HORSE RIDING TRAILS IN JOHN FORREST NATIONAL PARK: AN ENVIRONMENTAL IMPACT ASSESSMENT

A Report Compiled by P. Royce B.Sc. (Hons.)
Commissioned by the National Parks Authority
of Western Australia. November 1983.

RECOMMENDATIONS

1. Horse riding trails should be prohibited in all National Parks in Western Australia where trails have not already been approved.

2. Environmental impact studies should be made in all National Parks which already have approved horse trails and recommendations made on the need to phase out trails.

3. Applications to increase horse trails in National Parks which already have approved trails should be rejected.

4. Horse trails in John Forrest National Park should be phased out immediately using legislative powers available to the N.P.A.

5. If point 4. is considered inappropriate then :
   (a) information signs outlining the environmental impacts of horse riding should be installed at strategic locations. This could be supplemented by booklets and talks to members of riding clubs who use John Forrest National Park.
   (b) a maximum limit of 15 riders in each riding school group should be imposed. A limit to the number of groups allowed each week should also be imposed.
   (c) adequate funds should be allocated to the Park for erosion, dieback and weed control and general trail maintenance.
   (d) signs should be installed at entrances to illegal trails warning riders that prosecution may result if caught using the trails. Rangers should have powers to prosecute riders.
   (e) vandal-proof signs showing approved horse trails should be installed.
   (f) commercial enterprises which use and benefit from horse trails should be made to pay not less than $500 but not more than $1,000 annually toward train maintenance.
   (g) expansion of the current horse trail system should not be permitted.
   (h) a programme of regular monitoring of horse trails should be established to identify changes in environmental impacts.

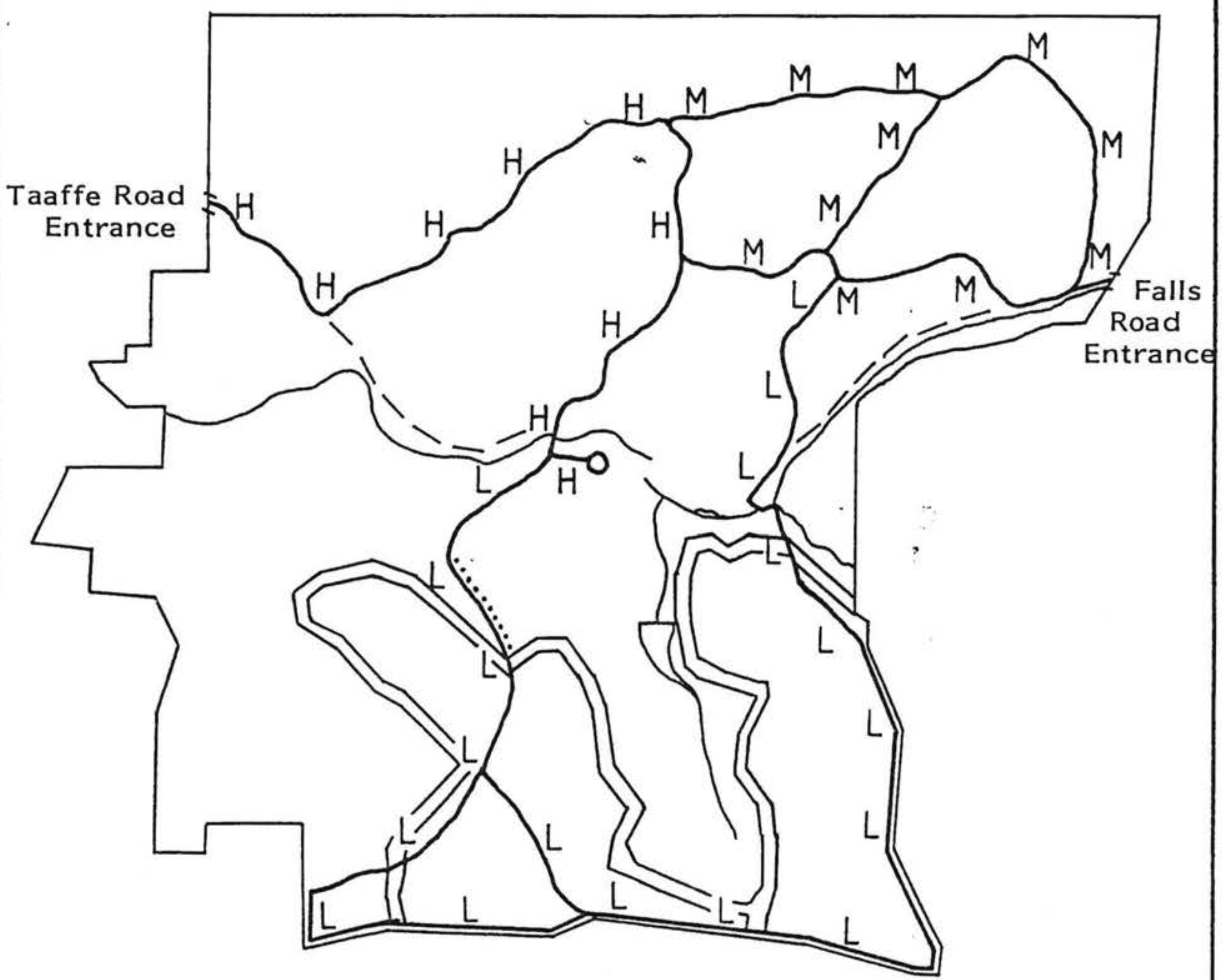
1.0. INTRODUCTION

Official permission for horse riding in John Forrest National Park was first granted upon request in 1969. The approved horse trails were then only 4.9kms of firebreaks. During the 1970's however, the increasing popularity of horse riding led to demands for more trails. In response to recent public pressure, particularly from the John Forrest Riders Association, the National Parks Authority (hereafter N.P.A.) approved more trails and re-routed old ones on several occasions. This resulted in an increase of approved trails from 7.1kms in 1980 to 22.7kms in 1981 - a 320% increase. No alterations have since been made. The currently approved horse trails in John Forrest National Park are shown in Map 1.

Although statistics on trail use are unavailable, relative levels of use are known. As shown on Map 1, three use-levels are recognised. The trail with the heaviest use extends from the Taaffe Road entrance in the north-west to the holding yard above the barbecue facilities south of the old railway alignment. This 5.3km trail is used mostly by riders from the Swan View Equestrian Lodge. Groups of 50 horses from the riding school have been sighted on this trail. The trails with moderate use are in the north-eastern area of the Park. The closest approved entrance is Falls Road, although several firebreaks are sometimes illegally used. These trails are 6.1kms long. Residents from localities east and south, and possibly west, of the Park are the main users of these trails. Riding school groups rarely use these trails. The trails with low use are mostly south of the railway alignment. Riders are rarely sighted on these trails. These 11.3km trails are probably used by residents south of the Park as access routes to trails north of the railway alignment. All trails are primarily firebreaks serving the dual roles of horse trail and firebreak, although one 610m section of the low use trail was constructed by Rangers expressly as a horse trail.

Two major illegal trails occur: one branches off the trail with heavy use near Taaffe Road, the second parallels Jane Brook between Hovea Falls and the Falls Road entrance. Of these, the Taaffe Road illegal trail is the more heavily used. The Jane Brook illegal trail also serves as a pedestrian trail. Many other firebreaks throughout the Park are also occasionally used illegally - particularly north of the railway alignment. The most popular period for horse riding on all trails is

Map 1 : The Approved Horse Trails and Illegal Trails in John Forrest National Park.



L = Trail with Low Use

M = Trail with Moderate Use

H = Trail with Heavy Use

— — = Illegal Trails

═ (dotted) = Trail Constructed by Rangers.

during the winter or spring months.

Annual or daily permits are required for horse riding in the Park. Of the 40 annual permits issued since November 1981, 30 (75%) of applicants were from localities adjoining the Park, with the rest from more distant localities such as Maylands, Mt. Lawley and Balga (Table 1). These permits have entitled 125 people to use the trails, of which 99 (79%) were from adjoining localities. Thus most horse trail users with permits reside close to the Park. The majority of trail users however are members of riding school groups and not included on annual permits. Together, annual permit holders and estimated numbers in riding school groups represent only 4% of the annual visitors to John Forrest National Park (B. Muir, N.P.A. Ecologist: pers. Comm.).

Table 1 The Number and Localities of Annual Permit Holders Since November, 1981.

A. Localities Adjoining J.F.N.P.	Total Permits Issued	Permit Renewals	Total on Permits
Swanview	4	1	16
Greenmount	3	1	7
Darlington	3	1	11
Glen Forrest	10	3	41
Hovea	7	2	20
Parkerville	3	1	4
	30	9	99
B. Localities Not Adjoining J.F.N.P.			
Mundaring (7kms)	5	2	12
South Guildford (10kms)	1	0	1
Welshpool (16kms)	1	0	4
Maylands (19kms)	1	0	4
Mt. Lawley (20kms)	1	0	4
Balga (24kms)	1	0	1
	10	2	26

The environmental impacts of horse trails have caused concern since 1971, but moreso since 1978 when the N.P.A.'s Ecologist (Dr. Start) reported that horse trails had caused problems with erosion, introduction and spread of weeds, trampling of native plants, spread of dieback (Phytophthora cinnamomi), removal of bark from trees and trail corner-cutting. Additional problems described by the Park Superintendent in June 1980 included the introduction of exotic plants on horse trails and the cropping of Blackboys (Xanthorrhoea preissii). Another descriptive report in August 1980 by the N.P.A.'s Ecologist (Mr. B. Muir) confirmed previously stated environmental impacts and added soil compaction, soil break-up, trail anastomosation and fouling of pedestrian trails. Many public complaints to the N.P.A. and Rangers have concerned environmental damage by horses. These have included Blackboy cropping, bark removal, corner-cutting and fouling pedestrian trails. To date however, no study has quantified these environmental impacts of horse trails.

1.1. Study Rationale and Objectives

Due to present and anticipated future public pressure to install horse trails in Yanchep, Neerabump, Pemberton, Yalgorup and other National Parks, and to increase horse trails already installed in John Forrest, Torndirrup, Walpole, Kalamunda and Walyunga National Parks, it is important that Western Australian decision-makers and Park administrators understand the environmental impacts of horse trails. Through improved understanding of these environmental impacts, better informed management decisions regarding horse trails in National Parks can be made. This scenario is the basic rationale for this report.

The major objectives of this study were :

1. Provide an environmental impact assessment of horse trails and illegal trails in John Forrest National Park.

2. Provide recommendations concerning horse trails in John Forrest National Park and in National Parks generally.

To achieve these objectives, an analytical approach was used - trails with relatively similar environmental characteristics, but with different levels of use were compared. Observed differences between trails were due to differences in trail use. Aspects of the environment examined, included soil compaction, erosion, trail anastomosation, Blackboy cropping, weed cover, floristic health, vegetation cover reduction, dieback and several others.

2.0. THE ENVIRONMENTAL IMPACT OF HORSE RIDING: A BRIEF LITERATURE REVIEW

The environmental impact of trampling by pedestrians has been the subject of much research (see reviews by Speight, 1973; Liddle, 1975). The environmental impact of trampling by horses however has not. The following review includes some aspects of pedestrian trampling which are applicable to horse trampling.

2.1 Vegetation

Trampling by horses can result in either enrichment or impoverishment of plant communities (Westhoff, 1967). Enrichment occurs through the creation of more favourable environmental conditions for new colonizers, the removal of plant competitors allowing new species to invade, or the introduction of plant seeds transported via horse manure or hooves. For example, some trampling can stimulate plant biomass and increase species diversity through improving plant root access to higher moisture-retaining soils (Bayfield, 1971; Liddle and Greig-Smith, 1975a). Only low levels of trampling however can result in enrichment of plant communities.

When trampling is increased beyond the carrying capacity of the environment, deterioration or impoverishment of plant communities occur (Westhoff, 1967). Horses affect plant communities directly or indirectly. Direct effects are the cropping, breakage and trampling of plants on horse trails. Cropping of trailside vegetation is dependent on the palatability of plants and can result in significant plant cover reductions (Cole, 1981). Where trails are narrow, horses can break off shrub branches. This can lead to plant deaths. The resistibility of plants to breakage and trampling varies: those without appropriate growth forms or organic structures (e.g. tree seedlings, shrubs), are rapidly replaced by more resistant plant forms (e.g. certain grasses), resulting in changes to floristic composition (Perring, 1967; Liddle, 1975; Liddle and Greig-Smith, 1975a). Generally, as trampling levels increase, dicotyledonous species are replaced by more resistant monocotyledonous species (Liddle and Greig-Smith, 1975a). The higher susceptibility to trampling of dense forests compared with open forests or grasslands can be attributed to inappropriate growth forms (Cole, 1978).

The effects of trampling are more serious in winter, when the soil is wet, than in summer (Liddle, 1975). Indirect effects include unfavourable alterations to soil properties and microclimate, such as soil compaction causing root desiccation (McQuaid-Cook, 1978). Horses are efficient vectors for plant dispersal (Cole, 1981). This can result in introductions of undesirable exotic plants and weeds. The spread of plant diseases on horses hooves can also result in reduced trailside vegetation.

Both direct and indirect effects can alter floristic composition, reduce species diversity, reduce plant cover, reduce plant biomass and reduce community stability along horse trails (Westhoff, 1967; Perring, 1967; Liddle, 1975; Cole, 1981). These effects on vegetation are evident some distance from horse trails: up to 7m from meadow trails (Foin et al, 1977). Most effects however are observed within 1-2m of the trail (Bayfield, 1971; Burden and Randerson, 1972; Dale and Weaver, 1974; Weaver and Dale, 1978). The distance from trails of floristic impacts is determined by vegetation type and intensity of use (Cole, 1981).

2.2. Soil

The major impacts of horse trampling on soil are soil compaction and erosion. The severity of these depend on climate, slope, drainage, rockiness, soil texture, organic content, vegetation and level of use (Weaver and Dale, 1978; Summer, 1980). Most soil compaction occurs on flat terrain with fine textured soils (McQuaid-Cook, 1978). The horse-weight per unit area and frequent use of trails can result in rapid soil compaction: trails can become 13-26 times more compact after one trail-riding season Summer, 1980). Soil compaction causes depressions which can act as watercourses, thereby facilitating surface run-off and erosion. Consequences of compaction on soil properties include reduced soil structure, reduced infiltration capacity, reduced soil oxygen, reduced nutrient diffusion in soil water, limited mineralization of organic matter and numerous soil chemical changes (Burden and Randerson, 1972; Liddle and Greig-Smith, 1975a). Soil micro- and macro-fauna, soil micro-flora and trailside plants can be reduced by soil compaction (Chappell et al, 1971; McQuaid-Cook, 1978).

Erosion occurs on slopes, becoming more severe with increasing use and slope (McQuaid-Cook, 1978). Horse hooves have a ploughing or scooping action. This action accelerates plant removal and causes soil loosening or soil-breakup (McQuaid-Cook, 1978; Summer, 1980). Horses can push soil downslope or transport soil in hooves along trails. Surface run-off carries loose soil downslope in water channels. With time, severe gully erosion occurs. Horses also kick free rocks which would otherwise help prevent soil-loss. When trail conditions become unpassable, horses find alternative routes. These trailside alternative routes soon become well-used, increasing the damage to plant cover and resulting in further erosion (McQuaid-Cook, 1978; Summer, 1980).

2.3. Water Quality

Horse trails in catchment areas or near watercourses can cause deterioration of water quality (McFeters and Stuart, 1976). This can be the consequence of manure washed into watercourses from trails, camping sites or holding yards (McFeters and Stuart, 1976). The impact of nitrogen and other nutrients from horse manure into aquatic ecosystems can endanger aquatic life downstream. Water quality deterioration can also result from more indirect means. For example, lakeside trampling resulting in reduced plant cover and severe erosion has led to high phosphorus loadings, high turbidity, changes in phytoplankton composition and generally eutrophic conditions in a small wilderness lake (Dickman and Dorais, 1977).

2.4. Horses and Pedestrians : A Comparison

The environmental impact of horses is much greater than the environmental impact of pedestrians. Horses remove more vegetation cover, create wider trails, create deeper trails and cause higher soil compaction than pedestrians on both slope and level terrain and in both grassland and forest areas (Weaver and Dale, 1978; Weaver et al, 1978). Recovery of trails after use is also slower after horses than pedestrians (Weaver and Dale, 1978). Due to differences in weight per unit area, in walking actions and in hoof/shoe hardness, horses cause more soil loosening and soil break-up on slopes than pedestrians. Therefore horses would cause more erosion than pedestrians. For similar reasons, horses would remove more vegetation cover during trampling than pedestrians. Both horses and pedestrians cause more environmental damage descending slopes than ascending slopes (Weaver and Dale, 1978).

3.0. METHODS

3.1. Soil Compaction

The compaction, or penetration resistance, of trail soils to a depth of 300mm was measured using a 'drop-block' soil penetrometer. Soil compaction was measured on the trail and again 1-3m from the trail. Samples were repeated every 40-60m along the trail. All sampling was conducted on sections of trail where slope was negligible (0-3%). Vehicular traffic and recent trail maintenance precluded compaction tests on the low, moderate or heavy use trails. Sampling was therefore restricted to the Taaffe Road and Jane Brook illegal trails and the Ranger-constructed trail.

3.2. Soil Erosion

Cross-section profiles were made at 2.5m intervals along 18, 10m transects on the Taaffe Road and Jane Brook illegal trails. At each cross-section, trail width and trail depths were measured and used to calculate compacted soil-loss volumes for each 10m transect (see Bannister and Raymond, 1977). To identify possible relationships between soil-loss volumes and slope and/or soil texture, transect sites were selected from a range of slopes (0-12%) and soil textures (sandy - loam - gravel). Measurements were initially made using a Topcon TL-20 theodolite. This however proved too time-consuming, so a tape-measure and inclinometer were used instead.

3.3. Trail Anastomosation

The Taaffe Road illegal trail had one main trail with many smaller alternative trails. Total lengths of the main and alternative trails were measured using a 100m tape-measure. In flat areas, distances were paced. Point transects were used to determine the number of alternative trails within 15m of the main trail.

3.4. Blackboy Cropping

The incidence of Blackboy (Xanthorrhoea preissii) cropping was examined using 50m x 5m belt transects adjacent to trails in areas with large (> 20) Blackboy populations. The dead/knocked over, uncropped, lightly cropped and severely cropped Blackboys were counted in each transect. Totals were converted to relative proportions. Blackboys without visible growing points were considered dead. Blackboys with 0-50% of their leaves intact were considered lightly cropped, those with 50-100% of their leaves intact were considered severely cropped. Trails with low, moderate and heavy use, illegal trails and unused areas were sampled using 10 transects per trail.

3.5. Weed Cover

The percent cover of weeds in a $1m^2$ quadrat adjacent to trails was estimated and assigned a grading. The grading scheme used was : 1(0-15% cover of weeds), 2 (15-30%).....5(60-75%), 6 (over 75%). Thus lower grades represented lower percent cover of weeds. To negate the influences of some trails having more habitats which were more favourable for weed establishment than others, sampling was conducted on flat, slope and in gully areas on each trail. Thus weed cover gradings on flat, slope and in gully areas were comparable. Between 19 and 25 quadrats were used on trails with low, moderate and heavy use, illegal trails and unused areas. Sampling was not conducted near Great Eastern Highway and Park Road due to possible influences from weeds in road verges.

3.6. Floristic Health and Cover Reduction

Both floristic health and percent cover reduction were estimated from two $1m^2$ quadrats: one adjacent to the trail, and another 10m from the trail. This 10m distance was chosen to avoid trailside influences (see Section 2.1). A grading scheme (0-3) was used to quantify floristic health. Factors considered were: visible plant damage, presence of weeds, presence of dead or dying plants, adult/seedling plant ratios and percent bare ground. Lower grades represented better floristic health.

Percent cover was estimated in each quadrat. The percent cover reduction between quadrats (trailside - 10m) was calculated using the method described by Cole (1978, 1981). The trails with low, moderate and heavy use were sampled for floristic health and cover reduction using 22 paired quadrats. Illegal trails were sampled using 44 paired quadrats.

3.7. Dieback

The incidence of dieback (Phytophthora cinnamomi), as measured by the number of dead plants, was examined using 25m x 2m belt transects adjacent to trails. Dead plants in the transect were counted. Although natural senescence would have caused some plant deaths, the relative proportion of these deaths should be similar between trails. Thus observed differences in numbers of dead plants between trails could be atrributed to dieback. Where possible, dead plants were identified. Ten transects were positioned on each trail with low, moderate and heavy use, illegal trails and unused areas.

3.8. Comparison With 1980 Baseline

In September 1980, a photographic record of new horse trails was made. This enabled a comparison between environmental conditions in 1980 with environmental conditions in 1983. At each comparable location, the following were examined and graded: current level of use (low-moderate-heavy), current incidence of dieback relative to 1980 (1-5), current erosion problems relative to 1980 (1-5), regeneration/growth of vegetation since 1980 (1-5) and the overall change in environmental quality since 1980 (-5-5). Overall environmental quality assessments considered presence/absence of weeds, dieback, erosion, Blackboy cropping and general floristic health. Minus values represented deterioration and positive values improvement since 1980. For each environmental assessment, lower gradings represented smaller changes. A total of 26 locations were compared.

3.9. Miscellaneous

Visual assessments were made of the effects of trampling and on the incidence of corner-cutting, fouling of pedestrian trails, bark removal and potential risks of horses to water quality on all trails.

3.10. Data Analysis

The statistical and comparative analysis of data is summarised in Table 2. Student T-tests were used to find significant differences between means. The 5% level of significance was used in all

Table 2 - Summary of Data Analysis

Assessment	Data	Test	Conducted On	Tested Between
Soil Compaction	Q	Student T-test	I, R	Trailside - 10m from trail
Trail Erosion	Q	Student T-test	I	Slope and Soil Texture
Trail Anastomosation	Q	Comparative	I	Main and Alternative trails
Blackboy Cropping	Q	Test of Proportions	U, L, M, H, I	All trails
Weed Cover	G	Student T-test	U, L, M, H, I	Flat, Slope and Gullies on all trails
Floristic Health	G	Student T-test	L, M, H, I	All trails
Cover Reduction	E	Student T-test	L, M, H, I	All trails
Dieback	Q	Student T-test	U, L, M, H, I	All trails
Comparison With 1980 Baseline	G	Comparative	L, M, H	Comparative Locations On All Trails
	E=Estimation G=Grading Q=Quantitative		R=Ranger-constructed Trail U=Unused Area L=Low Use Trail M=Moderate Use Trail H=Heavy Use Trail I=Illegal Trail	

tests, unless otherwise stated. Means were calculated from grades awarded for weed cover and floristic health. Most tests were between trails. Other tests compared data from trails with data from adjacent areas.

4.0. RESULTS

4.1. Soil Compaction

Soil compaction was significantly higher on all trails examined than in areas 1-3m off the trail (Table 3). All differences were significant at 1%. The largest percent difference in compaction between trails and adjacent areas was for the Jane Brook trail (303%), and the smallest for the Ranger-constructed trail (138%). According to one soil compaction classification, all trails were 'compact' and all adjacent areas 'loose', except the Jane Brook trail which was 'very loose' (see Capper and Cassie, 1976).

Table 3 - Soil Compaction on Trails and 1-3m From Trails

		On Trail		1-3m From Trail	
Trail	N	Mean	s.d.	Mean	s.d.
Taaffe Road Illegal Trail	25	15.6^{2}	4.30	6.9^{1}	2.37
Jane Brook Illegal Trail	20	10.0^{2}	2.59	3.3^{1}	1.35
Ranger-constructed Trail	15	12.6^{2}	3.83	9.1^{1}	2.86

NOTE: Numerical symbols denote significant differences between soil compaction on each trail: similar numerals represents no significant difference; Dissimilar numerals represents a significant difference.

Visual assessments on other trails indicated that soil compaction was higher in sandy-loam areas than gravelly areas. Where horses have travelled in single file, distinct compacted depressions 250mm wide and 60-120mm deep have formed. These depressions were seen in flat areas on trails with heavy use. No depressions were seen on trails with low or moderate use.

4.2. Trail Erosion

The volume of soil-loss increased with slope on both illegal trails (Table 4). The mean volume on 0-3% slopes (.46m³) was significantly less than those on 4-7% slopes (.89m³) or 8-12% slopes (1.08m³).

This correlation with slope was due to trail depth, not trail width: trail depth increased significantly with slope, whereas trail width did not. The source of soil-loss was therefore in the vertical plane (depth), not the horizontal plane (width). Inadequate sample sizes precluded conclusions on possible soil texture - soil-loss volume correlations for each slope class, except that volumes of soil-loss in both gravel and sandy-loam soils increased with slope. Although the mean soil-loss volumes appear small, these calculations are the 'compacted' volumes: actual volumes of soil lost could be almost 20% more.

Table 4 - Soil-Loss Volumes in Various Slope and Soil Texture Classes

Percent Slope	N	Trail Width (mm)	Trail Depth (mm)	Soil-Loss Volumes (m^3): All Soil-textures	Gravel	Sandy-Loam
0-3	6	795^{1}	74.0^{1}	$.46^{1}$	.53(2)	.43(4)
4-7	5	787^{1}	137.0^{2}	$.89^{2}$	.82(2)	.94(3)
8-12	7	821^{1}	166.0^{3}	1.08^{2}	1.15(3)	1.03(4)

NOTE: Numerical symbols denote significant differences between slope classes and either trail widths, trail depths or soil-loss volumes: similar numerals represent no significant difference; dissimilar numerals represent a significant difference. Figures in parentheses represent sample sizes for each soil texture in each slope class.

Visual assessments on trails with low, moderate and heavy use indicated all had some erosion problems. The severity of erosion however was correlated with the level of use. Erosion was most severe on slopes over 8%, regardless of soil texture. Surface run-off has created broad and deep gullies on most slopes. On the heavily used trail,one 12-15% slope had some gullies measuring 400-550mm wide and 250-350mm deep. Horses have assisted erosion on slopes through soil break-up and kicking free stones which help prevent soil-loss.

4.3 Trail Anastomosation

The main trail on the Taaffe Road illegal trail was 2.23 kms long, compared with 2.61kms of alternative trails. Each alternative trail had several minor trails which often connected with other alternative trails. Point transects indicated that within 15m of the main trail, up to four alternative trails can be present. This has resulted in a maze of trails which dissect the landscape.

The Jane Brook illegal trail had only minor trail anastomosation compared with the Taaffe Road illegal trail. Most alternative trails on this trail crossed the old railway alignment and Jane Brook from nearby private properties. Some cross-country routes were also noted leaving the trail.

4.4. Blackboy Cropping

Proportionally more Blackboys were cropped and killed with increasing trail use (Table 5). The trail with the heaviest use and illegal trails had significantly higher proportions of lightly and severely cropped and dead/knocked over Blackboys than trails with low or moderate use and unused areas. Conversely, the proportion of uncropped Blackboys on the heavily used trail and illegal trails were significantly lower than other trails and unused areas. Almost half the 383 Blackboys on the heavily used trail were severely cropped or dead/knocked over. Dead/knocked over Blackboys on the illegal Taaffe Road trail represented almost 94% of the proportion shown in Table 5 for both illegal trails. Blackboys on top of steep slopes were often cropped which suggested horses were allowed to graze while resting or waiting for stragglers.

Table 5 - The Proportion of Dead/Knocked Over, Lightly Cropped, Severely Cropped and Uncropped Blackboys (X.preissii) on Each Trail

Trail	n	Lightly Cropped	Severely Cropped	Dead/Knocked Over	Uncropped
Unused Areas	512	$.057^{1}$	$.014^{1}$	$.043^{1}$	$.886^{3}$
Low Use Trail	312	$.080^{1}$	$.013^{1}$	$.032^{1}$	$.875^{3}$
Moderate Use Trail	339	$.159^{2}$	$.038^{2}$	$.021^{1}$	$.782^{2}$
Heavy Use Trail	383	$.232^{3}$	$.243^{4}$	$.204^{2}$	$.321^{1}$
Illegal Trails	447	$.262^{3}$	$.123^{3}$	$.239^{2}$	$.376^{1}$
	1,993				

NOTE: Numerical symbols denote significant differences between trails in each stage of cropping: similar numerals represent no significant difference; dissimilar numerals represent a significant difference.

4.5. Weed Cover

The percent cover of weeds generally increased with increasing trail use (Table 6). Trails with moderate and heavy use had significantly higher weed cover in gullies than trails with low use and unused areas. The heavily used trail had over three times the weed cover in gullies than trails with low use. The illegal trails and moderately used trail had similar weed covers. No significant differences were found on slopes between trails, although the highest weed cover was on trails with moderate and heavy use and the lowest on trails with low use. On flat areas trails with heavy use had significantly higher weed cover than trails with low use. Thus weed cover in gullies, on slopes and flats increased with increasing trail use.

Table 6 - Mean Weed Cover Gradings on Flats and Slopes and in Gullies on all Trails

	Flat			Slope			Gully		
Trail	n	mean	s.d.	n	mean	s.d.	n	mean	s.d.
Unused Areas	6	1.2^{12}	.408	8	1.4^{1}	.517	8	1.9^{1}	.641
Low Use Trail	8	1.0^{1}	0	7	1.1^{1}	.378	4	1.5^{1}	.577
Moderate Use Trail	8	1.1^{12}	.353	10	1.6^{1}	.843	7	3.4^{23}	1.718
Heavy Use Trail	7	1.6^{2}	.787	8	1.6^{1}	.744	9	4.7^{3}	1.414
Illegal Trails	7	1.4^{12}	.534	8	1.1^{1}	.353	9	2.7^{2}	.707

NOTE: Numerical symbols denote significant differences between trails with mean weed cover gradings on flats and slopes and in gullies: similar numerals represent no significant difference; dissimilar numerals represent a significant difference. Lower gradings represent lower percent cover of weeds.

The weeds observed included: Capeweed (Arctotheca calendula), Clover (Trifolium sp.), Flatweed (Hypochaeris radicata), Soursob (Oxalis pescaprae), Patersons Curse (Echium plantagineum), Stinkwort (Inula graveolens), and the grasses Wildoat (Avena sativa), Bearded oat (A. barbata), Annual ryegrass (Lolium rigidum), Couch (Cynodon dactylon), Kangaroo grass (Themeda australis), African Lovegrass (Eragrostis curvula) and several more. Other weeds were observed but not identified.

Weed cover was particularly high in and below the holding yard, on the slope leading up from the Jane Brook crossing and around Jane Brook. All these were located on heavily used trails but were not sampled. Percent weed cover in these areas would be 80-100%. Weeds such as those cited above were often observed growing from lumps of horse manure. The trail with the heaviest use had the most manure and consequently the most weeds growing from manure.

4.6. Floristic Health and Cover Reduction

Floristic health on trails deteriorated with increasing trail use (Table 7). The floristic health on illegal trails and trails with heavy use were significantly poorer than that on trails with low use. The floristic health 10m from all trails was similar.

Table 7 - Floristic Health, Cover Reduction and Dieback on all Trails

	Floristic Health			Cover Reduction		Dieback	
Trail	N	Adj. to Trail	10m from Trail	N	mean %	N	No. dead plants
Unused areas	-	-	-	-	-	10	6.7[1]
Low use trail	22	1.0[1]	.6[1]	22	12.4[1]	10	7.6[1]
Moderate use trail	22	1.2[1]	.7[1]	22	16.5[1]	10	10.9[2]
Heavy use trail	22	1.6[2]	.7[1]	22	27.8[1]	10	19.5[3]
Illegal trails	44	1.6[2]	.5[1]	44	21.2[1]	15	13.3[2]

NOTE: Numerical symbols denote significant differences between trails and floristic health gradings, mean cover reduction and dieback (number of dead plants): similar numerals represent no significant difference; dissimilar numerals represent a significant difference. Lower gradings for floristic health represent better health.

Floristic health improved with distance from trails (Table 7). Floristic health was significantly poorer on trails with moderate and heavy use and illegal trails than 10m from the trail. Trails with low use also had poorer floristic trailside than 10m from the trail, but the difference was not significant. Thus, more damaged plants, more weeds, more dead or dying plants, higher adult/seedling plant ratios or more bare-ground occurred on trails than 10m from trails.

The mean percent cover reduction increased slightly with increasing trail use (Table 7). No significant differences however were observed. High variability accounted for this - cover reduction ranged between 89% and -128% on a single trail.

4.7. Dieback

The incidence of dieback, as measured by the number of dead plants, increased with increasing trail use (Table 7). The trails with moderate use and illegal trails had significantly higher numbers of dead plants than trails with low use and unused areas. The most heavily used trail had significantly more dead plants than all trails. The plants most susceptible to dieback appeared to be Hakea spp, Isopogon spp, Dryandra spp, Banksia spp and Blackboys. Other dead plants could not be identified.

4.8. Comparison With 1980 Baseline

Because 77% of 1980 baseline photographs were taken on trails with low use, comparative studies between trails with different uses were limited. It was apparent however that on trails with low use major environmental changes had not occurred (Table 8). A higher incidence of dieback in 1983 compared with 1980 was observed in 35% of localities. However all increases, but one, were marginal. Erosion was unchanged between 1980 and 1983 in all but four locations which were on steep gravel slopes. Regeneration or growth of vegetation was observed in 35% of locations, of which all differences were again marginal. Since 1980, changes in environmental quality varied. Overall, environmental deterioration was greater than the environmental improvements.

Table 8 - Comparison of Environmental Quality Changes Since 1980 at Locations on all Trails

Location	Level of Trail use	Dieback	Erosion	Regeneration/ Growth	Overall change in Env. Quality
	(low-mod-heavy)	(1-5)	(1-5)	(1-5)	(-5-5)
Peg 1	Low	2	1	2	+1
Peg 2	Low	3	1	1	-2
Peg 3	Low	2	1	1	-1
Peg 4	Low	1	1	1	0
Peg 5	Low	1	1	1	0
Peg 6	Low	1	1	1	0
Peg 7	Low	1	1	1	0
Peg 8	Low	1	1	1	0
Peg 9	Low	1	1	1	0
Peg 10	Low	1	1	2	+1
Peg 11	Low	1	1	2	+1
Peg 12	Low	2	1	2	+1
Peg 13	Low	2	1	2	+1
Peg 14	Low	2	1	1	0
Trail edge	Low	2	1	2	+2
Peg 15	Low	1	2	1	-1
Peg 16	Low	1	2	1	-2
Peg 17	Low	1	2	1	-2
Peg 18	Low	1	2	1	-1
Creek	Low	1	1	2	+1
Holding Yard	Heavy	2	1	1	-2
Slope to H.Y.	Heavy	2	2	1	-2
Crossing	Heavy	1	2	1	-1
Peg 19	Moderate	2	1	1	-1
Peg 20	Moderate	3	1	1	-2
Peg 21	Moderate	1	1	1	0

NOTE: Low values indicate less change since 1980. Minus signs represent environmental deterioration since 1980. Positive signs represent environmental improvement since 1980.

All locations on trails with moderate and heavy use, but one, had declines in overall environmental quality. Responsible for these declines were weeds, dieback and Blackboy cropping. All locations had low regeneration or growth of vegetation. Thus locations on trails with moderate or heavy use experienced more environmental deterioration than locations on trails with low use.

4.9 Miscellaneous

Some plants such as Dryandra spp appeared very susceptible to damage from trampling. This was particularly evident on the Taaffe Road illegal trail. When trampled plants on slopes had died and use continued, soil-loss, gullying and freeing of rocks has occurred. This has resulted in rugged trail conditions. Some horses have by-passed these conditions by cutting through trailside vegetation resulting in further plant deaths.

Corner-cutting has occurred on all trails, particularly the trail with heavy use. Sometimes corner-cutting has saved 2-3m, other times up to three kilometres. The Taaffe Road illegal trail, for example, halves the distance of the approved horse trail.

Bark removal by horses has occurred in the holding yard area. No tree deaths have resulted from this practise.

Horse manure is visible on all trails and both illegal trails. Some lumps of manure on the Taaffe Road illegal trail were sighted in a winter water-course. Both illegal trails have places where winter water-courses must be forded. Erosion of creek banks has already occurred at these crossings. These winter crossings may also assist spreading of dieback.

5.0 DISCUSSION

Comparisons between trails indicated that environmental impact was strongly correlated with level of use. The trail with heaviest use had more erosion (visual assessment), more Blackboy cropping, more weeds in gullies and on flats, more dieback, poorer floristic health and greater overall environmental deterioration since 1980 than trails with low use. Likewise, trails with moderate use were affected more than trails with low use. Unused areas and trails with low use were however similar. Based on environmental impact, the illegal trails, and particularly the Taaffe Road illegal trail, rated with the moderate-heavy use trails.

Most erosion problems occurred on trails with slopes exceeding about 8%, regardless of soil texture. Below 8%, the finer textured soils were more eroded than were the coarser-textured soils. All erosion had occurred since pre-winter 1983 when the trails were last repaired. Thus within one horse riding season, severe erosion had occurred. That horses exuberate erosion problems was demonstrated when equivalent slopes on the heavily used trail and in unused areas were compared : horse-used slopes were more severely eroded. Severely eroded trails can prevent fire-fighting vehicles with heavy equipment from rapidly reaching and fighting fire out-breaks in remote areas of the Park. This is a major problem. For Park safety, all trails should allow rapid movement of vehicles.

Blackboy cropping was perhaps the most visible and aesthetically detracting environmental impact examined. The horse riders are directly responsible for this practise : if riders did not permit horses to graze on native shrubs the problem would not exist. Because many Blackboy populations above steep slopes were severely cropped up to 15m from the trail, it was apparent that riders either use these locations to rest or wait for stragglers, and while so doing allow horses to graze on Blackboys.

The introduction of weeds into the Park and the spread of dieback were major problems which have detracted much from the natural plant community. These problems however cannot be directly attributed to rider negligence, unless horses had moved from the approved trails. In the case of weeds, once established they will continue to flourish due to the creation of favourable conditions such as disturbed areas following trampling. In the case of dieback, the number of dead plants observed along the heavily used trail indicates that dieback has spread from the main concentration south of the old railway alignment. Three years ago, the northern areas were relatively dieback free. Horses would have carried the dieback in their hooves into these areas.

Plant cover reduction did not differ between trails. This was surprising because with the effects of soil compaction, dieback and cropping of native shrubs on the trails, it was expected that plant cover on the trail would have been much less than 10m from the trail, with the difference in plant cover reduction increasing with heavier trail use. Floristic health gradings were mostly determined by the incidence of weeds and dieback and were therefore reasonably well correlated with them. Trail anastomosation on the Taaffe Road illegal trail could be indicative of what might develop on approved trails in future years - simple corner-cutting might lead eventually to a maze of well used illegal trails. Because most horse riding was in the winter-early spring months, the tramping effects on vegetation were probably more severe than if trampling had occurred in summer.

The result of horse riding has been to seriously deteriorate the environmental quality of large areas in John Forrest National Park. Horse riding has thereby lowered the aesthetic value for which many Park visitors have come to enjoy. More importantly, horse riding has caused considerable damage to plant communities on the Darling Escarpment, which is, at best, inadequately represented elsewhere.

Many short-term strategies to rectify the environmental impacts of horse riding are made difficult by the ability of horses to go anywhere. Attempts to obstruct illegal trail entrances, for example, would prove futile because horses could manoeuvre around any obstruction. Therefore such strategies are not practical.

Some activities such as Blackboy cropping and corner-cutting are preventable if riders were made aware of their environmental impacts. The installation of information signs at approved horse trail entrances and at the holding yard could convey useful information regarding the environmental impacts of horse riding. This information should be simple, interesting and concise, yet not authoritarian. Currently this information is outlined on sheets with maps indicating the layout of approved horse trails. This has a limited effect however because they would only be read once. With information signs at strategic locations, riders would be constantly reminded. This strategy would be most effective for members of riding school groups who would otherwise be totally unaware of the environmental impact of their activities. Information signs could be supplemented with booklets and talks to members of riding clubs who use the Park about the environmental impacts of horse riding.

The most effective action to reduce all environmental impacts is to reduce the number of riders allowed on trails. Because annual permit holders ride in very small groups and constitute only a small portion of the total trail users, restrictions on use should not affect these riders. Instead, strict limitations should be imposed on riding school groups. These cause more environmental impacts than all other riders by virtue of their superior numbers. The level of impact would be substantially reduced if riding school groups were restricted to a maximum of 15 riders and to three or four outings each week.

Erosion is best rectified through continual maintenance. Eroded slopes should be resurfaced and regraded, have water bars constructed to prevent channelization of surface run-off and have more water diversion channels installed to direct water from the trail. The expense to maintain all trails however would be exorbitant. An alternative strategy could be to re-route trail sections where erosion was particularly severe.

Use of illegal trails might be reduced if a two-step strategy was adopted. Firstly, notices should be installed at entrances to all illegal trails warning riders that they were not permitted on the trail and that prosection could be brought against them if found using the trail. Secondly, Rangers should have power to prosecute riders caught using illegal trails. This strategy could operate successfully if time was available to periodically patrol illegal trails.

Another action which might reduce illegal use of trails is to better mark approved trails. Wooden trail markers were previously installed but were soon removed by the public. More permanent trail markers which would thwart attempts to dislodge should be erected.

Both regular trail maintenance and the strategies outlined cost much money. From a total budget of $30,000 for all Park management in John Forrest National Park, one third has been allocated to horse trails. To recoup some of this expenditure, commercial enterprises which use and benefit from horse trails should be made to contribute more toward maintenance costs. The $200 annual fee currently paid by commercial enterprises should be increased to at least $500, but not more than $1,000. This increase is justified on the grounds that only a token annual fee is currently charged commercial enterprises who almost exclusively use and damage the heavily used trail for financial profit, while much of the total Park budget is spent, through necessity, on that section of horse trail. Therefore a greater contribution toward trail maintenance should be made.

The long term strategy proposed is to phase out horse trails in John Forrest National Park. The NPA has the legislative power (NPA Act 1976 Part (11),4,) to close horse trails, however it would do so against pressure from the John Forrest Riders Association. However, as demonstrated by the lack of real demand for certain trails heralded by the Association to be needed in their 1980 submission on horse trails, this pressure might in reality be the loud voice of a small minority. The considerable environmental impact of horse riding should be justification enough to close all horse trails, particularly as horse riders constitute only 4% of total Park visitors and yet their environmental impact is probably greater than that of all other Park users. Horse riding has undoubtedly detracted from the aesthetic value of many areas in the Park. This and other reasons has caused an adverse public opinion toward horse riding in the Park (see Muir, B. (1980) Attachment 3). Thus phasing out horse trails would be well received by most of the public. If horse trails were to be phased out, this would bring Western Australian policy in line with those found interstate and overseas.

6.0 SUMMARY

Horse riding in John Forrest National Park has caused considerable environmental damage, the severity of which was correlated with intensity of use. The environmental factors examined were soil compaction, trail erosion, trail anastomosation, Blackboy cropping, weed cover, dieback, cover reduction,floristic health and changes in environmental quality since 1980. The direct and indirect impacts of horse riding were probably greater than the rest of the Park visitors even though horse riders represented only about 4% of the total Park visitors. Various short-term strategies such as methods to make horse riders more environmentally conscious, restrictions on the number in and frequency of riding school groups, maintenance programmes to reduce trail erosion, improved sign-posting of the approved trails and the introduction of prosecutions on horse riders who illegally used trails were proposed to help reduce/rectify the environment impacts. It was also proposed that commercial enterprises which use and benefit from horse trails should contribute more toward trail maintenance. Because of the considerable environmental impacts of horse riding, a long-term strategy that horse trails in the Park be phased out was proposed.

7.0 REFERENCES

Bannister.A. and Raymond.S. (1977) Surveying Pitman International Text. London.

Bayfield.N. (1971) A simple method for detecting variations in walker pressure laterally across trails J. appl. Ecol 8:533-36.

Burden.R. and Randerson.P. (1972) Quantitative studies of the effects of human trampling on vegetation and as an aid to the management of semi-natural areas. J.appl.Ecol. 9:439-57

Capper P.L. and Cassie W.F. (1976) The Mechanics of Engineering Soils E and F.N. Spon Ltd London.

Chappell H.G., Ainsworth J.F., Cameron R.A.D. and Redfern M. (1971) The effects of trampling on a chalk grassland ecosystem J.appl.Ecol 8:869-82.

Cole D.N. (1978) Estimating the susceptibility of wildland vegetation to trailside alteration J.appl. Ecol 15:281-86.

Cole D.N. (1981) Vegetational changes associated with recreational use and fire suppression in the Eagle Cap Wilderness, Oregon : some management implications Biol. Consv 20:247-70.

Dale D. and Weaver T. (1974) Trampling effects on vegetation of the trail corridors of north rocky mountain forest J.appl.Ecol 11:767-72.

Dickman M. and Dorais M. (1977) The impact of human trampling on phosphorus loading to a small lake in Gatineau Park Quebec Canada J. Env. Man. 5:335-44.

Foin T.C., Garton E.O., Bowen C.W., Everingham J.M., Schultz R.D. and Holton B. (1977) Quantitative studies of visitor impacts on environments of Yosemite National Park California and their implications for park management policy J.Env.Man. 5:1-22

Liddle M.J. (1975) A selective review of the ecological effects of human trampling on natural ecosystems Biol. Conserv 7:17-36.

Liddle M.J. and Greig-Smith P. (1975a) A survey of tracks and paths in a sand dune ecosystem 11. Vegetation J.appl.Ecol 12:909-30.

Liddle M.J. and Greig-Smith P. (1975b) A survey of tracks and paths in a sand dune ecosystem 1. Soils J.appl.Ecol. 12:893-908.

McFeters G.A. and Stuart S.A. (1976) Impact of horses on the bacterial water quality of Cottonwood Creek Grand Teton National Park J.Env.Health 39:123-25.

McQuaid-Cook J. (1978) Effects of hikers and horses on mountain trails J. Env.Man 6:209-12.

Muir B. (1980) Report on Horse Trails in National Parks An unpublished internal report to the National Parks Authority.

Perring F.H. (1967) Changes in chalk grassland caused by galloping. pp 134-42 in The Biotic Effects of Public Pressures on the Environment Ed. E. Duffey. Monks Wood Experimental Station Symposium No 3, The Native Conservancy.

Speight M.C.D. (1973) Outdoor recreation and its ecological effects : a bibliography and review Discussion Papers in Conservation, University College London 4 .

Summer R.M. (1980) Impact of horse traffic on trails in Rocky Mountain National Park J.Soil. Water Conserv. 35:85-87.

Weaver T. and Dale D. (1978) Trampling effects of hikers, motorcycles and horses in meadows and forests J. appl.Ecol. 15:451-57

Weaver T., Dale D. and Hartley (1978) The relationship of trail condition to use, vegetation, user, slope, season and time pp 94-100 in Recreational Impact on Wildlands Conference Proceedings Oct 27-29 US Forest Service Washington

Westhoff V. (1967) The ecological impact of pedestrian, equestrian and vehicular traffic on vegetation Ecological Impact of Recreation and Tourism Upon Temperate Environments IUCN No 7 Tenth Technical Meeting pp 218-23.