Chapter 10: Discussion and Conclusion

Eastern disjunct occurrence of *Triodia scariosa*, an arid adapted species, on an outcrop at the western margin of the New England Batholith (Severn River), overlooking cleared agricultural land and the Pindari Dam Enlargement Project.

Chapter 10

Discussion and Conclusion

10.1 Introduction

The distribution of species richness and diversity across landscapes is of fundamental importance to any biogeographical investigation and consequently to conservation. In many situations, islands and 'island-like' systems are 'hotspots' for biodiversity or are places where a major disjunction in biotas occurs. This thesis has aimed to provide an understanding of the changes in richness and diversity across a landscape and some of the processes that have caused such patterns, both in terms of development and maintenance. With the elucidation of these patterns and processes, it was intended that the consequences of the findings would be transferable to other insular and non-insular systems and thus provide guidance relevant to the preservation and conservation of this and other systems.

There are many problems associated with the investigations of insular systems. Glenn and Nudds (1989) highlighted that most insular studies suffer from a number of drawbacks that include: small sample sizes; heterogeneous regions being compared; assumptions being made about pre-insularisation assemblages where insularisation has been a secondary event; and no distinction being made between the dispersal abilities of taxa. The design of this current investigation overcomes many of these problems. Here a single very large homogeneous region was chosen, and within it, a total 216 outcrop 'islands' were sampled via the placement of 522 survey sites. Outcrops are also relatively stable over very long periods of time (Bussell & James 1997). Although the dispersal abilities of different taxa have not been presented here, segregation and subsequent separate analysis of insular guild classes (Chapter 3) and lifeform groups has been performed (Chapters 3, 5, 6 & 8).

10.2 The flora of granitic outcrops of the New England Batholith and those elsewhere in the world

It is important to understand whether this system of outcrops conforms with other outcrop systems for which much research has previously been presented in the literature (Chapter 1). Are the basic features of outcrop systems, in terms of habitat and microclimate, but more importantly species adaptations and responses, similar to those reported for other outcrop systems?

The physical environment is certainly the same as represented for other granitic outcrop systems elsewhere in the world (Chapter 1). Data collected for this project and published formally by Hunter *et al.* (1998) shows that temperatures on granitic outcrops of the New England Batholith can be diurnally up to 8°C cooler and 10°C hotter (up to 18°C increase in temperature range) compared with the adjacent surrounding forest over the same period. This is similar to temperature ranges reported for other outcrop systems. There is no reason to assume that this granitic outcrop system is substantially different physically, or that the patterns of macro- or micro-environmental modification are different, from other systems.

Some large-scale patterns in the composition of the flora of outcrops of the New England Batholith are also the same as those elucidated from previously published literature on outcrops elsewhere (Chapter 1), although some differences were also noted. As expressed in a number of studies (Porembski *et al.* 1994; Ibisch *et al.* 1995; Porembski 1995; Fleischmann *et al.* 1996; Gröger & Barthlott 1996; Hopper *et al.* 1997; Burke *et al.* 1998), there often appears to be a reduction of endemics with increasing aridity. This is also the case on the New England Batholith (Chapter 3), with insularity increasing in the north east and decreasing westward correlated to decreasing rainfall and increasing temperature and radiation gradients.

The flora on the granitic outcrops in this investigation was an assemblage of species from the surrounding district, with a minority of species being disjunct from typically more arid environments, introduced weeds or those distinctive and restricted to outcrops

(Chapter 3, 4 & 8) as has been shown in other outcrop systems (McVaugh 1943; Winterringer & Vestal 1956; Bharucha & Ansari 1962; Burbank & Platt 1964; Axelrod 1972; Wyatt & Fowler 1977; Burgman 1987; Ornduff 1987; Erickson *et al.* 1991; Pignatti & Pignatti 1994; Porembski *et al.* 1994; Ibisch *et al.* 1995; Fleischmann *et al.* 1996; Porembski 1996; Hopper 1997; Main 1997a). Similarly, as with many outcrop systems (Moran & Hopper 1983; Fuls *et al.* 1992; Gröger & Barthlott 1996; Beard 1997; Hopper *et al.* 1997; Hunter 1998a; Lawler *et al.* 1998), outcrops on the New England Batholith provide refuge sites for fire evading species in an otherwise fire prone broader environment (Chapter 9).

The floras of outcrops are largely characterised by a high beta diversity (turnover between sites and habitats) which expresses itself in a lack of consistency in the dominant taxa and the composition of adjacent patches of vegetation, making phytosociological units difficult to interpret (Winterringer & Vestal 1956; Hambler 1964; Ashton & Webb 1977; Tracy 1982; Moran & Hopper 1983; Ornduff 1987; Maycock & Fahselt 1992; Binns 1995 a, b; Chapman & Binns 1995; Ibisch *et al.* 1995; Porembski 1995; Dörrstock *et al.* 1996; Hopper *et al.* 1997). By contrast, low beta diversity has been reported in some regions with more arid environments (Porembski *et al.* 1994; Porembski 1995; Porembski *et al.* 1996). Although high beta diversity was found across the outcrops of the New England Batholith (Chapters 5 & 7), no correlations could be found with environmental variables, suggesting that this measure may not be related to an aridity gradient. High species turnover did not significantly deter the definition of useful phytosociological units using quantitative analyses (Chapter 4). Problems faced by previous researchers are largely due to a less intensive survey protocol and reliance on structure over floristics (Chapter 4). Due to the comparatively arid nature of outcrops, the structure of outcrop vegetation communities is simpler than in the surrounding vegetated matrix, both in this investigation and in work conducted elsewhere. Correspondingly, the structure of outcrop vegetation becomes simpler across the batholith from east to west along an aridity gradient (heath to shrublands to herblands) as in other outcrop systems (Chapter 4).

Although a number of subjective phytosociological units have been suggested for granitic outcrop floras (Barthlott *et al.* 1993) many of these were not found to occur on the granitic outcrops of the New England Batholith (Chapter 4). Some of these units are also missing from other granitic outcrop systems elsewhere in Australia (Hopper 1999). As phytosociological units of value (Chapters 5 to 8) were easily defined in this system by quantitative methods (Chapter 4), despite high beta diversity (Chapter 5 & 7), it is suggested that such analyses be used elsewhere, in preference to qualitative units. It is only with quantitatively defined units that bias can be removed and direct comparisons can be made between communities and the dynamics associated with them.

One noticeable compositional difference from some outcrop systems reported elsewhere is the relative lack of introduced weeds on the outcrops of the New England Batholith. While the low richness of weeds is not unusual in a worldwide sense, it is noticeably different from that of the flora of outcrops in Western Australia. Following Hopper (1999), this difference may be partially explained as a lack of glacial activity in Western Australia (Chapter 4), but other processes must also be involved as great differences in weed richness were found in this investigation between outcrops with the same geological history.

The granitic outcrops of the New England Batholith and many of the patterns shown by their floras, are not noticeably dissimilar to those described in published accounts of granitic outcrops elsewhere in the world. Therefore, many of the issues raised in this thesis and the patterns described in terms of richness, diversity and conservation are of direct relevance to other outcrop systems worldwide. As the granitic outcrops of the New England Batholith are examples of insular environments, the patterns shown by the flora may also have some relevance to a far broader array of both natural and altered ecosystems, and to the conservation of their biodiversity.

10.3 Important aspects of insular systems: how insular is insular?

One of the more striking findings of this project was the degree to which the apparent insularity of outcrops changed across the study area (Chapter 3). Such a finding is of fundamental importance as it directly relates to all aspects of insular investigations, including aspects of competition, adaptive radiation, the effectiveness of barriers and of course richness and diversity. This investigation has shown that supposed 'habitat' or 'ecological islands' are not always truly insular and that even within a single habitat type insularity may vary greatly (nearly a 3-fold difference found; Chapter 3).

Essentially outcrops were comparatively more insular to the north east of the batholith and less insular along the west of the batholith. There was a somewhat unimodal pattern, with both the western and eastern extremes of the batholith having the lowest Quotient of Insularity (QI) scores, although these areas achieved lower insularity by different means (Chapter 3). Apparent insularity correlated strongly with a number of environmental and structural features of an outcrop. Smaller, flatter, more disturbed outcrops that were more exposed to the north, had a high pH, and occurred in areas with a decreased rainfall but higher incident radiation and temperature, were associated with a lower Quotient of Insularity score. As the surrounding vegetation ('sea') became more 'arid', more of its species were shared with outcrops making them correspondingly less insular floristically. Basically, the less different the outcrop environment was from the surrounding vegetated matrix the less insular was the outcrop. Corresponding changes have been found elsewhere in the world (Chapter 1; Section 10.2).

These changes in composition, and the effective isolation of outcrop floras from the surrounding vegetation, have implications for how species richness and abundance are maintained on outcrops. They suggest that populations may be maintained differently across the New England Batholith. For outcrops that are highly insular, the surrounding vegetation is hostile to most of the constituent flora. However, where outcrops are less insular, the surrounding vegetated areas are not as hostile and therefore the mechanisms that maintain species populations will shift from adaptations for persistence to adaptations for dispersal. This affirmation is consistent with the correlation shown between an increase in species range size and increasing incident radiation loads (Chapter 8).

The degree to which outcrops differed in their flora from the surrounding vegetation, as measured by the Quotient of Insularity, was one of the most consistent and significant correlative variables with species richness (Chapter 6). Outcrops with higher Quotient of Insularity scores were also found to have higher species/genus ratios. This potentially indicates that highly insular outcrops may provide opportunities for adaptive radiation, potentially increasing richness over time by speciation.

This project has highlighted the importance of investigations of insularity. Here, as the effective insularity of outcrops increased there was a corresponding decrease in species richness but an increase in congeners. The degree of insularity is of great significance in determining species richness on outcrops of the New England Batholith and is important in determining some of the processes that achieve or maintain richness and abundance. It is likely that this will also be true for other insular systems. As such it is a quality that should be investigated in other continental insular systems.

10.4 Differences in the dynamics of the floras of outcrops (virtual 'islands') and the surrounding forests and woodlands (virtual 'sea') of the New England Batholith

Throughout this thesis evidence has been presented confirming that the outcrop ('island') floras of the New England Batholith are different compared with the surrounding vegetation ('sea') in terms of floristics and the processes controlling species composition. The environment of granitic outcrops is semi-arid to arid, often in marked contrast to the mesic vegetation that surrounds it. Hence, structurally the vegetation on granitic outcrops is simpler than the surrounding vegetation (Chapter 4; Appendix E). The floristic difference between outcrop ('island') vegetation and the surrounding vegetation ('sea') is a constant feature across the batholith. However, this difference does vary considerably, being more pronounced in the north east along correlated gradients associated primarily with altitude, rainfall and incident radiation (Chapter 3).

Outcrops may provide refuges from fire. A majority of species on outcrops are obligate seeders, compared to the higher proportion of resprouting species seen in the surrounding vegetation (Chapter 9). However, a floristic distinction was constant even after fire, including two fires in two consecutive years (Chapter 9). Fire may even reinforce such differences (Chapter 3) by the promotion of a seemingly fire ephemeral flora, although evidence does suggest that prolonged high frequency fires may decrease the floristic distinctiveness of outcrops (Binns 1992; Hunter 1999a).

In comparison with the surrounding vegetation, the species richness of vegetation on outcrops at the 0.1 ha scale (alpha diversity) was poorer. This difference is statistically significant, with the surrounding vegetation being, on average, around 30% richer (Chapter 5). This is not surprising as outcrops are essentially 'semi-arid' environments and the richness of many other semi-arid environments within Australia are of the same magnitude (Rice & Westoby 1983). There is however, greater between-habitat diversity (beta diversity) on granitic outcrops than in the surrounding vegetation (Chapter 5). Correspondingly, there is greater evenness in the rank order distribution of species abundances in the surrounding vegetation. This indicates that there is more disorder in the abundances (a greater rank abundance range) of species on granitic outcrops.

Somewhat surprisingly though, there is little difference (although still statistically significant) between the collective sizes of species ranges, as measured by range saturation (Chapter 8), between outcrop and the surrounding vegetation floras. This indicates that while species ranges are in general smaller on outcrops, the processes that frame patterns of species range size may be operating in a similar way in both the outcrop and the surrounding vegetation floras.

Many observations seen throughout this thesis indicate that many of the processes involved in generating and maintaining richness and diversity in fragmented systems are likely to be different from those found in other less fragmented systems.

10.5 Granitic outcrops of the New England Batholith and the theory of Island Biogeography

The results presented in this thesis indicate that Island Biogeography may be deficient as an explanatory theory for species richness in many insular systems, including this one. Although a correlation was found with area in a number of models, most of these appeared to be related to the scale of grain or extent. Palmer and White (1994), Böhning-Gaese (1997) and Kholin and Nilsson (1998) argued that at small spatial scales, habitat heterogeneity would be the most significant explanatory variable, with area being more significant at larger scales. The significance of area on species richness was dependent on both the grain and extent size. Deshaye and Morisset (1988) and

Eriksson (1993) found the strength of the relationship of area depends on the size of the habitat species pool. If the equilibrium hypothesis was of overriding importance, then richness at the quadrat grain should still show a significant residual effect of area (Kelly *et al.* 1989). The results presented here do not support the equilibrium hypothesis, as area did not occur as a significant variable with any extent or species pool sizes tested ('archipelago', Element, batholith) at the quadrat grain size (Chapter 6), even though area was of overriding importance at larger grains. At larger non-area standardised grains, area must be a surrogate for either random placement or habitat heterogeneity. As factors of habitat heterogeneity (Vegetation Cover, Boulder Cover etc.) did appear as a subordinate variable in analyses at larger grain and extent sizes, this may provide an appropriate explanation for the patterns noted in species richness across the outcrops of the New England Batholith. Such results indicate both the usefulness of the fixed sized quadrat methodology (as employed here) and the importance of scale in biogeographic regression analyses. Regression analyses of biogeographic patterns need to perform 'zoom-sampling' (as was used here) in order to justify the conclusions drawn.

Area was not a significant correlative value in any of the fixed quadrat grain size models for species/genus ratios. Additionally species/genus ratios were not as low as predicted by the random sample hypothesis (Linhart 1980). Although tested for, area was found to be of no statistical significance within lifeform richness canonical correspondence analysis (Chapter 6), providing further evidence that habitat heterogeneity is of overriding importance.

The evidence suggests that the habitat heterogeneity hypothesis is more likely a correct model for determining some aspects of species richness in insular systems. Most importantly though, as has been found in a number of recent investigations (Schoener and Schoener 1983a; Deshaye & Morisset 1988; Wiens 1989; Lomolino 1994; Böhning-Gaese 1997; MacNally & Watson 1997; Kholin and Nilsson 1998), scale is of great importance. Evidence can be provided to apparently support a number of hypotheses simply by changing the grain or extent size. In some instances such as with area, these correlations may support a probable falsehood, but in others the significance of variables may indeed be scale dependent (e.g. factors associated with habitat heterogeneity), with other factors becoming more important at higher or lower levels (Wiens 1989; Reed *et al.* 1993).

10.6 Are natural and human-induced fragmented systems the same?

The flora of granitic outcrops has evolved over millennia to survive in a highly fragmented environment. Broadly, there appear to be two main strategies, persistence and distance dispersal, employed to allow species to persist in the fragmented system investigated here. Species that are primarily, or entirely, restricted to granitic outcrops of the New England Batholith possess strategies for persistence, as do species from other highly fragmented environments (Green 1994; Dieckmann *et al.* 1999). Means of persistence may involve mechanisms for retaining heterozygosity in the face of small population size, such as highlighted by James (1982) in the outcrop endemic *Isotoma petraea*, in which lethal recessive genes are balanced under inbreeding conditions. Slow growth and long generation times along with dormancy and localised dispersal strategies are yet other means employed for persistence (Green 1994; Dieckmann *et al.* 1999; Hopper 1999). Other more ubiquitous species of outcrops that are shared with the surrounding vegetated matrix commonly have mechanisms for distance dispersal, and as such can perpetually re-invade from populations found nearby.

An implication of the results of this thesis is that the processes maintaining richness and diversity in insular systems may not be the same as those for non-insular systems. In non-fragmented environments that subsequently become fragmented, few if any of these species will have evolved strategies of persistence. Additionally, by definition, there is also no corresponding surrounding intact vegetation unit from which most of the flora can re-invade, unlike in the granitic outcrop scenario.

Correspondingly, there may be little use in studying systems that have been fragmented by human induced disturbance in order to infer mechanisms controlling richness and diversity in naturally fragmented habitats. Certainly many aspects of fragmented systems (‘natural’ or created by human disturbance) are likely to be comparable. It is in the delineation of processes that are shared and those that are evolutionarily independent that research needs to be conducted. Using one environment to infer mechanisms in another without knowledge of which processes are actually applicable may have dire consequences for the management of fragmented environments, be they natural or human induced.

10.7 The maintenance of richness and diversity on the granitic outcrops of the New England Batholith

The modified climate of granitic outcrops is semi-arid. In line with this, the species richness at the 0.1 ha scale is similar to that of other non-Mediterranean semi-arid areas within Australia and elsewhere in the world (Rice & Westoby 1983; Westoby 1993) that may indicate an underlying structure to site richness.

During this investigation a number of factors were found that are significantly correlated to species richness on granitic outcrops. However, some correlative factors were found to be scale-dependent and thus varied in importance and representation (as a significant factor) depending on the grain and extent of analyses (Chapter 6). Despite this, some variables were found with a reasonably consistent significance across scales. In particular, factors associated with habitat heterogeneity were found to be of highly significant (Chapter 6; section 10.5). An increase in factors associated with habitat heterogeneity was found to correlate with increased species richness across the batholith, although the correlated affect of this variable was often masked by the colinear area variable (Chapter 6). In addition to this factor, higher temperature and radiation were significantly correlated with increased species richness. In at least one model, isolation was also of significance, with increasing isolation corresponding to decreasing species richness. An increase in the insular nature of granitic outcrops, as measured by the Quotient of Insularity, was consistently correlated with a decrease in species richness across most scales of investigation.

Although there is variability within the system, overall these factors imply that species richness decreases towards the east of the batholith where insularity is at its highest, but temperatures and incident radiation is lowered. Correspondingly, the eastern portion of the batholith also has a slight decrease in cumulative species range size correlated with decreased incident radiation loads (Chapter 8) and an increase in outcrop restricted (Chapter 3) and congeneric taxa (Chapter 6).

Fire was also found to be a factor that was correlated with increased species richness at larger extent and grain sizes (Chapter 3). However, after specific fire trials were conducted, the null hypothesis of no significant change after burning could not be rejected (Chapter 9). These trials indicated that, despite a disturbance such as fire, species richness and diversity were not significantly different from those of the starting point and that succeeding floras are based largely on initial floristic composition (Chapter 9). Structurally, fragmentation was also found to affect species richness (Chapter 7) with the overall species richness being greater the more fragmented and disconnected the outcrops were. These results indicate that there is potentially an inherent structure to the richness of outcrops.

Species richness at the 0.1 ha scale (alpha diversity) was correlated with, and likely to be primarily structured by the physical nature of the outcrop: the crevices and rock basins available for colonisation, overall area available, the range of boulder sizes and their abundance, the modified climate, amount of runoff, depth of soils, and exposure, to name a few specific factors.

Granitic outcrops are harsh habitats that are often at, or beyond, the physiological tolerances of most species and competition between species is therefore low (Chapter 1). Suitable spaces for establishment are limited. Individual plants may be long lived and, once established, may dominate spatial resources. Even when sites are available, the chances of colonisation followed by establishment are low. Density independent extinctions are common place. Furthermore, the microclimates on granitic outcrops can be extremely different from those of surrounding vegetation and also differ greatly within a single outcrop (Chapter 1). To nearly a third of the species, those granitic outcrops are highly fragmented and disconnected system. Such factors, amongst many others, inherently mean that no individual species can dominate across habitats or the landscape. This is expressed in the high turnover of species between habitats, which has been shown by the high beta diversity, low nestedness (Chapter 5 & 7) and the lack of relationship between species range size and abundance (Chapter 8). Thus species richness is maintained across the landscape (gamma diversity) primarily by high levels of beta diversity.

The constituents of the flora indicate that the presence and abundance of species on outcrops are maintained by proportionally different means across the New England Batholith. Along the western side of the batholith there is a higher proportion of disjunct taxa from areas much further afield (Chapters 3 & 8), species ranges are cumulatively larger (Chapter 8), there are fewer outcrop restricted species (endemics) (Chapter 3), and importantly, there are more species shared with the surrounding forest (Chapter 3). The converse may be applied to the eastern side of the batholith. All of these factors are reflected in the geographic distribution of the Quotient of Insularity scores. In addition, there is a positive correlation between the Quotient of Insularity and congeneric representation (Chapter 6), indicating that radiation may be of greater importance as a means of generating richness in the east compared to the west. What this means is that species richness are more likely to be maintained by colonisation in the western parts of the batholith due to the higher numbers of shared taxa. In the east, where outcrops are in general more 'island-like' (Chapter 3), mechanisms for persistence and adaptive radiation may be of proportionally greater importance.

Thus not only does the physical and semi-arid nature of outcrops structure alpha diversity, but it structures the high level of beta diversity, thereby maintaining richness at the landscape scale, i.e. gamma diversity. However, richness and diversity is likely to have, to some degree, been developed and maintained by proportionately different means across the New England Batholith, for example colonisation, persistence or radiation. Such potentially proportionately different methods of maintaining biodiversity within a single system (New England Batholith) has important implications for other insular systems. Providing support for mechanisms that maintain biodiversity in one part of a single insular system may not mean that such systems can be transferred to other parts of the same system. Each insular system needs to be investigated in detail so that such variations can be elucidated.

10.8 Implications for conservation

A number of lines of evidence throughout this thesis are of relevance to protocols for conservation and reservation of the flora of granitic outcrops on the New England Batholith. It is likely that such protocols may also have wider applicability. It has been shown that many of the floristic assemblages defined for the New England Batholith are not in any form of reservation (Chapter 4), particularly for communities restricted to the western side of the batholith. In contrast, many of the assemblages on the eastern side of the batholith are well represented in the reserve network. Certainly, for a comprehensive representation of all communities a number of reserves would need to be created on the western side of the batholith. However, whether as much representation is needed for assemblages on the west as is currently found to the east is debatable.

A constant feature of granitic outcrop floras throughout the batholith, regardless of assemblage, is the high level of species turnover. This is evidenced by results including high beta diversity (Chapter 5), low nestedness and high species saturation values (Chapter 7). All of this demonstrates that more species are found if the number of outcrops used in any reserve are maximised. In particular, the high species saturation values show that in every scenario, the same area of small outcrops will have more species than an equivalent area of large outcrops. Such evidence suggests that, across the New England Batholith, the number of outcrops within reserves should be maximized within a given area. This implies that the 'several-small' side of the SLOSS debate is more relevant to the flora of granitic outcrops on the New England Batholith than the 'few-large' side. This is also likely to be the case for other naturally fragmented systems. The combined use of nestedness, saturation and beta diversity measurements provide clear indicators of appropriate reservation strategies. These methods should be employed more widely.

Conservation necessarily implies not only that assemblages are important, but also the representation of individual species. An increase in species richness on outcrops was correlated with higher temperatures and radiation and greater vegetation cover. All of these factors are commonly (but not exclusively) associated with the western side of the batholith (Chapter 6). Furthermore, species richness decreases with an increasing

Quotient of Insularity (Chapter 3), which is associated with the north east corner of the batholith. On face value this would suggest the outcrops to the west are of greater conservation importance (being richer in species), particularly since the effects of fragmentation, nestedness and beta diversity are not significantly different across the batholith.

An additional aspect of conservation importance is the distribution of constituent species, including both species range size and fidelity. A significant positive correlation occurs with species range size and the highest period of incident radiation (Chapter 8). This indicates that in general a greater proportion of widespread species, are found on the western side of the batholith. Species with smaller geographic ranges are found in more eastern parts of the batholith (Chapter 8). The Quotient of Insularity provides a measure of the restriction of species to outcrops within the New England Batholith (Chapter 3). This measure is important in terms of species fidelity to outcrops. Species with a high restriction to outcrops and which are subsequently rare, or not occurring in other vegetation types, have greater representation on outcrops to the north east of the batholith. Correspondingly, greater proportions of species occurring on outcrops along the western margin of the batholith are shared with the vegetative matrix that surrounds the outcrops (the virtual 'sea'). Overall this indicates that species of greater conservation importance (those that are rare or restricted) are more frequently found to the east. Despite the high turnover of species on outcrops to the west, much of the turnover is likely to be in species that are ubiquitous and common to many other communities.

In terms of composition and the representativeness of individual taxa, those outcrops along the eastern margin of the batholith may be of higher priority for reservation (rare and restricted species). Yet those of the western side of batholith are likely to be more prone to a reduction in richness and diversity if the surrounding vegetation ('sea') is highly modified (non-persisting lifestyle; Section 10.7). At present there is already a high proportion of reserves on the eastern parts of the batholith. The western parts of the batholith need some representation in reserves. This need not be to the same level as on the east. However, there may need to be a greater proportion of surrounding vegetation ('sea') in such reserves in order to maintain biodiversity on the outcrops.

This scenario is simplistic, as it negates other conservation imperatives and deals only with granitic outcrops of the New England Batholith. Obviously, other constraints both in terms of maximising the representativeness of non-outcrop assemblages and various political obstacles affect the strategies employed by conservation managers. This research highlights that the several-small side of the SLOSS debate is likely to be of greater benefit in naturally highly fragmented environments. However, the differences in the abilities of species to persist in small 'islands' divorced from nearby source pools will need to be taken into consideration (i.e. persisting as opposed to non-persisting strategies) if the current diversity is to be maintained.

10.9 Conclusion

The geographical insularity of the continental 'ecological islands' provided by granitic outcrops has been defined and circumscribed. It has been found that the extent to which the granitic outcrop floras are insular, differing from the surrounding vegetation, is variable across the New England Batholith, and that these differences are correlated to a number of environmental variables. In addition, the insularity of individual outcrops has a bearing on their biodiversity.

The richness of granitic outcrops is circumscribed by their physical and semi-arid nature. Alpha diversity is comparatively low, typical of semi-arid environments around the world. Beta diversity is very high and is related to the isolated, fragmented and harsh habitat that outcrops provide, causing high levels of population extinction and stochastic colonisation and establishment. Diversity is maintained at the landscape scale (gamma diversity) by the high levels of beta diversity. Richness and the abundance of component species on outcrops may be maintained proportionately by different means across the batholith. In the east, greater proportions of the flora are restricted to the granitic outcrops (more endemism) and populations may be maintained by strategies of persistence and by speciation. Wider species ranges allow populations to be maintained by re-colonisation on the western side of the batholith.

The dynamics that cause and maintain species richness and diversity on granitic outcrops across the New England Batholith are likely to be similar to those of other outcrop regions of the world. As such, the mechanisms and patterns found here should be transferable to other similarly structured systems. However, there is evidence to suggest that human induced fragmented systems will have many dissimilar processes. Consequently, processes described for naturally fragmented systems should not be applied to human induced fragmented systems. Evidence presented within this thesis indicates that maximising the number of small outcrops within a reserve system will preserve the greatest number of species, or that any outcrop no matter how small is of conservation importance. Such reservation strategies are likely to be true for any highly fragmented system with a high beta diversity.

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