13.3	9.3	70.4	20.4

APPENDIX THREE

PUNAKAIKI:A, WESTLAND, SOUTH ISLAND, NEW ZEALAND

family	species name	specimen number	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	lepto1	lepto 2	micro1	micro2	micro 3	meso 1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base Cordate	base round	base acute	L:W<1:1	1-2:1	2-3:1	3-4:1	>4:1	shape obovate	shape elliptical	shape ovate
ARALIACEAE	*Scheffiera digitata*	PA/4	0	0	1	1/2	0	1	0	0	0	1/4	1/4	1/4	1/4	0	1	1/2	1/2	0	0	0	1	0	1/2	1/2	0	0	1/2	1/2	0
COMPOSITAE	*Brachyglottis repanda* *	PA/6	0	0	1/2	1/2	1	0	0	0	0	0	0	1/3	1/3	1/3	0	1/2	1/2	0	1	0	0	0	1	0	0	0	0	1	0
CORNACEAE	*Griselinia littoralis*	PA/1	0	1	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	1	1	0	0	0	1	0	0	1	0	0	0	0	1	0
CORNACEAE	*Griselinia lucida* *	PA/8	0	1	0	0	0	0	0	0	0	0	0	1/3	1/3	1/3	0	1	0	0	1/2	1/2	0	0	1	0	0	0	0	1	0
CUNONIACEAE	*Weinmannia racemosa*	PA/12	0	0	1	1	1/2	1/2	0	0	1/4	1/4	1/4	1/4	0	0	0	0	1	0	0	1	0	0	1/2	1/2	0	0	0	1	0
ELAEOCARPACEAE	*Aristotelia serrata*	PA/3	0	0	1/2	1/2	0	1	1	0	0	1/5	1/5	1/5	1/5	1/5	0	0	1/2	1/2	1	0	0	0	1	0	0	0	0	1/2	1/2
ESCALLONIACEAE	*Carpodetus serratus*	PA/7	0	1	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	0	1/2	1/2	0	0	1	0	0	1	0	0	0	0	1	0
MONIMIACEAE	*Hedycarya arborea*	PA/5	0	0	0	0	1/2	1/2	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0	1/2	1/2	0	0	1	0
MYRSINACEAE	*Myrsine salicina*	PA/10	0	1	0	0	0	0	0	0	0	0	1/2	1/2	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0
MYRSINACEAE	*Myrsine salicina*	PA/11	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	1	0	1	0
MYRTACEAE	*Metrosideros umbellata*	PA/16	0	1	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	1	1	0	0	0	1/2	1/2	0	1/2	1/2	0	0	0	1	0
MYRTACEAE	*Metrosideros diffusa*	PA/17	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1/2	1/2	0	0	1	0	0	0	1	0	0	0	1/2	1/2
MYRTACEAE	*Metrosideros colensoi*	PA/18	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	1/2	1/2	0	1	0	0	0	0	1	0
PIPERACEAE	*Macropiper excelsum*	PA/13	0	1	0	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	1	1	0	0	0	1	0	0	0	0	1	0
RANUNCULACEAE	*Clematis foetida* *	PA/2	0	0	0	1/2	1	0	0	0	1/2	1/2	0	0	0	0	0	1/3	1/3	1/3	0	1	0	0	1	0	0	0	0	1/2	1/2
RUBIACEAE	*Coprosma grandifolia*	PA/9	0	1	0	0	0	0	0	0	0	0	0	0	1/2	1/2	0	0	1	0	0	0	1	0	0	1	0	0	0	1	0
VIOLACEAE	*Melicytus ramiflorus*	PA/14	0	0	1	1/2	1	0	1/2	0	0	0	1/2	1/2	0	0	0	1	0	0	0	1	0	0	0	1	0	0	1/2	1/2	0
MORACEAE	*Streblus heterophylla*	PA/19	1/2	0	1/2	1/2	0	1	1/2	0	1	0	0	0	0	0	0	1/2	1/2	0	0	0	1	0	1	0	0	0	1/2	1/2	0
	CLAMP SCORE		2.8	63.2	18.4	18.4	21.1	15.8	10.5	4.4	22.3	11.5	16.8	22.1	15.5	7.2	15.8	51.7	35.9	12.3	18.4	55.3	26.3	0.0	55.3	36.8	2.6	5.3	7.9	84.2	7.9

APPENDIX THREE

PUNAKAIKI:B, WESTLAND, SOUTH ISLAND, NEW ZEALAND

family	species name	specimen number	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	lepto1	lepto 2	micro1	micro2	micro 3	meso 1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base Cordate	base round	base acute	L:W<1:1	1-2:1	2-3:1	3-4:1	>4:1	shape obovate	shape elliptical	shape ovate
APOCYNACEAE	*Parsonsia heterophylius*	PB/18	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	1	0
ARALIACEAE	*Schefflera digitata*	PB/1	0	0	1	1/2	0	1	0	0	1/5	1/5	1/5	1/5	1/5	0	0	0	0	1	0	1/2	1/2	0	1/2	1/2	0	0	1/2	1/2	0
ARALIACEAE	*Pseudopanax crassifolius*	PB/12	0	0	1/2	0	0	1	0	0	0	0	0	1	0	0	0	1/2	1/2	0	0	1	0	0	0	0	0	1	0	1	0
ARALIACEAE	*Pseudopanax crassifolius*	PB/13	0	0	0	0	0	1	1/2	0	0	0	0	0	1/2	1/2	0	1/2	1/2	0	0	1	0	0	0	0	0	1	0	1	0
COMPOSITAE	*Brachyglottis repanda*	PB/7	0	0	0	0	1/2	1/2	1/2	0	0	0	1/4	1/4	1/4	1/4	0	0	1	0	1	0	0	0	1	0	0	0	0	1/2	1/2
CORNACEAE	*Griselinia littoralis*	PB/6	0	1	0	0	0	0	0	0	0	0	0	1/2	1/2	0	1	1	0	0	0	1	0	0	1	0	0	0	0	1	0
CUNONIACEAE	*Weinmannia racemosa*	PB/19	0	0	1	1	1	0	0	0	1/3	1/3	1/3	0	0	0	0	0	1	0	0	1/2	1/2	0	1/2	1/2	0	0	0	1	0
ELAEOCARPACEAE	*Aristotelia serrata*	PB/2	0	0	1	1	0	1	1	0	0	1/3	1/3	1/3	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0	1/2	1/2
ESCALLONIACEAE	*Quintinia acutifolia*	PB/3	0	1/2	0	0	1/2	0	0	0	0	1/3	1/3	1/3	0	0	1	1/2	0	1/2	0	1/2	1/2	0	1/3	1/3	1/3	0	1/2	1/2	0
ESCALLONIACEAE	*Carpodetus serratus*	PB/26	0	1	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	0	1/2	1/2	0	0	1	0	0	1/2	1/2	0	0	0	1	0
FAGACEAE	*Nothofagus menziesii* *	PB/14	0	0	1	1	1	0	1	0	1	0	0	0	0	0	0	1	0	0	0	1	0	1/2	1/2	0	0	0	0	1/2	1/2
FAGACEAE	*Nothofagus truncata*	PB/15	0	0	1	1	1	0	0	0	1/2	1/2	0	0	0	0	0	1	0	0	0	1/2	1/2	0	1	0	0	0	0	0	1
ICACINACEAE	*Pennantia corymbosa*	PB/23	0	0	0	1/2	1	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	1/2	1/2	0	1	0	0	0	1/2	1/2	0
MONIMIACEAE	*Hedycarya arborea*	PB/5	0	0	0	0	1/2	1/2	0	0	0	0	0	1/2	1/2	0	0	0	1	0	0	1	0	0	0	1	0	0	0	1	0
MYRSINACEAE	*Myrsine salicina*	PB/8	0	1	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	1	1	0	0	0	1	0	0	0	1/3	1/3	1/3	1/2	1/2	0
MYRTACEAE	*Metrosideros diffusa*	PB/20	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1/2	1/2	0	0	1	0	0	1/2	1/2	0	0	0	1/2	1/2
ONAGRACEAE	*Fuchsia excorticata*	PB/11	0	0	0	0	1	0	0	0	1/4	1/4	1/4	1/4	0	0	0	0	1/2	1/2	0	1	0	0	0	1	0	0	0	1	0
RUBIACEAE	*Coprosma lucida*	PB/9	0	1	0	0	0	0	0	0	0	1/4	1/4	1/4	1/4	0	0	0	1/2	1/2	0	1	0	0	0	1	0	0	0	1	0
RUBIACEAE	*Coprosma rigida*	PB/21	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	1	0	0	1	0	0	0	0	1	0
RUBIACEAE	*Coprosma areolata*	PB/22	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1/2	1/2	0	0	1	0	0	1	0	0	0	0	1	0
RUBIACEAE	*Coprosma propinqua*	PB/24	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	1	0
RUBIACEAE	*Coprosma foetidissima*	PB/25	0	1	0	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1	0	0	0	0	1	0	1/2	1/2	0	0	0	1	0
SCROPHULARIACEAE	*Hebe salicifolia*	PB/17	0	1/2	1/4	0	0	1/2	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	1	0
VIOLACEAE	*Melicytus ramiflorus*	PB/10	0	1	0	0	0	0	0	0	0	0	1/2	1/2	0	0	0	0	1/2	1/2	0	1	0	0	0	1/2	1/2	0	0	1	0
WINTERACEAE	*Pseudowintera colorata*	PB/16	0	1	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	1	1	0	0	0	1	0	0	1/2	1/2	0	0	0	1	0
	CLAMP SCORE		0.0	52.0	23.0	20.0	26.0	22.0	12.0	15.3	19.8	20.7	14.4	17.8	8.8	3.0	16.0	50.0	34.0	16.0	8.0	78.0	14.0	2.0	43.3	28.6	4.6	21.3	8.0	80.0	12.0

APPENDIX THREE

TONGARIRO 1390-1410, NORTH ISLAND, NEW ZEALAND

family	species name	specimen number	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	leptol	lepto 2	micro1	micro2	micro 3	meso 1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base Cordate	base round	base acute	L:W<1:1	1-2:1	2-3:1	3-4:1	>4:1	shape obovate	shape elliptical	shape ovate
ARALIACEAE	*Pseudopanax colensoi*	T1/2	0	0	0	0	1/2	1/2	0	0	0	1/2	1/2	0	0	0	0	1	0	0	0	0	1	0	1/2	1/2	0	0	0	1	0
COMPOSITAE	*Celmisia sp. A 2i*	T1/1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0
COMPOSITAE	*Cassinia vauvilliersii*	T1/16	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0	1	0
COMPOSITEAE	*Brachiglottis bidwillii*	T1/9	0	1	0	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1	0	0	0	1	0	0	1/2	1/2	0	0	1/2	1/2	0
ERICACEAE	*Gaultheria colensoi* *	T1/8	0	0	1	1	1/2	1/2	0	1/2	1/2	0	0	0	0	0	0	1	0	0	1/2	1/2	0	1/3	1/3	1/3	0	0	0	1	0
FAGACEAE	*Nothofagus solandri var. cliffortioid*	T1/3	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	1/2	1/2	0	0	1	0	0	0	0	0	1
FAGACEAE	*Nothofagus solandri*	T1/4	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1/2	1/2	0	0	1	0	0	1/2	1/2	0	0	0	0	1
MYRSINEACEAE	*Myrsine divaricata*	T1/7	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1	1	0	0	0	1	0	0	1	0	0	0	0	1	0
RUBIACEAE	*Coprosma depressa* *	T1/5	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	1/2	1/2	0	0	1	0	0	0	1	0
RUBIACEAE	*Coprosma cheesmanii* *	T1/6	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0
RUBIACEAE	*Coprosma foetidissima*	T1/13	0	1	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	1	1	0	0	0	0	1	0	1/3	1/3	1/3	0	0	1	0
RUBIACEAE	*Coprosma propinqua*	T1/18	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0
SCHROPHULARIACEAE	*Hebe odora* *	T1/11	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	0	0	0	1	0
SCHROPHULARIACEAE	*Hebe sp. B (8j)*	T1/12	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	1/2	1/2	0
SCHROPHULARIACEAE	*Hebe sp. A (8k)*	T1/14	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	1	0
THYMELACEAE	*Pimelia buxifolia* *	T1/10	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	0	1	0	0	1	0	0	1/2	1/2	0	0	0	0	1
THYMELACEAE	*Pimelia microphylla* *	T1/15	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1/2	1/2	0	0	1	0	0	1	0	0	0	1	0
	CLAMP SCORE		0.0	88.2	5.9	5.9	5.9	5.9	0.0	54.9	28.4	13.7	2.9	0.0	0.0	0.0	11.8	76.5	23.5	0.0	5.9	67.6	26.5	1.9	33.3	56.8	7.8	0.0	5.9	76.5	17.6

APPENDIX THREE

TONGARIRO 1160-1180m, NORTH ISLAND, NEW ZEALAND

family	species name	specimen number	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	lepto1	lepto 2	micro1	micro2	micro 3	meso 1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base Cordate	base round	base acute	L:W<1:1	1-2:1	2-3:1	3-4:1	>4:1	shape obovate	shape elliptical	shape ovate
ARALIACEAE	*Pseudopanax colensoi*	T2/4	0	0	0	1	0	1	1/2	0	0	1/4	1/4	1/4	1/4	0	0	1/2	1/2	0	0	1/2	1/2	0	1/2	1/2	0	0	0	1	0
ARALIACEAE	*Pseudopanax simplex*	T2/9	0	0	0	1/2	0	1	1/2	0	1/3	1/3	1/3	0	0	0	0	0	1	0	0	0	1	0	0	1/2	1/2	0	0	1	0
COMPOSITAE	*Olearia arborescens*	T2/2	0	1/2	0	0	1/2	0	0	0	1/4	1/4	1/4	1/4	0	0	0	1/2	1/2	0	0	1	0	0	1	0	0	0	0	1	0
COMPOSITAE	*Brachyglottis bidwillii* *	T2/8	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	1/2	1/2	0	0	0	1	0
CORNACEAE	*Griselinia littoralis*	T2/1	0	1	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	1	1	0	0	0	1/2	1/2	0	1	0	0	0	0	1/2	1/2
FAGACEAE	*Nothofagus solandri*	T2/6	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1	1	0	0	0	1	0	1/2	1/2	0	0	0	0	0	1
FAGACEAE	*Nothofagus solandri var. cliffortioid*	T2/7	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	1	0	0	1/2	1/2	0	0	0	1	0
FAGACEAE	*Nothofagus truncata*	T2/13	0	0	1	1/2	1	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	1	0
MYRSINACEAE	*Myrsine divaricata*	T2/11	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1	1	0	0	0	1/2	1/2	0	1/2	1/2	0	0	0	1	0
MYRTACEAE	*Neomyrtus pedunculata*	T214	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	1/2	1/2	0	1	0	0	0	1/2	1/2	0
MYRTACEAE	*Leptospermum ericoides*	T2/15	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	1	0	0	1	0	0	0	0	1	0
RUBIACEAE	*Coprosma foetidissima*	T2/12	0	1	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	0	1	0	0	0	0	1	0	1/2	1/2	0	0	0	1	0
RUBIACEAE	*Coprosma pseudocuneata*	T2/16	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	1/2	1/2	0
RUBIACEAE	*Coprosma parviflora*	T2/17	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1/2	1/2	0	0	1/2	1/2	0
SCROPHULARIACEAE	*Hebe subalpina*	T2/3	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1/2	1/2	0	0	1	0	0	0	1	0	0	0	1	0
SCROPHULARIACEAE	*Hebe sp. A (8k)*	T2/10	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	1	0
	CLAMP SCORE		0.0	78.1	6.3	12.5	9.4	12.5	6.3	42.7	27.6	15.6	7.3	5.2	1.6	0.0	18.8	75.0	25.0	0.0	0.0	62.5	37.5	3.1	59.4	34.4	3.1	0.0	9.4	81.3	9.4

APPENDIX THREE

TONGARIRO 980m, NORTH ISLAND, NEW ZEALAND

family	species name	specimen number	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	lepto1	lepto 2	micro1	micro2	micro 3	meso 1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base Cordate	base round	base acute	L:W<1:1	1-2:1	2-3:1	3-4:1	>4:1	shape obovate	shape elliptical	shape ovate
ARALIACEAE	*Pseudopanax colensoi*	T3/5	0	0	0	1/2	0	1	0	0	0	0	1/3	1/3	1/3	0	0	0	1	0	0	1	0	0	0	1	0	0	0	1/2	1/2
CORNACEAE	*Griselinia littoralis*	T3/9	0	1	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	1	1/2	1/2	0	0	1/2	1/2	0	1/2	1/2	0	0	0	1	0
ELAEOCARPACEAE	*Aristotelia serrata*	T3/1	0	0	1/2	1	0	1	1	0	0	1/4	1/4	1/4	1/4	0	0	0	1/2	1/2	1/2	1/2	0	0	1	0	0	0	0	1	0
ESCALLONIACEAE	*Carpodetus serratus*	T3/15	0	1	0	0	0	0	0	1/4	1/4	1/4	1/4	0	0	0	0	1/2	1/2	0	0	1	0	0	1	0	0	0	0	1	0
FAGACEAE	*Nothofagus menziesii*	T3/7	0	0	1/2	1/2	1	0	1	1/3	1/3	1/3	0	0	0	0	0	1	0	0	0	1	0	1/2	1/2	0	0	0	0	1	0
FAGACEAE	*Nothofagus solandri*	T3/13	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	1	0
MYRTACEAE	*Neomyrtus pedunculata*	T3/11	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1/2	1/2	0	0	1/2	1/2	1/2
ONAGRACEAE	*Fuchsia excorticata*	T3/10	0	0	0	0	1	0	0	1/5	1/5	1/5	1/5	1/5	0	0	0	0	1	0	0	1	0	0	0	1	0	0	1/2	1/2	1/2
PITTOSPORACEAE	*Pittosporum tenuifolium*	T3/4	0	1	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	1	0	0	1	0	0	0	1	0	0	0	1	0
ROSACEAE	*Rubus squarrosus* *	T3/14	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0	1/2	0
RUBIACEAE	*Coprosma tenuifolia*	T3/6	0	1	0	0	0	0	0	0	1/4	1/4	1/4	1/4	0	0	1	0	1	0	0	1	0	0	1/2	1/2	0	0	0	1/2	0
RUBIACEAE	*Coprosma foetidissima*	T3/3	0	1	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	0	1	0	0	0	0	1	0	1	0	0	0	0	1/2	0
RUBIACEAE	*Coprosma parviflora*	T3/8	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	0	1	0	1/2	1/2	0	0	0	0	1
WINTERACEAE	*Pseudowintera colorata*	T3/2	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	0	0	1	0	0	0	1	0	0	1/3	1/3	1/3	0	0	0	1
MYRSINACEAE	*Myrsine divaricata* *	T3/12	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1	1	0	0	0	1/2	1/2	0	1	0	0	0	1/2	1	0
	CLAMP SCORE		0.0	73.3	6.7	13.3	13.3	13.3	13.3	24.1	19.1	18.5	22.9	11.3	3.9	0.0	20.0	53.3	43.3	3.3	10.0	63.3	26.7	3.3	52.2	35.5	2.2	6.7	10.0	66.7	23.3

APPENDIX THREE

TONGARIRO 680-700m, NORTH ISLAND, NEW ZEALAND

family	species name	specimen number	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	leptol	lepto 2	microl	micro2	micro 3	meso 1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base Cordate	base round	base acute	L:W<1:1	1-2:1	2-3:1	3-4:1	>4:1	shape obovate	shape elliptical	shape ovate
ARALIACEAE	*Pseudopanax crassifolius*	T4/11	0	0	1/2	0	0	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	1	0
ARALIACEAE	*Schefflera digitata*	T4/14	0	0	1	1/2	0	1	0	0	0	1/3	1/3	1/3	0	0	0	1/2	0	1/2	0	1	0	0	0	1	0	0	1/2	1/2	0
ARALIACEAE	*Pseudopanax arboreus*	T4/25	0	0	0	1/2	0	1	0	0	0	1/3	1/3	1/3	0	0	0	0	1	0	0	1	0	0	1/2	1/2	0	0	0	1	0
COMPOSITAE	*Brachyglottis repanda*	T4/19	0	0	0	0	1	0	0	0	1/6	1/6	1/6	1/6	1/6	1/6	0	1/2	1/2	0	1/2	1/2	0	0	1/2	1/2	0	0	0	1	0
COMPOSITAE	*Unidentified 8y*	T4/7	0	0	0	0	0	1	0	0	1/3	1/3	1/3	0	0	0	1	1/2	1/2	0	0	1/2	1/2	0	1/3	1/3	1/3	0	0	1	0
COMPOSITAE	*Brachyglottis sciadophila* *	T4/9	0	0	0	0	1/2	1/2	1/2	0	1/3	1/3	1/3	0	0	0	0	1	0	0	0	1	0	1/2	1/2	0	0	0	0	1/2	1/2
CUNONIACEAE	*Weinmannia racemosa*	T4/2	0	0	1	1	1/2	1/2	1/2	0	1/4	1/4	1/4	1/4	0	0	1	1/2	1/2	0	0	1/2	1/2	0	1/3	1/3	1/3	0	0	1	0
ELAEOCARPACEAE	*Elaeocarpus dentatus*	T4/13	0	0	1	0	1	0	0	0	0	0	1/2	1/2	0	0	0	1/2	0	1/2	0	1	0	0	0	0	1/2	1/2	1	0	0
ELAEOCARPACEAE	*Aristotelia serrata*	T4/18	0	0	1/2	1	0	1	1	0	0	0	1/3	1/3	1/3	0	0	0	1/2	1/2	1/2	1/2	0	0	1	0	0	0	0	1/2	1/2
ESCALLONIACEAE	*Carpodetus serratus*	T4/24	0	1	0	0	0	0	0	1/4	1/4	1/4	1/4	0	0	0	0	1/2	1/2	0	0	1	0	0	1	0	0	0	0	1	0
ICACINACEAE	*Pennantia corymbosa*	T4/22	0	1	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	1/2	1/2	0	0	1	0	0	1/2	1/2	0	0	1	0
MYRSINACEAE	*Myrsine salicina*	T4/10	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	1	0
MYRTACEAE	*Metrosideros diffusa*	T4/6	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1/2	1/2	0	0	1	0	0	1/3	1/3	1/3	0	0	1/2	1/2
OLEACEAE	*Nestegis montana*	T4/12	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	1	0
PITTOSPORACEAE	*Pittosporum tenuifolium*	T4/17	0	1	0	0	0	0	0	0	0	0	1/2	1/2	0	0	0	1	0	0	0	1	0	0	1/2	1/2	0	0	0	1	0
RANUNCULACEAE	*Clematis forsteri* *	T4/1	1/2	1/2	0	0	1/2	0	0	0	1/3	1/3	1/3	0	0	0	0	0	1	0	1/2	1/2	0	0	0	1	0	0	0	0	1
RANUNCULACEAE	*Clematis foetida* *	T4/20	1/2	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1/2	1/2	0	0	1	0	0	1	0	0	0	0	1/2	1/2
RUBIACEAE	*Coprosma robusta*	T4/4	0	1	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	1/2	1/2	0	0	0	1	0	0	1	0	0	0	1	0
RUBIACEAE	*Coprosma grandifolia*	T4/8+3	0	1	0	0	0	0	0	0	1/6	1/6	1/6	1/6	1/6	1/6	0	1/3	1/3	1/3	0	1	0	0	1/2	1/2	0	0	0	1/2	1/2
RUBIACEAE	*Coprosma rhamnoides*	T4/15	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1/2	1/2	0	0	1	0	0	1	0	0	0	0	1	0
RUBIACEAE	*Coprosma foetidissima*	T4/21	0	1	0	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1	0	0	0	1/2	1/2	0	1/2	1/2	0	0	0	1	0
RUBIACEAE	*Coprosma lucida*	T4/23	0	0	0	1/2	1	0	0	1/3	1/3	1/3	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	1	0
VIOLACEAE	*Melicytus ramiflorus*	T4/5	0	0	0	1/2	1/2	1/2	0	0	0	0	1/2	1/2	0	0	0	0	1/2	1/2	0	1/2	1/2	0	0	1	0	0	0	1	0
WINTERACEAE	*Pseudowintera colorata*	T4/16	0	1	0	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	1	0	0	0	1	0	0	0	1/3	1/3	1/3	0	1	0
	CLAMP SCORE		4.2	52.1	16.7	16.7	20.8	27.1	8.3	8.7	18.7	17.9	30.4	19.7	2.8	1.4	8.3	47.2	41.0	11.8	6.3	72.9	20.8	2.1	37.5	34.7	9.7	16.0	6.3	79.2	14.6

APPENDIX THREE

TRONSON KAURI PARK, NORTHLAND, NORTH ISLAND, NEW ZEALAND

ARALIACEAE	*Pseudopanax crassifolius*	TKP/1	0	0	1/2	0	0	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	1	0
ESCALLONIACEAE	*Quintinia serrata* *	TKP/2	0	0	0	0	1	0	1/2	0	0	0	1/2	1/2	0	0	0	0	1/2	1/2	0	1	0	0	0	1/2	1/2	0	0	1	0
ESCALLONIACEAE	*Ixerba brexioides* *	TKP/3	0	0	1/2	1/2	1	0	1/2	0	0	0	1/2	1/2	0	0	0	1/2	0	1/2	0	1	0	0	0	1/3	1/3	1/3	1/2	1/2	0
PROTACEAE	*Knightia excelsa* *	TKP/4+5	0	0	1/2	1/2	1/2	1/2	1/2	0	0	0	1/3	1/3	1/3	0	1	1/2	0	1/2	0	1	0	0	0	0	0	1	2/7	2/7	2/7
VIOLACEAE	*Melicytus ramiflorus* *	TKP/6	0	0	1	1/2	1	0	1/2	0	0	0	0	1/2	1/2	0	0	1/2	0	1/2	0	1	0	0	0	1/2	1/2	0	0	1	0
VIOLACEAE	*Melicytus macrophyllus* *	TKP/7	0	0	0	0	1	0	0	0	0	0	1/4	1/4	1/4	1/4	0	1/2	0	1/2	0	0	1	0	0	1/2	1/2	0	1/2	1/2	0
MYRTACEAE	*Caldcluvia rosaefolia* *	TKP/8	0	0	1/2	1	1/2	1/2	0	0	1/2	1/2	0	0	0	0	0	1/2	1/2	0	0	1/2	1/2	0	0	1/2	1/2	0	0	1	0
ALSEUOSMIACEAE	*Alseuosmia sp.* *	TKP/9	0	1/2	0	0	1/2	0	0	0	1/4	1/4	1/4	1/4	0	0	0	1/2	0	1/2	0	0	1	0	0	1	0	0	0	1	0
MONIMIACEAE	*Hedycarya arborea*	TKP/10	0	1/2	0	0	0	1/2	0	0	0	1/3	1/3	1/3	0	0	0	1/2	1/2	0	0	1/2	1/2	0	0	1/2	1/2	0	0	1	0
ARALIACEAE	*Scheffiera digitata*	TKP/11	0	0	1	1/2	0	1	0	0	1/6	1/6	1/6	1/6	1/6	1/6	1	1/2	0	1/2	0	1	0	0	0	1	0	0	1/2	1/2	0
RUTACEAE	*Melicope simplex* *	TKP/12	0	0	0	0	1	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	1/2	1/2	0	1	0	0	0	0	1	0
ROSACEAE	*Rubus australis*	TKP/13	0	0	0	1/2	1/2	1/2	1/2	0	1/2	1/2	0	0	0	0	0	1/2	1/2	0	0	1	0	0	1	0	0	0	0	1/2	1/2
OLEACEAE	*Nestegis cunninghamii* *	TKP/15	0	1/2	0	0	1/2	0	0	0	0	1/3	1/3	1/3	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	1	0
OLEACEAE	*Nestegis montana* *	TKP/16	0	1	0	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0	1	0
OLEACEAE	*Nestegis lanceolata* *	TKP/17	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	1/2	0	1/2	0	0	1	0	0	0	0	1	0	1	0
NYCTAGINACEAE	*Pisonia brunonia* *	TKP/19	0	1	0	0	0	0	0	0	0	0	1/4	1/4	1/4	1/4	1	1	0	0	0	1	0	0	1/2	1/2	0	0	0	1	0
LAURACEAE	*Bilschmiedia tarairi* *	TKP/20	0	1	0	0	0	0	0	0	0	0	0	0	1/2	1/2	1	1	0	0	0	1	0	0	0	1	0	0	1/2	1/2	0
MYRTACEAE	*Metrosideros robusta* *	TKP/21	0	1	0	0	0	0	0	0	1/2	1/2	0	0	0	0	1	1	0	0	0	1/2	1/2	0	1/2	1/2	0	0	0	1	0
MYRTACEAE	*Metrosidros diffusa*	TKP/22	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	1/2	1/2
RUBIACEAE	*Coprosma areolata*	TKP/23	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	1/2	1/2	0	1	0	0	0	0	1/2	1/2
RUBIACEAE	*Coprosma spathulata* *	TKP/24	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	1	0	1	0	0	0	0	1	0
MYRTACEAE	*Metrosiderос sp. A 50* *	TKP/25	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	1	0
LOGANIACEAE	*Genistoma rupeste* *	TKP/26	0	1	0	0	0	0	0	1/5	1/5	1/5	1/5	1/5	0	0	0	0	0	1	0	1	0	0	0	1	0	0	0	1	0
MYSINACEAE	*Myrsine australis*	TKP/27	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1	0	0	1	0	0	1/2	1/2	0	0	0	1	0
RUBIACEAE	*Coprosma grandifolia*	TKP/28	0	1	0	0	0	0	0	0	0	0	0	0	1/2	1/2	0	1/2	1/2	0	0	1	0	0	0	1/2	1/2	0	0	1	0
PITTOSPORACEAE	*Pittosporum huttonianum* *	TKP/29	0	1	0	0	0	0	0	0	0	0	0	1/2	1/2	0	0	1/2	1/2	0	0	1	0	0	1	0	0	0	0	1	0
RUBIACEAE	*Coprosma lucida*	TKP/30	0	1	0	0	0	0	0	0	0	0	1/3	1/3	1/3	0	1	1/2	1/2	0	0	1/2	1/2	0	0	1	0	0	0	1/2	1/2
CORNOCARPACEAE	*Corynocarpus laevigatus* *	TKP/31	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	1	0	0	0	1	0	0	1/2	1/2	0
	CLAMP SCORE		0.0	58.9	14.3	12.5	26.8	14.3	8.9	7.9	20.1	18.8	12.3	23.0	11.9	6.0	32.1	55.4	26.8	17.9	0.0	71.4	28.6	0.0	30.4	38.7	11.9	19.0	10.0	81.4	8.2

APPENDIX THREE

ULVA ISLAND, OFF STEWART ISLAND, NEW ZEALAND

family	species name	specimen number	lobed	no teeth	teeth reg	teeth close	teeth round	teeth acute	teeth compound	lepto1	lepto 2	micro1	micro2	micro 3	meso 1	meso2	apex emarginate	apex round	apex acute	apex attenuate	base Cordate	base round	base acute	L:W<1:1	1-2:1	2-3:1	3-4:1	>4:1	shape obovate	shape elliptical	shape ovate
ARALIACAEA	*Pseudopanax colensoi*	UV3	0	0	0	1/2	0	1	1/2	0	0	0	1/4	1/4	1/4	1/4	0	1/2	1/2	0	0	1/2	1/2	0	1/2	1/2	0	0	1/2	1/2	0
ARALIACAEA	*Pseudopanax crassifolius*	UV5	0	0	1/2	0	0	1	1/2	0	0	0	0	1/3	1/3	1/3	0	1/2	1/2	0	0	0	1	0	0	0	0	1	0	1	0
ARALIACAEA	*Pseudopanax simplex*	UV10	0	0	0	1/2	0	1	1/2	0	0	1/4	1/4	1/4	1/4	0	0	1/2	1/2	0	0	1/2	1/2	0	0	1	0	0	0	1	0
ARALIACAEA	*Pseudopanax edgerleyi*	UV23	1	0	1/2	1/2	1	0	1/2	0	0	1/3	1/3	2/7	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0	1	0
COMPOSITAE	*Brachyglottis rotundifolia* *	UV18	0	1	0	0	0	0	0	0	0	0	0	1/3	1/3	1/3	1	1	0	0	1/2	1/2	0	0	1	0	0	0	0	1	0
CORNACEAE	*Griselinia littoralis*	UV7	0	1	0	0	0	0	0	0	1/5	1/5	1/5	1/5	1/5	0	0	1	0	0	0	1	0	0	1	0	0	0	0	1	0
CUNONIACEAE	*Weinmannia racemosa*	UV6	0	0	1	1	1	0	1/2	0	1/4	1/4	1/4	1/4	0	0	0	1/3	1/3	1/3	0	1	0	0	0	1	0	0	0	1	0
ESCALLONIACEAE	*Carpodetus serratus*	UV8	0	1	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	1	0
MYRSINACEAE	*Myrsine chathamica* *	UV21	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	0	1	1	0	0	0	1	0	0	1	0	0	0	0	1	0
MYRTACEAE	*Metrosideros umbellata*	UV9	0	1	0	0	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1/2	1/2	0	1	0	0	0	1/2	1/2	0	0	1	0
MYRTACEAE	*Neomyrtus pedunculata*	UV13	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	0	1	0	0	1/2	1/2	0	1	0	0	0	1/2	1/2	0
ONAGRACEAE	*Fuchsia excorticata*	UV20	0	1/2	0	0	0	1/2	0	0	0	1/2	1/2	0	0	0	0	0	1/2	1/2	0	1	0	0	0	1	0	0	0	1	0
ROSACEAE	*Rubus schmidelioides*	UV19	0	0	1	1	0	1	1/2	0	0	0	1/2	1/2	0	0	0	0	1/2	1/2	1	0	0	0	0	1	0	0	0	0	1
RUBIACEAE	*Coprosma lucida*	UV1 /UV4	0	1	0	0	0	0	0	0	0	1/4	1/4	1/4	1/4	0	1	1/2	1/2	0	0	1/2	1/2	0	1/2	1/2	0	0	1/2	1/2	0
RUBIACEAE	*Coprosma areolata*	UV11	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	0	0	0	1	0	1	0	0	1/2	1/2	0	0	0	1	0
RUBIACEAE	*Coprosma rhamnoides*	UV12	0	1	0	0	0	0	0	1/2	1/2	0	0	0	0	0	1	1	0	0	0	0	1	0	1	0	0	0	1/2	1/2	0
RUBIACEAE	*Coprosma rotundifolia*	UV15	0	1	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	0	1	0	0	0	1/2	1/2	0	1/3	1/3	1/3	0	0	1	0
RUBIACEAE	*Coprosma rigida* *	UV16	0	1	0	0	0	0	0	1/3	1/3	1/3	0	0	0	0	1	1	0	0	0	1/2	1/2	0	1/2	1/2	0	0	1/3	1/3	1/3
RUBIACEAE	*Coprosma foetidissima*	UV17	0	1	0	0	0	0	0	1/4	1/4	1/4	1/4	0	0	0	0	1	0	0	0	1/2	1/2	0	1/2	1/2	0	0	0	1	0
COMPOSITAE	*Olearia fragrantissima*	UV14	0	1	0	0	0	0	0	0	1/3	1/3	1/3	0	0	0	1	1	0	0	0	1	0	0	1/2	1/2	0	0	0	1	0
	CLAMP SCORE		5.0	70.5	13.6	15.9	9.1	20.5	13.6	11.0	16.0	21.3	24.0	15.9	7.3	4.1	27.3	58.3	24.2	17.4	6.8	63.6	29.5	0.0	42.4	44.7	8.3	4.5	10.6	81.0	8.3