Succession in the Kaimaumau gumland, Northland, New Zealand, following fire

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Abstract

The vegetation recovery at Kaimaumau gumland was monitored in seven permanent plots from 1988 to 1999 following a large fire in 1988 in order to determine rates and patterns of vegetation recovery.

A succession profile for the key vegetation types that are currently developing is suggested. *Schoenus brevifolius* was the first species to colonise from rhizomes after the fire, and has remained the dominant species in the peat bog communities. By ten years, the vegetation of the peat bog has returned to its pre-fire composition. In scrubland communities, weeds such as Sydney golden wattle and gorse have become dominant.

A likely trajectory of succession is projected, which shows that the peat bog community is likely to remain in a steady state, as it exists now, in the ab sense of disturbance. Future fires may increase weeds clue to their adapta tions to fire. In areas that are weedy, the weeds are likely to remain. These weeds are likely to impact on the vegetation composition of Kaimaumau in the future. Their nitrogen-fixing ability could lead to increased nutrients and altered soil properties of the sites. This could cause further invasion of ex otic plants.

1. Introduction

Gumland is one of the few vegetation types in New Zealand adapted to a disturbance regime including recurrent fires (Dodson et al. 1988, Wardle 1991). However, fire may also provide opportunities for invasion of weeds which may unacceptably alter ecosystems. In this study, we followed vegetation changes in a gumland ecosystem after fire, particularly noting the effect of fire on weed populations.

1.1 BACKGROUND

The Kaimaumau gumland lies 27 km north of Kaitaia (Fig. 1), and stretches 11 km from the mouth of Rangaunu Harbour near Kaimaumau north-westwards to Motutangi. The gumland consists of a series of flats and ridges, rising to 10 m above sea level, which originated from a series of sand dunes. Soil formation beneath generations of kauri forest produced impermeable hardpans that act as barriers between the surface water and groundwater, resulting in impeded drainage and thus peat accumulation (Hicks et al. 1997). The soils are characterised by poor drainage, poor structure, low cation and phosphorus content, low nitrogen mineralisation rate, and very low pH. Vegetation consists of sedges, rushes and shrubs, and is representative of acid low-fertility wetlands that were once more widespread on the sand country of the Aupouri and Karikari Peninsulas (Hicks et al. 1997). At least twelve species present are listed as threatened, including a number of orchids (Hicks et al. 1997). The area is the only remaining freshwater wetland in Northland that exceeds 1000 ha, and 955 ha of this is protected as a Scientific Reserve administered by the Northland Conservancy of the Department of Conservation. A further 2312 ha of wetland and dunes are protected as Conservation Area.

Invasion into Kaimaumau of legume weeds such as gorse *(Ulex europaeus)*, Sydney golden wattle (wattle) *(Racosperma longifolium)*, *Albizia*, *Oxylobium lanceolatum* and *Psoralea*, plus the non-legume weed, prickly hakea *(Hakea sericea)*, have given rise to fears that these plants will both change the character of the gumland through the ability of legumes to fix atmospheric nitrogen, and predispose the community to other invaders. It is assumed that the predominance of legume invaders is partly due to their ability to compete on the low nitrogen soils of the swamp ecosystem.

On Friday 4 November 1988, a fire was accidentally ignited in this area, eventually burning 3345 ha over a period of 5 days (Fig. 2). Only a small patch to the west of the airstrip was not burnt.

1.2 PRE-FIRE VEGETATION

The vegetation of Kaimaumau prior to the 1988 fire had been surveyed by Dell (1982) and Clunie (1988). While the exact post-fire plot sites were not surveyed at that time, the vegetation is similar throughout the landforms, and can be deduced from these surveys,an examination of post-fire compositions, and personal accounts.

Plot 1

This peat bog site was predominately, *Schoenus brevifolius* and manuka, with some prickly hakea.

Plot 2

This interdune peat bog margin site consisted predominantly of short (less than 1 m) manuka, with occasional 2 m specimens. Prickly hakea, *Schoenus brevifolius* and marginal gorse were also present.

Plot 3

Predominately, *Schoenus brevifolius* and manuka of less than 1 m (occasional specimens to 3 m tall) were found at this peat bog site. Dense stands of prickly hakea were present on higher ground.

Plot 4

This shrubland site was predominantly 2 m tall manuka and prickly hakea. Occasional taller wattle was found throughout.

Plot 5

This peat hog site was composed of large areas of *Schoenus brevifolius.* Manuka 3 m tall was present on ridges.

Plot 6

This dune site was a mixture of prickly hakea, gorse and manuka up to 3 m tall.

Plot 7

This shrubland site consisted of a mixture of manuka and wattle with prickly hakea. Vegetation was up to 4 m tall.

2. Method

Seven sites were selected in different pre-fire vegetation types (Fig. 2). Three sites were placed into scrub vegetation, and four were placed into peat bog vegetation type. At each site, 25 points were measured along each of 4 transects in a rectangular arrangement with 10 paces between each transect. Vegetation was surveyed using the `boot toe' method of Atkinson (1962) for open communities, tussockland, shrubland, scrub, etc. All plants over the toe of the boot were recorded as present at each point. Surveys were carried out in February 1989, March 1990, November 1990, December 1991, January 1994 and February 1999 (four plots only). Comparisons were also made from photographs taken at permanent photopoints.

The data from each site were entered into a spreadsheet with data from the four lines accumulated to give 100 points per site. All hits over the toe of the boot were recorded and up to eight species were recorded at one time. Species were given a value of 1 if they appeared at a point even if multiple species were present. The hits recorded for each species were then summed to give a value of abundance. Abundances were graphed for each year. This method may be imperfect for species such as *Cassytha paniculata,* a parasite, for which it is impossible to determine individual plants. This species may be over-represented in the following analysis because of this.

Nomenclature follows that of Allan (1982), Moore & Edgar (1976), Healy & Edgar (1980) and Webb et al. (1988).

3. Results

3.1 INITIAL IMPACT OF FIRES

The 1988 fire covered the majority of the Kaimaumau gumland area, and burned down to 2 m into the peat in some places. The degree of burning would have differed slightly at each plot location, but the effects on each site were similar. Plots 1, 3 and 6 burnt during the first day of the fire, when the wind was travelling in a westerly direction. At plots 1, 3 and 6 the fire resulted in blackened dead standing shrub vegetation. Plots 2 and 7 were burnt two days after the start of the fire, from a nor-westerly direction. This also resulted in blackened dead standing shrub vegetation. Plots 4 and 5 were burnt four days after the fire began, from an easterly direction. Again shrub vegetation was blackened, dead but still standing. It is presumed that less woody material, such as *Schoenus* and *Baumea* species were completely burnt in the fire. Whether or not the rhizomes of these species were burnt is uncertain, as the depth of the burn was not specifically measured at each plot. However, this information can be inferred from the time taken for colonisation of these species. Rhizome regeneration will occur within a much shorter time than seedling germination.

3.2 VEGETATION RECOVERY

Vegetation data are presented graphically in Appendix 1. Appendix 2 is a photo sequence and shows the vegetation recovery at all 7 plots.

Schoenus brevifolius was present in all plots by the first measurement (four months following the fire). This suggests that it grew from rhizomes. Bracken *(Pteridium esculentum)* was also present from rhizome regeneration by 4 months, if it was found at all. In all plots except plot 4, manuka did not arrive until up to one year after the fire, suggesting it grew from seeds from a nearby source. *Gleichenia dicarpa* was present early on in most plots, presumably able to regenerate from rhizomes as well. In plots 2 and 4, *Pomaderris kumeraho* reached a peak frequency in 1994 but declined after that. *P. kumeraho* is generally adapted to rapid regeneration after fire, before being outcompeted by other species.

In plot 7, wattle was established by four months. Wattle was present at this plot before the fire. It is noted for its large seed bank and ability to regenerate after fire. This coverage occurred within twelve weeks of a fire, so it is probable that wattle recorded in plot 7 at four months came from rapid regeneration from the soil seed bank. In contrast, in other plots where wattle was found, first recordings were not made until up to one year after the fire. This suggests that at these sites the soil seed bank was much reduced and that seed had to arrive from surrounding wattle trees.

At plot 6, (a pre-fire gorse stand) gorse was growing by four months. In other post-fire plots where gorse was present, it took at least a year to grow. Gorse creates a large seed bank that is viable for many decades in the soil. Thus, as with wattle, at sites where it existed before the fire, the large seed bank enabled rapid regeneration. At other sites, seed had to arrive from surrounding sources.

Prickly hakea was generally quick to establish in all plots. It also retains a large seed bank on the plant, which is released by fire (Hicks et al. 1997). Seeds germinate quickly (Hicks et al. 1997). From photographs of plot 4, prickly hakea can be seen still standing, blackened and dead, with all the seedpods present on its branches open and unburned inside, suggesting a large amount of viable seed fall.

Plots 1 and 5 were the only plots to have orchids present. In plot 1, Thelymitra was present in March 1989, but had disappeared by the following year. In plot 5, Cryptostylis could be found during the entire measurement period.

3.3 SUCCESSION PROFILE FOR KEY VEGETATION TYPES

For plots 2, 4, 5 and 7, data are available for ten years following the fire. Fig. 3 shows a ten-year trend of species richness summed over these four plots. Fig. 4 shows species richness summed over all seven plots, but only up to 1994. Fig. 4 shows that, over five years, native species richness appears to be declining over all seven plots. However, the ten-year data show less of a decline, suggesting that recruitment of species has ceased and these plots are now stable. A comparison of the vegetation ten years after the fire with pre-fire vegetation shows that at least all the species that were present before the fire are found at each site.

Fig. 4 shows that the weed species richness is slightly less after five years than immediately after the fire. Fig. 3 shows that weed species richness after ten years has not increased since the first weed species were recorded four months after the fire. However, the ten-year data set does not include plot 6, which contained an extremely high proportion of weeds compared to the other plots. Therefore, comparisons between the five- and ten-year weed data should be made with caution.

The number of plants present after the fire has increased linearly with time (Figs 5 and 6). Native plants have doubled in number in the ten years following the fire.

While the native plant numbers are still increasing, weed numbers are levelling out.

From the patterns of vegetation recovery, the successional profile for key vegetation types that are currently developing can be determined. Overall, it seems that species richness is approaching a steady level, which indicates that the community is approaching stability.

The peat bog sites (plots l, 2, 3, 5) have vegetation compositions similar to the pre-fire compositions. Plots 4, 6 and 7 have not followed the same patterns of succession as the other plots due the presence of weed species and different pre-fire vegetation. The succession of these plots will he discussed in Section 3.4.

In the peat bog sites, *Scboenus brevifolius* was the dominant species in terms of amount. Manuka was generally the next most common, although manuka was replaced by *Gleicbenia dicarpca* in plot 5. Overall, for these sites, the general trend of succession can he summarised as follows: *Scboenus brevifolius* established quickly from rhizomes and remained the dominant species. Over ten years, the amount of *S. brevifolius* changed little since it was first measured four months after the fire. Manuka was slower to establish (the exception being plot 1), because it must establish from seed present in the seed bank, or from nearby seed sources. Manuka continued to increase in number after establishment, and ten years after the fire was still increasing. Bracken was able to establish quickly from rhizomes, but remained at low levels in all plots. The parasite *Cassytha paniculata* increased dramatically in most plots after 1994. This species could he described as late successional, as it depends on the presence of other plants for its survival. However, the amount of this plant may have been overestimated, as mentioned in section 2.

Overall, all the species that are present at the peat bog sites colonised shortly after the fire and continued to increase in abundance.

3.4 IMPACTS OF EXOTIC WEEDS

Plots 4, 6 and 7 were the most affected by exotic weeds as is shown in Figs 7, 8 and 9. These three sites were all a mixture of scrub vegetation pre-fire, in contrast to the less weedy peat swamp vegetation. Plot 4 has been the most impacted by exotic weeds. Pre-fire, wattle was only occasional, whereas post-fire, it became the dominant species. Recruitment of wattle became constant after an initial period of rapid increase. *Scboenus brevifolius* and prickly hakea increased, while manuka declined. As manuka requires high light levels for germination, it is likely that the shading from the wattle is preventing new seedling growth. Bracken and kumeraho *(Pomaderris kumeraho)* also declined from a shading effect.

In plot 7, there was a dominance of wattle. Bracken was also present in high amounts. The other native species have followed similar trends to that described for the peat bog vegetation, although the amounts of these species were reduced.

In plot 6, the increase in the amount of gorse has ceased. Kanuka and manuka have begun to increase. Gorse is often promoted as a nursery plant, facilitating the growth of natives. This may be what is happening here, but a longer time-span will be needed to see if gorse will eventually give way to manuka and kanuka.

Prickly hakea was present in all seven plots to some extent. In all but plots 2 and 4, it remained constant at low levels. In plots 2 and 4 it increased. Prickly hakea does not appear to have displaced any natives, but as there is no control plot where prickly hakea is absent, this cannot be confirmed.

Overall, the impact of the exotic weeds gorse and wattle on succession has been to displace the dominance of manuka, kanuka and other shrub vegetation. Future impacts of exotic weeds are discussed in Section 4.2.

4. Discussion

4.1 LIKELY TRAJECTORY OF SUCCESSION

Connell & Slatyer (1977) define succession as the changes observed in an ecological community following a perturbation that opens up a relatively large space. The succession described for Kaimaumau after a large fire shows similar patterns to other wetland vegetation as described by Timmins (1992) and Clarkson (1997). An important determinant of plant succession is the range of species present at the outset and migrating to the site. Vegetation rapidly recovers the burnt surface from rhizomatous growth, rapid seedling germination or resprouting of burnt bases. By ten years, the vegetation has largely returned to pre-fire conditions in places where weeds are absent. Without any further disturbance, the wetland vegetation could be largely expected to remain in a steady state as it exists now. Fire causes a break in the slow successional processes going on in a wetland under normal conditions (Timmins 1992). However, on a longer time scale, the vegetational change in response to fire is short-lived (Timmins 1992).

In the absence of further disturbance, the Kaimaumau peat bog vegetation would remain essentially unchanged, with any succession occurring at such a slow rate as to be unseen in a lifetime. Future disturbance, however, may increase the abundance of weeds present at Kaimaumau. For example, wattle was able to increase dramatically after fire in plot 4. It eventually forms monocultural stands in areas where it invades, with few species present in the understory (J. McQueen unpubl. data). These stands are likely to become a permanent feature of the site due to the presence of a long-lived seed bank which is stimulated to germinate on disturbance.

4.2 FUTURE IMPACTS OF EXOTIC WEEDS

The three main weed species reported in these results (wattle, gorse and prickly hakea) are all adapted to fire regimes. Both prickly hakea and wattle originate from Australia and are adapted to grow on nutrient-poor soils. They can also survive frequent fires. Although a large portion of the seed bank may be destroyed by fire, Pieterse & Cairns (1986) found that a 3% emergence of the seed bank resulted in coverage of 75 seedlings/m·. Wattle and gorse also produce high fuel loads that increase fire risk. Because of the high production of seeds from these species, and fire adaptations that are superior to the natives present, it is likely that these species will remain at Kaimaumau.

Wattle stands are likely to remain either wattle or gorse due to the high numbers of both these species present in the soil seed bank (J. McQueen unpubl.

data). Gorse may act as a nurse crop and eventually give rise to kanuka and manuka stands. However, a longer time is needed to confirm any trends.

Prickly hakea is also likely to remain in the long term because of the huge amount that is present in almost all vegetation types. It is unlikely to be outcompeted by natives in the long term, nor is it likely to increase in distribution without the aid of further fires. However, data from South Africa suggests that we should not be complacent about the threat that prickly hakea poses to the ecosystem. In South Africa, the species has become a major weed of the fynbos, occupying an estimated 480 000 ha, and forming impenetrable thickets of up to 8900 plants/ha (Hicks et al. 1997).

Vitousek (1990) suggests that invaders change ecosystems where they 1) are very different from natives in resource acquisition or utilisation; 2) alter the trophic structure of the invaded area; or 3) alter disturbance intensity or frequency. Gorse and wattle are nitrogen fixers, and thus have a competitive advantage over non-fixing native species. Through nitrogen fixation, there is the potential that these species can cliange the character of the gumland. Increased soil nutrient enrichment is a mechanism thought to promote invasions, alter competitive interactions, and reduce species richness (Maron & Connors 1996). Aesthetic values of the area are also degraded by the much taller wattle. Other effects of these species include changes in soil properties such as aeration, pH, and drainage. The native vegetation of Kaimaumau is adapted to grow in low pH, nutrient-poor, waterlogged conditions. These changes are making the site less suitable for the native vegetation which could, in the long term, be displaced by faster growing exotics or natives not naturally found here.

5. Conclusions

The monitoring of vegetation recovery following fire in 1988 at Kaimaumau indicates that the vegetation of the peat bog recovered quickly, reaching pre-fire compositions by ten years. *Schoenus brevifolius* was the first species to colonise from underground rhizomes. Bracken and *Gleichenia* were also able to recover quickly from rhizomes. Prickly hakea was able to establish quickly from the vast quantities of viable seed released after the fire. Manuka was slower to establish, growing from seeds. Wattle and gorse established quickly in sites where they were present before the fire, from a large soil seed bank. In other areas, establishment was slower as seeds came from nearby sources.

The peat bog vegetation has recovered to its pre-fire composition and is likely to stay that way in the absence of further disturbance. In the long term, vegetation changes caused by fire are short-lived. Succession of the peat bog, like that of other wetlands, is proceeding at an extremely slow rate.

Where weed species have established, the natural succession of manuka/kanuka scrub has been replaced by monocultural stands of wattle and gorse. Manuka and kanuka may be increasing in the gorse stands and may eventually replace it. However, continued monitoring will be needed to confirm this trend. Where wattle has established, it is unlikely to give way to manuka and kanuka. The absence of understory species and the huge amounts of wattle and gorse seeds present underneath suggest that these stands will regrow following disturbance. Since wattle is able to outcompete gorse on dry sites, it is likely to stay.

Wattle and prickly hakea have had the opportunity to expand their ranges following the fire. Therefore it will be necessary to control fires in the future to help prevent the spread of these species. However Wardle (1991) suggests that retaining gumland vegetation "depends on establishment of reserves where fire can be accepted as a management tool" (p. 201). This poses the question of how to manage fires to retain the vegetation type, without encouraging weeds.

6. Recommendations

1. That the Department of Conservation continue to monitor at 1-2 yearly intervals changes in the vegetation at each of the seven sites, particularly those with weed species present (plots 4, 6 and 7) in order to provide long-term data on the effect of these species on natural succession, or to provide before and after data if control measures are put into place.

2. That the Department of Conservation continue control programmes on the weed species, wattle, gorse and prickly hakea, present at Kaimaumau.

3. That the Department of Conservation continues to control and contain fires within Kaimaumau in order to prevent the spread of fire-adapted exotic weeds, while ensuring tile survival of gumland vegetation types.

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Figure 1. Kaimaumau wetland, showing boundaries of conservation lands.

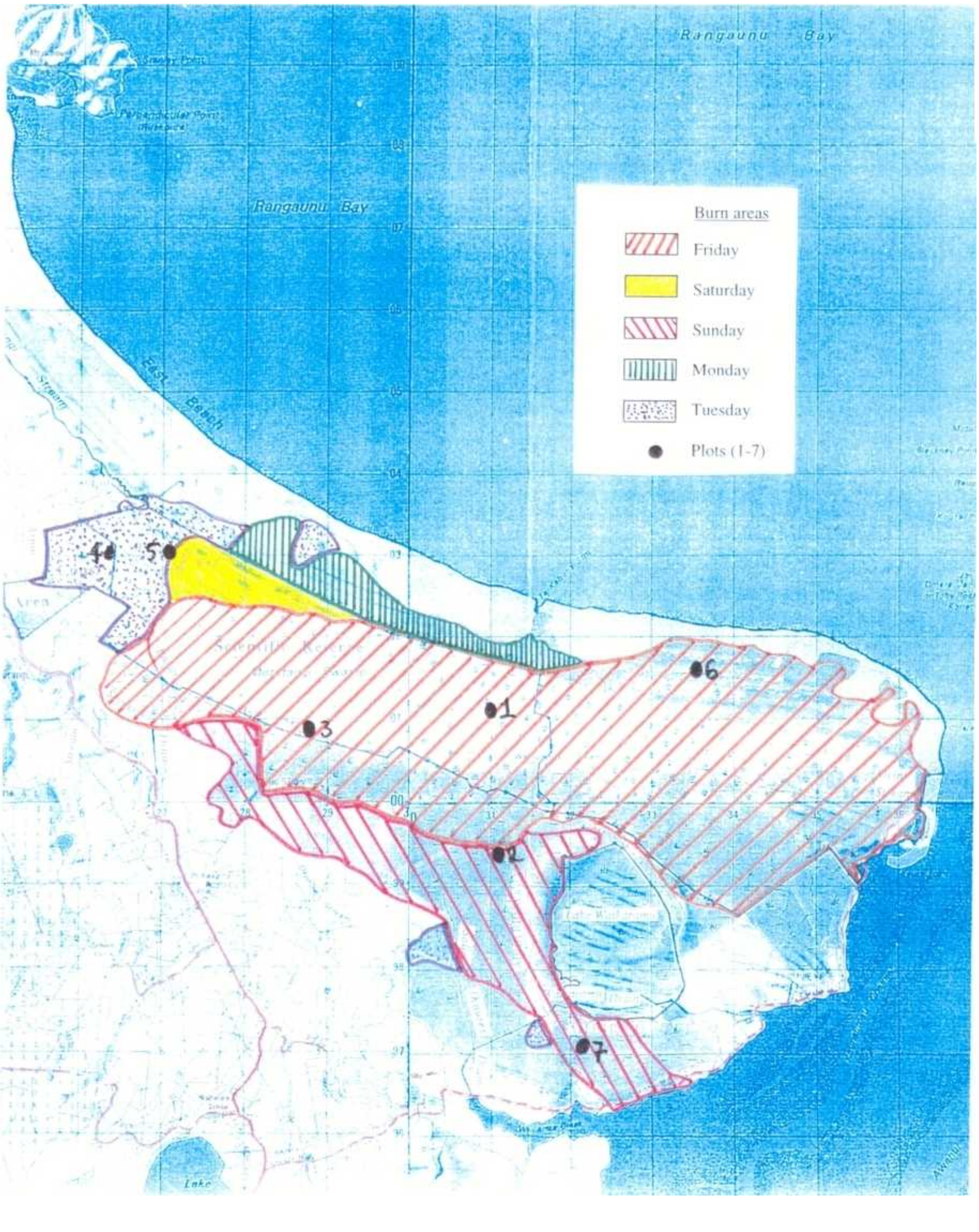

Figure 2. Extent of 1988 fire in Kaimaumau gumland, and location of experimental plots.

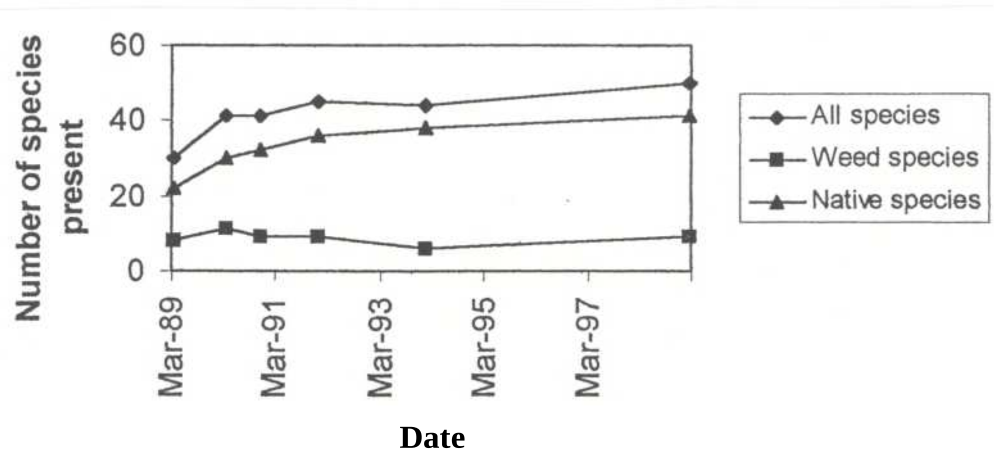

Figure 3. Species richness versus time for ten years. Data is the sum of plots 2, 4, 5 and 7 .

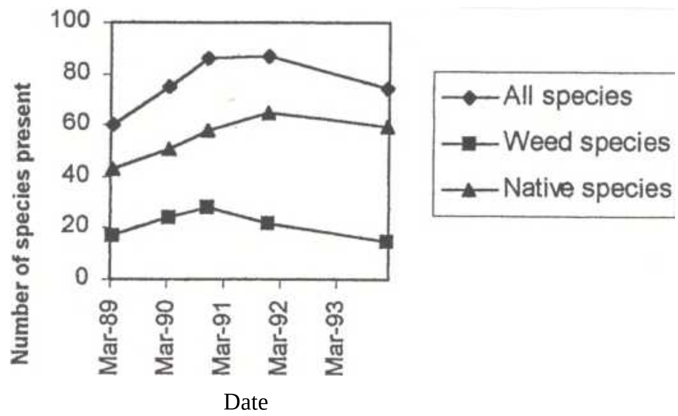

Figure 4. Species richness versus time for five years. Data is the sum of all seven plots.

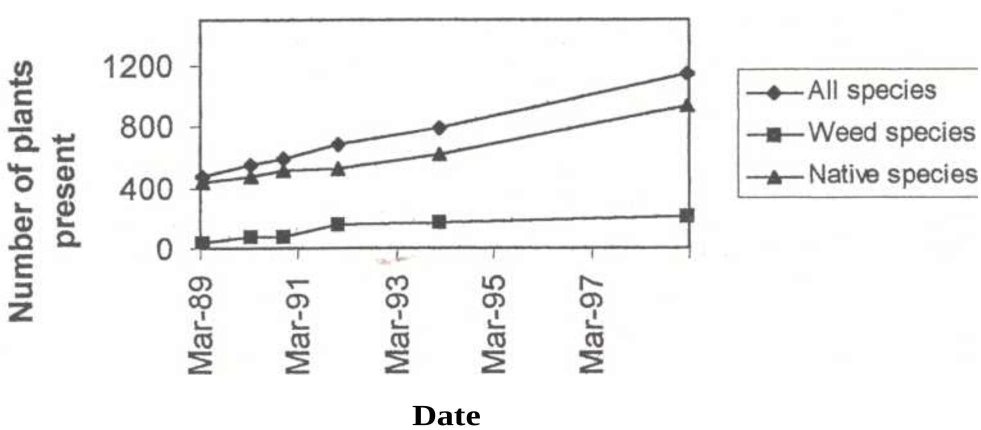

Figure 5. Species abundance versus time for ten years. Data is the sum of plots 2, 4, 5 and 7.

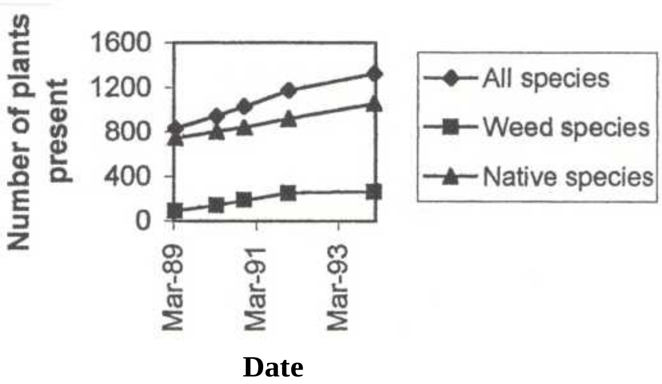

Figure 6. Species abundance versus time for five years. Data is the sum of all seven plots.

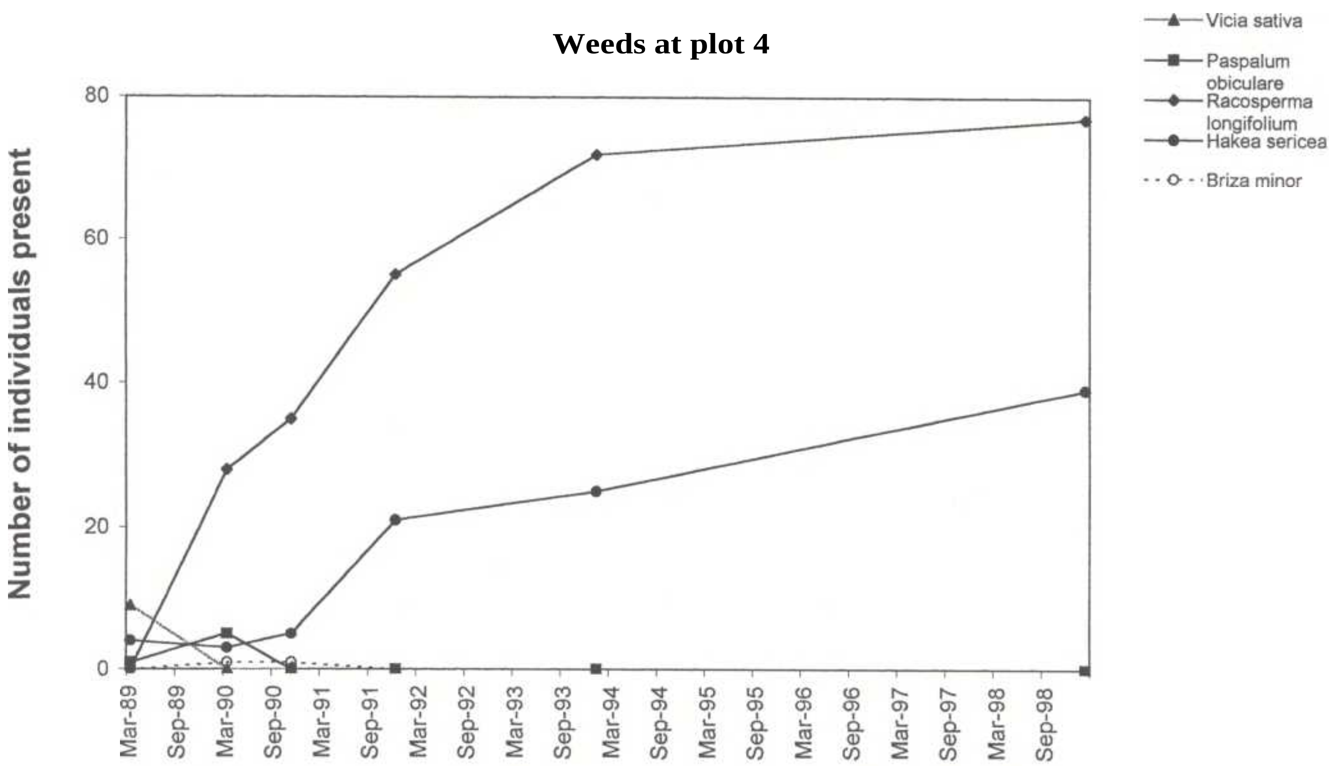

Figure 7. The abundance of weed species present at plot 4 for ten years .

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