BIOPHYSICAL IMPACTS OF TOURISM

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ABSTRACT

Twelve studies of biophysical impacts of tourism in New Zealand are selected and critically reviewed in terms of the length of study, constraints on research, repeatability, application to other sites, relationship between impacts and level of use, recommendations for further study and relevance to the Department of Conservation. Most studies focus on the impacts on vegetation, some look at soils and a few focus on wildlife. Only one study looks at damage to natural features. Studies of tourism impacts on water quality, soil contamination or air pollution are absent from the reviewed literature. Almost all research covers one season only and few studies make links between the extent of the impacts and level and type of visitor use. No reference is made to management objectives of the site or area in the studies.

A description of methods used in New Zealand to evaluate different biophysical impacts of tourism are reviewed and supplemented with some methods used overseas. However, at this stage, the number of New Zealand studies of any one type is so limited that recommendations of the most useful indicators and methods are difficult to make.

1 INTRODUCTION

The Department of Conservation's Draft Visitor Strategy Discussion Document (1995) has as one of its three goals: "to protect natural and historic resources by minimising the impact of visitor activities and the impacts of facilities and services they require."

The four key priority actions under this goal are to:

a) Set standards for facilities and services (including interpretation and signage) so they are situated, designed and maintained to minimise impacts on natural and historic resources. Where appropriate, visitor numbers will be limited.

b) Develop and implement a process for identifying and overcoming unacceptable visitor impacts. This will include developing a range of environmental indicators, monitoring visitor impacts and educating visitors through environmental messages.

c) Develop messages to inform visitors about appropriate behaviour. When unacceptable impacts occur, visitors will be informed of action to be taken to overcome these impacts, and how they can participate in this process.

d) Contribute to the debate on the impacts of increasing numbers of overseas visitors to New Zealand.

The second priority action to develop and implement a process for identifying and overcoming unacceptable visitor impacts is relevant to this study.

Before this action can be undertaken, it is necessary to know the nature and extent of the impacts. This study, therefore, looks in some detail at existing work on the biophysical impacts of visitors in New Zealand. The study builds on work carried out for the Ministry of Tourism (now the Tourism Policy Group) in 1994 by Ward and Beanland where a 4-stage process was developed for gathering information on environmental impacts.

1.1 Objectives

To assist the Department of Conservation to define and identify unacceptable visitor impacts, this study has two parts:

a) A critical review of key references (Appendix I) identified by Booth and Cullen (1995) in their review of recreation impacts. The purpose is to determine their usefulness in assisting the practical management of biophysical impacts of visitors.

   For each reference the review provides:

   - An outline of the problem investigated;
   - Identification of the potential impacts considered and variables chosen to assess the impacts;
   - An outline of the method(s) used to assess the variables;
   - An outline of the findings, and any comments made by the researcher(s) about the findings, for example, reservations, limitations of applicability;
   - Identification of researchers and their experience in the field;
   - A critique of the research, eg: weaknesses in design;

- Comment on the value or potential value of the research to the Department in developing a monitoring programme for environmental indicators or in management aimed at reducing or controlling visitor impacts.

The research findings are presented under the relevant Potential Environmental Impact headings from the model in Ward and Beanland (1994). For ease of reading, the summary of the research (first five bullet points above) for each reference is shown in Appendix II. The critique and comment on the research is covered in Section 2 of this Paper.

b) The study looks at available information about the most useful indicators of impacts and the associated monitoring techniques. Detailed descriptions and evaluations of methods are given, particularly those with long term measurements and those correlated with visitor numbers. This objective is covered in Section 3 of this Paper.

Potential environmental impacts as identified by Ward and Beanland (1994) have been divided into terrestrial, wildlife and environmental quality impacts in Tables 1 to 4. Visitors may impact on environmental quality in two ways: impacts on the biophysical and historic resource, and impacts on the visitor experience (Draft Visitor Strategy Discussion Document, Department of Conservation, 1995). Table 3 focuses on the biophysical impacts of degraded water quality, contaminated soil and polluted air. Table 4 identifies the social impacts which may affect the visitor experience as well as the environment. These social impacts are not discussed further in this Paper.

These tables form the basic structure of this Paper. They are related and need to be used as a group for all environmental impacts to be considered at any one site. All variables to be assessed depend on baseline conditions.

Table 1: Terrestrial impacts

POTENTIAL BIOPHYSICAL IMPACTS	VARIABLES TO BE ASSESSED	
	Site Qualities	**Visitor Impacts**
Vegetation/habitat degradation	• Soil type • Soil, aspect • Climate	• Area degraded • Change in species composition • % cover of introduced weeds • Cumulative use of site
Soil erosion and compaction	• Soil type • Slope, aspect • Climate	• Area affected • % of bare ground
Damage to natural features		Type of damage, area affected

Table 2: Wildlife impacts

POTENTIAL BIOPHYSICAL IMPACTS	VARIABLES TO BE ASSESSED
Wildlife disturbance affecting: - behaviour - breeding success	• Change in feeding patterns (quantify) • Breeding success: Number of eggs laid, young reared to adults • Effect on productivity resulting in disturbance of essential functions • Severe exertion (quantify) • % displacement • % survival • Change in behaviour patterns (qualitative & quantitative) • Change in population size
Habitat alteration	• % loss of habitat • % loss of food supply/loss of food source (species) • Change in biodiversity • Indirect effects on other species (change in behaviour, productivity, etc)

Table 3: Visitor impacts on environmental quality

POTENTIAL BIOPHYSICAL IMPACTS	VARIABLES TO BE ASSESSED
Degraded water quality	• Provision for sewage treatment and disposal • Sewage discharged (level of treatment, amount, quality, frequency) • Level of use (visitor numbers) • Faecal coliforms/enterococci • Giardia • Erosion and sedimentation rates • Flow and dilution rates • Nutrient enrichment (levels of N and P) • Introduced aquatic weeds • Visual colour and clarity of water • Odour • Groundwater pollution • Extent and health of riparian margin
Contaminated soil (solid wastes and litter)	• Provision for sewage treatment and disposal (sludge) • Level of use (visitor numbers) • Provision for waste and litter disposal • Waste produced (amount/year) • Litter collected (amount/year)
Air pollution	• Provision/availability of transport (traffic counts, distance to road, boat/flight hours, fuel used/year) • Particulate • Chemical • Odour

Table 4: Social impacts on the visitor experience

POTENTIAL BIOPHYSICAL IMPACTS	VARIABLES TO BE ASSESSED
Noise pollution	• Source: air, road, boat traffic • Complaints, user surveys • Change in visitor numbers
Decrease in amenity values (negative effects associated with crowding, structures, etc)	• Complaints, user surveys • Change in visitor numbers • Visual (aesthetic) • Change in natural character, water quality

2 STUDIES OF BIOPHYSICAL IMPACTS OF TOURISM IN NEW ZEALAND

2.1 Methods

The Booth and Cullen (1995) chapter on *Recreation Impacts* provided forty references (listed in Appendix I). Most of these focused on social impacts so they were not considered further. Eighteen references were reviewed. Twelve of these were considered relevant to the first part of this study and are discussed further in this Paper (Section 2.2 and Appendix II). The additional six references are elaborated in Appendix III. Some of these are relevant to the second part of this study (Section 3). Additional references, not cited in Booth and Cullen (1995), are also elaborated in Appendix III.

The twelve references relevant to this study were divided into Terrestrial impacts (8) and Wildlife impacts (4). No references specifically addressed Environmental Quality impacts (Table 3) although impacts noted in passing included litter (Norton, 1989); careless use of fire (Rich, 1991); waste disposal capacity of the soil, accumulation of rubbish and water pollution (Beamish, 1977).

Ward and Beanland (1994) introduced a 4-stage process for gathering information to develop indicators of the environmental impacts of tourism. The process included the identification of ecosystem type, the type of tourist attraction sought by visitors and the scale of activity, statutory protection and existing management objectives of the site or area, and information on potential environmental impacts associated with the type of ecosystem and use to which it is subjected.

This process was used as a basis for a critique of the twelve references by developing a set of criteria to determine the usefulness of the studies to the Department of Conservation. The criteria included the information gathering process as discussed above; the length of the study; its relevance to the Department; its robustness in terms of repeatability and application to other sites; the constraints on research in terms of time, skills, equipment, data and finances; whether the study was purely descriptive or related to visitor numbers; and whether it provided recommendations for further research and on-going monitoring.

2.2 Results

A critical review was done on the following twelve references from Booth and Cullen. A summary of each reference is given in Appendix II.

Terrestrial impacts - soil and vegetation

- Beamish, SF (1977): *The Route Burn track: an application of environmental impact analysis.* Report for the Mt Aspiring National Parks Board. University of Otago.
- Clayton, TO (1990): *Impacts of use of walking tracks in Tongariro National Park, New Zealand.* Unpublished MSc thesis, University of Auckland.
- Grant, IJ; Crozier, MJ; Marx, SL (1977): *Off-road vehicle recreation study: characteristics, demand and impact on the social and physical environment.* Prepared for the Wellington Regional Planning Authority by Applied Geology Associates, Wellington.
- McQueen, D (1991): *Environmental impact of recreational use on DoC estate: (1) Guidelines on track location, management and repair.* DSIR Land Resources Contract Report No 91/54 (Part 1) prepared for the Department of Conservation.
- McQueen, D; Williams, P; Lilley, G (1991): *Environmental impact of recreational use on DoC estate: (2) Effects of camping.* DSIR Land Resources Report No 91/54 (Part 2) prepared for the Department of Conservation.
- Norton, DA (1989): *Environmental impact report on Mingha/Deception section of Coast-to-Coast endurance event.* Report prepared for Robin Judkins, Christchurch.
- Simmons, DG and Cessford, GR (1989): *The St James Walkway study.* Occasional Paper No 1, Department of Parks, Recreation and Tourism, Lincoln University.
- Swaine, C (1992): *Vandals in the temple: a study of the physical and cultural impacts of rockclimbing in Tongariro National Park, New Zealand, with emphasis on vegetation values.* Unpublished dissertation for part II, Fitzwilliam College, Cambridge University.

Wildlife impacts - marine mammals

- Gordon, J; Leaper, R; Hartley, FG and Chappell, O (1992): *Effects of whale-watching vessels on the surface and underwater acoustic behaviour of sperm whales off Kaikoura, New Zealand.* Science and Research Series Report No 52, Department of Conservation.

Wildlife impacts - fish and birds

- Jeffs, A (1993): *The impacts of a glass-bottom boat operation in Goat Island Bay.* An independent impact assessment for the Department of Conservation on behalf of the Habitat Exploration Partnership, Auckland.
- MacGibbon, J (1991): *Responses of sperm whales (Physeter macrocephalus) to commercial whale watching boats off the coast of Kaikoura.* Unpublished report, Department of Conservation, Wellington.
- Montgomery, PJ (1991): *The effects of water-based recreational disturbance on water-birds at Lake Rotoiti, Rotorua.* A report for the Royal Forest and Bird Protection Society, the Department of Conservation and the Ministry for the Environment, Technical Report Series No 14, Department of Conservation, Rotorua.

A critique of each reference is listed in the following pages.

Beamish (1977): The Route Burn track: an application of environmental impact analysis

CRITERIA	COMMENTS
Ecosystem type	Routeburn Track. Variety of ecosystems.
Type of attraction	Primary activity: Tramping
Statutory protection/ management objectives	Mt Aspiring National Park
Impacts considered	• Effects of track activity - tramping • Effects of hut activity - camping, cooking, washing and waste disposal
Variables assessed	• Vegetation cover • Soil compaction and erosion • Geology • Rainfall
Relevance of study to DoC	Yes
Period of study	Summer 1975-76
Constraints on research	• One summer season only • Comprehensive short term study of physical and social environment showing awareness of interdependent nature of the two types of impacts
Repeatability over time	Yes
Application to other sites	Yes
Practicality of repeating study	Yes
Descriptive study only or relationship between level & type of use and impacts	Relationship between users, impacts and management developed but longer time frame needed
Recommendations for further research, monitoring, management?	Alternatives of future use of the track are made and recommendations for on-going monitoring and further research for predicting environmental parameters responsible for track erosion.
Value or potential value of the research to DoC in developing a monitoring programme for environmental indicators	Potential value because of the ability of the track to sustain present and future use.

Clayton (1990): Impacts of use of walking tracks in Tongariro National Park, New Zealand

CRITERIA	COMMENTS
Ecosystem type	Low alpine vegetation and subalpine scrub
Type of attraction	Natural area for short walks and tramping
Statutory protection/ management objectives	National Park
Impacts considered	Impacts of trampling on vegetation and soils
Variables assessed	• Plot size, location, slope, aspect, altitude • Track modification and dispersions, litter • Vegetation % cover, species, % each species, maximum height • Soil colour, infiltration rate, % organic matter, % fines
Relevance of study to DoC	Provides the basis for further research
Period of study	January - early February 1990, May 1990, August-September 1990
Constraints on research	The parameters chosen for measurement are intended to expose any differences while being practicable for one person to carry out in the field. Compromises were therefore necessary and the parameters measured are not necessarily those that would be chosen in an ideal situation. More soil measurements and botanical analyses needed. The most obvious omission in the field programme is the lack of a measure of the numbers of people using each of the walking tracks studied. The DoC and its predecessors have not had sufficient resources to undertake a comprehensive survey of the levels of use in Tongariro National park and such a task was beyond the scope of this thesis.
Repeatability over time	Yes
Application to other sites	Yes
Practicality of repeating study	Yes
Descriptive study only or relationship between level & type of use and impacts	Descriptive study only (see omission above)
Recommendations for further research, monitoring, management?	Increased number of observations, measurement of more variables including soil measurements and intensity of track use, further statistical analysis are recommended.
Value or potential value of the research to DoC in developing a monitoring programme for environmental indicators	Potential value; methods relevant.

Grant *et al.* (1977): Off-road vehicle recreation study: characteristics, demand and impact on the social and physical environment

CRITERIA	COMMENTS
Ecosystem type	Wellington Region Planning Authority region. A variety of locations were studied.
Type of attraction	Variety of locations/ecosystems within the region used for off-road motor vehicle recreation (motorcycles, 4-wheel drive light trucks and dune buggies)
Statutory protection/ management information	NA
Impacts considered	• Immediate impacts on vegetation and soil conditions • Long term impacts on vegetation cover, soil litter, and infiltration capacity
Variables assessed	Type and degree of impact are: slope angle, soil texture, soil compaction (including clay mineralogy and organic matter content), soil density, soil moisture and seasonal conditions, and vegetation cover.
Relevance of study to DoC	Relevant where Conservation land is used by ORVs
Period of study	15 months from 1.11.1975
Constraints on research	Large area and funds limited ability to carry out a fieldcheck
Repeatability over time	Yes, but probably not necessary or uses have altered
Application to other sites	Desktop but would require fieldcheck
Practicality of repeating study	Limited
Descriptive study only or relationship between type & level of use and impacts	Relationship between ORV use and environmental impact has been initiated
Recommendations for further research, monitoring, management?	Recommendations for fieldchecks, monitoring and management of impacts. Note study was carried out mainly in 1976.
Value or potential value of the research to DoC in developing a monitoring programme for environmental indicators	No value

McQueen (1991): Guidelines on track location, management and repair

CRITERIA	COMMENTS
Ecosystem type	Tararua Forest Park
Type of attraction	Primary activity: Tramping
Statutory protection/ management objectives	Forest Park
Impacts considered	Track erosion
Variables assessed	Climate, slope, soils, vegetation, level of use.
Relevance of study to DoC	Relevant to the location of new tracks, monitoring track degradation, predictive deterioration and protective action.
Period of study	Not specified, probably 1990
Constraints on research	Mainly literature search with one case study of track deterioration showing good correlation between user density and erosion severity (statistical relationship)
Repeatability over time	Yes
Application to other sites	Yes
Practicality of repeating study	Yes
Descriptive study only or relationship between type & level of use and impacts	Descriptive and analytical research with focus on prediction of impacts; levels of use related to environmental impacts.
Recommendations for further research, monitoring, management?	Recommendations to use systems for predicting track impacts for new tracks or major upgrades; to monitor existing tracks using techniques referenced; to develop a methodology to provide standards of acceptable track deterioration.
Value or potential value of the research to DoC in developing a monitoring programme for environmental indicators	Potential value

McQueen *et al.* (1991): Effects of camping

CRITERIA	COMMENTS
Ecosystem type	Abel Tasman National Park
Type of attraction	Primary activity: Camping (high, medium, low levels of use)
Statutory protection/ management objectives	National Park
Impacts considered	• Damage to or removal of vegetation • Soil compaction and removal • Reduced soil drainage • Accumulation of rubbish • Pollution of water supplies • Attraction of weeds and pests
Variables assessed	• Soil properties (physical, chemical and waste disposal potential) • Vegetation (diversity and quantity) • Soil invertebrates (susceptible to this kind of disturbance)
Relevance of study to DoC	Relevant to location of facilities, visitor use and behaviour, and appropriate management of vegetation cover.
Period of study	Not specified, probably summer 1990/91.
Constraints on research	Collection of user numbers not sufficiently accurate to establish levels of use and impact. Longer time frame would allow assessment of success of improvement programme.
Repeatability over time	Yes
Application to other sites	Yes
Practicality of repeating study	Yes
Descriptive study only or relationship between type and level of use and impacts	Levels of use related to environmental impacts.
Recommendations for further research, monitoring, management?	Recommendations to improve the design of camping areas; manage grass species to increase cover; monitor levels of use and impacts with time to assess management; optimise site selection; and extend the study to other areas.
Value or potential value of the research to DoC in developing a monitoring programme for environmental indicators	Good value for the development of a monitoring programme.

Norton (1989): Impacts associated with Coast to Coast Endurance Event

CRITERIA	COMMENTS
Ecosystem type	Rata Kamahi Forest (Deception Valley), subalpine shrubland, alpine vegetation (Goat Pass), Beech Forest (Mingha Valley).
Type of attraction	Natural area for recreation Primary activity: Running Level of use: c.650 competitors
Statutory protection/ management objectives	Arthur's Pass National Park
Impacts considered	• Vegetation degradation • Erosion • Wildlife (Blue duck only)
Variables assessed	• Vegetation impact • Weather conditions • Track width • Surface movement of track • Track usage • Blue duck
Relevance of study to DoC	Very relevant due to National Park status and increasing popularity of event
Period of study	January - March 1989
Constraints on research	• Length of study - only 3 months • Effects on fauna confined to birds, mainly blue duck, and not rigorously monitored
Repeatability over time	Yes
Application to other sites	Comparable monitoring could be carried out at other sites
Practicality of repeating study	This type of monitoring is relatively inexpensive
Descriptive study only or relationship between type & level of use and impacts	Descriptive one off study that records environmental impacts during and immediately after the endurance event
Recommendations for further research, monitoring, management?	Long-term monitoring of track condition is recommended, using photo points established in this study. Track counters needed to manage recreational users. No comments on on-going monitoring of bird populations.
Value or potential value of the research to DoC in developing a monitoring programme for environmental indicators	Method of track monitoring is useful. For objective statements on user impacts Norton recommends that DoC should continue regular monitoring of track condition, making use of established photo-points, re-photographing once per year at least one month after the event of both 'bad' and 'good' sections of the track. In order to adequately manage recreational users, it is imperative to have reliable data on actual usage. Norton states that at least one track counter in each valley be installed.

Simmons & Cessford (1989): The St James Walkway study

CRITERIA	COMMENTS
Ecosystem type	St James Walkway. Variety of ecosystems.
Type of attraction	Primary activity: Tramping
Statutory protection/ management objectives	Private land and reserve
Impacts considered	Track impact studies - physical impacts of use on new track: vegetation and soils
Variables assessed	• Track widening and deepening • Soil type • Loss of vegetation • Loss of topsoil • Rainfall • Drainage
Relevance of study to DoC	Relevant to development and siting of new tracks
Period of study	Five year programme
Constraints on research	Study covered three summer seasons, 1982-1985, after the opening of new track. Objective and subjective measurements taken of impacts as track was developing and hardening. Minimal impacts were noted except in small areas so concluded in hindsight that subjective assessment would have been adequate. Further summer monitoring not continued. Field studies carried out by students under University supervision. Soil studies provided useful information with regard to track sighting.
Repeatability over time	Yes
Application to other sites	Yes
Practicality of repeating study	Yes
Descriptive study only or relationship between type & level of use and impacts	Subjective approach provided adequate information as to impacts, their location and cause. Objective approach useful for specific sites where particular conditions considered. Longer time frame needed to integrate impacts with levels of use
Recommendations for further research, monitoring, management?	Monitoring over a longer period needed to ascertain more permanent impacts
Value or potential value of the research to DoC in developing a monitoring programme for environmental indicators	Potential value

Swaine (1992): Vandals in the temple

CRITERIA	COMMENTS
Ecosystem type	Subalpine scrub
Type of attraction	Primary activity: Rock climbing
Statutory protection/ management objectives	Tongariro National Park
Impacts considered	Effects of rock climbing on subalpine plant communities, rock and on Maori cultural values.
Variables assessed	• Bare ground • Vegetation height • Species numbers and abundance • Slope, aspect • Soil pH
Relevance of study to DoC	Very relevant due to increasing pressure for climbing sites in the area and elsewhere in New Zealand
Period of study	4 weeks field work and research at Tongariro National Park, July 1991
Constraints on research	• Length of study: too short • Vegetation and bare ground adequately monitored but slope, aspect, soil type and pH not assessed • Effects on fauna not assessed • Choice of high use site did not allow true comparison of data sets because of different site characteristics
Repeatability over time	Yes
Application to other sites	Comparable monitoring could be carried out at other sites, given inherent limitations of site characteristics
Practicality of repeating study	This type of monitoring is not constrained by legislation and is relatively inexpensive
Descriptive study only or relationship between type & level of use and impacts	Good description and analysis of Mangetepopo sites; high use site not statistically comparable. Relationship between level of use and impacts well established.
Recommendations for further research, monitoring, management?	Good recommendations for further research and monitoring (see previous page)
Value or potential value of the research to DoC in developing a monitoring programme for environmental indicators	Valuable contribution to management of climbing sites in this area

Gordon *et al.* (1992): Effects of whale-watching vessels on the surface and underwater acoustic behaviour of sperm whales off Kaikoura, New Zealand

CRITERIA	COMMENTS
Ecosystem type	Coastal marine
Category of attraction	Primary activity: • Whale watching using small high speed boats and air crafts • Four licensed boats up to 4 trips per day
Statutory protection/ management objectives	• Marine Mammal Protection Act 1978 • NZ Marine Mammal Regulations • Coastal Marine Area subject to Regional Coastal Plan
Impacts considered	Disturbance due to boat engine noise, pressure of boats on acoustic and surface behaviour changes of whales.
Variables assessed	• Sperm whale vocalisations • Visual and acoustic behavioural parameters - time on surface, ventilation periods, clicking after diving
Relevance of study to DoC	Whale population involved is all male, so impacts on animal behaviour rather than on species conservation.
Period of study	8/1/1992 to 9/3/1992
Constraints on research	Lack of satisfactory control for the effects due to differences between individual whales and location. Most whale watching took place with tolerant whales. Findings may not hold if less tolerant whales became subjects of the industry. Study took place in summer months only when whales appear more approachable (see MacGibbon, 1991).
Repeatability over time	Yes
Application to other sites	Site specific but may provide lessons for other places
Practicality of repeating study	Expensive
Descriptive study only or relationship between type & level of use and impacts	Descriptive study; effects of disturbance not dramatic; long term effects of disturbance on whales is unknown.
Recommendations for further research, monitoring, management?	Ongoing monitoring recommended to determine any long-term effects of disturbance
Value or potential value of the research to DoC in developing a monitoring programme for environmental indicators	Monitoring programme could be developed on the basis of this study.

Jeffs (1993): The impacts of a glass-bottom boat operation in Goat Island Bay

CRITERIA	COMMENTS
Ecosystem type	Coastal marine
Category of attraction	Primary activity: Glass-bottom boat operation
Statutory protection/ management objectives	Marine Reserve
Impacts considered	• Fish behaviour around boat • Bird behaviour around boat • Loading operations affecting marine life on the shore • Mooring buoy having an effect on marine life • Minute marine life affected by running outboard motors
Variables assessed	• Fish behaviour • Bird behaviour • Shore organisms • Abrasion of rock and seaweed associated with mooring buoy chain
Relevance of study to DoC	Not very relevant
Period of study	December 1992
Constraints on research	Observations only
Repeatability over time	No, different researcher could lead to different results. Subjective.
Application to other sites	Possibly, but very subjective.
Practicality of repeating study	Possibly, but very subjective.
Descriptive study only or relationship between type & level of use and impacts	Descriptive study but no quantitative assessment; limited relationship with use.
Recommendations for further research, monitoring, management?	Recommendations made on ways to minimise impacts on potentially important sites to birds
Value or potential value of the research to DoC in developing a monitoring programme for environmental indicators	No

MacGibbon (1991) : Responses of sperm whales (Physeter macrocephalus) to commercial whale watching boats off the coast of Kaikoura

CRITERIA	COMMENTS
Ecosystem type	Coastal marine
Category of attraction	Whale watching
Statutory protection/ management objectives	• Marine Mammal Protection Act 1978 • NZ Marine Mammal Regulations • Coastal Marine Area subject to Regional Coastal Plan
Impacts considered	Changes in whale behaviour in response to whale watching boats
Variables assessed	Behavioural parameters: respiration interval, length of submergence, surfacing length, speed and orientation on surface, occurrence of hasty dives and aerial behaviour.
Relevance of study to DoC	Useful information incorporated into report by Gordon *et al.*
Period of study	April-September 1990
Constraints on research	Analysis of results not completed
Repeatability over time	Yes
Application to other sites	No
Practicality of repeating study	(see later work by Gordon *et al.*)
Descriptive study only or relationship between type & level of use and impacts	Descriptive study with observations of whales before, during and after commercial boats were present.
Recommendations for further research, monitoring, management?	No
Value or potential value of the research to DoC in developing a monitoring programme for environmental indicators	No, but see later work by Gordon *et al.*

Montgomery (1991): The effects of water-based recreational disturbance on water-birds at Lake Rotoiti, Rotorua

CRITERIA	COMMENTS
Ecosystem type	Freshwater
Category of attraction	Primary activity: Recreational boating at high and low recreational use sites
Statutory protection/ management objectives	
Impacts considered	• Bird species most affected by recreational activities • Bird species tolerance to disturbance by slow moving motor boat
Variables assessed	• Comparison of bird abundance and diversity • Assessment of boat-bird disturbance distances
Relevance of study to DoC	Provides good baseline for further research
Period of study	Two months (no dates given)
Constraints on research	No previous studies to assess impacts of recreational activity on lake water-birds for comparison. Time frame too short (ideally medium to long term).
Repeatability over time	Yes
Application to other sites	Other lakes
Practicality of repeating study	Yes
Descriptive study only or relationship between type & level of use and impacts	Descriptive study well integrated with effect of different levels of disturbance
Recommendations for further research, monitoring, management?	Recommendations to repeat study over a longer time frame, to extend it to include adults with young and other bird species, to assess how far birds travel when disturbed, and to assess the effect of recreational disturbance on breeding success of shags and dabchicks.
Value or potential value of the research to DoC in developing a monitoring programme for environmental indicators	High value important baseline work. Robust study.

2.3 Discussion

The fact that only twelve suitable references were located from the Booth and Cullen chapter indicates the small number of studies undertaken in New Zealand. These twelve references cover a range of ecosystem types and tourist activities with the focus directed at the impacts on vegetation, to a lesser extent on soils, and less still on wildlife. Only one study looked at damage to natural features, despite the amount of climbing and visits to caves that takes place in New Zealand. No studies focused on tourist impacts on water quality, soil contamination or air pollution.

Almost all studies were short term covering only one season. This is due to the fact that four of the studies were student projects that rarely last for more than one season and also that long term funding is seldom available.

Most studies are repeatable and provide a basis for further research. However, the studies were nearly all independently carried out so relationships between different sites may be hard to obtain.

Links between different types of impacts, such as on vegetation, soils, bird life and water quality, were not always made so a study only looks at part of the total impact of visitors on a particular environment. Similarly, links between the extent or degree of the impact and the level and type of visitor use has seldom been clearly established. Unless past records of visitor use are available, the significance of any impacts recorded is lost.

The limited scope of some studies and the fact that they are seldom related to the management objectives of the site, park or area make interpretation for management difficult. However, a number of researchers have made good comments and recommendations that are worth further consideration.

Future research needs to be aware of other studies, including overseas literature, and look at the relationship between impacts and visitor numbers.

3 TECHNIQUES FOR MEASURING BIOPHYSICAL IMPACTS

This part of the study looks at available information about the most useful indicators of impacts and the associated monitoring techniques.

3.1 Methods

Studies that elaborate methods used to measure biophysical impacts and ongoing monitoring of impacts and visitor numbers were selected, initially using references cited in Booth and Cullen (1995) and then adding additional references as time allowed. The references from Booth and Cullen are listed in Appendix I and elaborated in the first part of this study and in Appendix II. The references are grouped according to activity and impact in the matrix of Tables 5 and 6. The different methods used for each combination of activity and impact are then assessed.

3.2 Results

Table 5: Studies of impacts on terrestrial ecosystems associated with recreational activities

ACTIVITIES	IMPACTS					
	Vegetation Degradation	**Soil Erosion & Compaction**	**Damage to Natural Features**	**Habitat Degradation**	**Water Pollution**	**Solid Waste & Litter**
TRAMPING/ WALKING						
Beamish ('77) - Routeburn Track	✓	✓				
Clayton ('90) - Tongariro NP	✓	✓				
McQueen ('91) - Tararua Forest Park	✓	✓				
Nelson ('82) - St James Walkway	✓					
Norton ('89) - Arthurs Pass NP	✓					
Stewart ('85) - St James Walkway		✓				
Tetteroo ('83) - St James Walkway	✓					
Young ('85) - Five South Island tracks		✓				
MOUNTAIN-BIKING						

(Table continued on next page)

Table 5: Studies of impacts on terrestrial ecosystems associated with recreational activities (cont'd)

ACTIVITIES	IMPACTS					
	Vegetation Degradation	**Soil Erosion & Compaction**	**Damage to Natural Features**	**Habitat Degradation**	**Water Pollution**	**Solid Waste & Litter**
CAMPING, HUT STAYS						
Beamish ('77) - Routeburn Track	✓					✓
McQueen *et al* ('91) - Able Tasman NP	✓	✓		✓		
Nelson ('82) - St James Walkway	✓					
Tetteroo ('93) - St James Walkway	✓					
ROCK CLIMBING						
Swaine ('92) - Tongariro NP	✓	✓	✓			
MOUNTAIN-EERING						
SKIING						
CAVING						
ORV RECREATION						
Grant *et al* ('77) - Wellington Region	✓	✓				
MULTI-SPORT ENDURANCE EVENTS						
Norton ('89) - Arthurs Pass NP	✓			✓		✓

Table 6: Studies of impacts on wildlife associated with recreational activities

Activity	Wildlife Disturbance	Alteration of Habitat
Marine Mammal Watching	MacGibbon (1991) - Kaikoura sperm whales Gordon (1992) - Kaikoura sperm whales	
Boating	Jeffs (1993) - Goat Island Marine Reserve Montgomery (1991) - Lake Rotoiti	

The methods used to assess each combination of activity and impact (Tables 5 and 6) are compared. Where only one method is cited, this is briefly mentioned.

3.2.1 Studies of Impacts on Terrestrial Ecosystems

3.2.1.1 Methods of measuring impacts of trampling on:

(a) Vegetation

In his literature search, McQueen (1991) identified the need to monitor representative areas of tracks for deterioration, soil loss and visual degradation. He noted that levels of use and site characteristics control level of impact. At lower levels of use, the main impact is on vegetation while at higher levels of use, soils have the most influence. Grassland has been found more resistant to trampling than forest vegetation. In Britain, 10,000 visitors/year were required for the ground to become bare in chalk grassland and 20,000/year were required before tracks of 1.5 m wide became established (Goldsmith, 1983). Harrison (1981) found after 400 passes on various grassland and heathland plots, there was a 50% reduction in plant cover while 1,600 passes caused 90% reduction. Cole (1987) found similar results after experimentally trampling a range of forest communities and a grassland community.

Liddle (1975a) estimated damage to plant communities by walking on previously unworn areas of vegetation and counting the number of passes that reduce the cover or biomass to 50% of its original value. This figure is taken as an index of vulnerability and used to compare the effects of trampling on different habitats. Evidence suggests that there is a relationship between vulnerability of vegetation to trampling and primary productivity (Liddle, 1975b). Primary productivity may be defined as the rate at which energy is stored, mainly by green plants, in the form of organic matter that can be used as food.

On the St James Walkway, Simmons and Cessford (1989) record only minimal impacts in grassland of 700 people over two years while there were significant impacts in forests. McQueen (1991) suggests that noticeable impacts begin at 10,000 users in tundra conditions with severe impacts at 50,000 users; in forest vegetation impacts are noticeable at 12,000 users and severe at 160,000; in grassland impacts are noticeable at 70,000 users and severe at 100,000.

From New Zealand information, depending on the environment, McQueen finds that 500-1000 users per year will result in track deterioration unless steps are taken to harden the track surface. Soil is almost totally removed on slopes with 2000-3000 users per year without protective measures. Young (1985) suggests three classes of South Island track environment: high rainfall - high use, high rainfall - low use and low rainfall - high use. He suggests erosion control techniques for each class with primary techniques forming the basis of water and erosion control on the track and secondary techniques used infrequently at specific sites. Some techniques such as culverts, retaining walls and boardwalks were found to be appropriate on all tracks while other techniques such as corduroy and steps should be avoided on all tracks. Primary techniques for high rainfall - high use tracks include cambered surfaces, ditches, culverts and surfacing. The primary technique for the other two classes is natural outslope.

Cole (1983) discusses three groups of techniques to assess actual track deterioration: replicable measurements of a small sample of track segments, rapid surveys of a large sample of track segments, and complete censuses of track problems or conditions. All these approaches have been used in the studies on the Routeburn track (Beamish, 1977) and the St James walkway (Nelson, 1982; Tetteroo, 1983). Cole suggests measurements may include track cross-sectional area and profile, track width, depth, moisture status, % of stones and exposed roots, degree of muddiness, walkability and assessment of erosion.

The New Zealand studies reviewed all have the disadvantage of short time frames. The studies by Clayton (1990), Beamish (1977), Nelson (1982) and Tetteroo (1983) were all student studies over one summer season. The last two were in consecutive summers on the St James Walkway but the main focus was methodology because the walkway was still becoming established. A follow up study after 12 years would give some useful results. Consequently although user numbers were usually noted, the effect of increasing users at the study sites has not been assessed.

Clayton (1990) used control and impact randomly selected plots in which physical parameters, % vegetation cover, and % each species with maximum height were measured. The use of control and impact plots was considered well suited to a study that is specifically concerned with establishing the degree of impact. However, it is suggested that the use of transects out from the tracks would produce more detailed data on the pattern and spatial extent of the impact in addition to the data collected in this study.

Beamish (1977) estimated vegetation cover and regrowth over sections of the track along with photo points. Cover was estimated in terms of % living plants, % plant litter, % bare ground, % dead matter and % rock. The first three showed highly significant differences along different sections of the track but variation in habitat and narrow extent of trampling made it difficult to establish a threshold of an indicator such as % bare ground.

Nelson (1982) measured full transects, partial transects, oblique and vertical photo points, subjective assessment of track quality between transects, and track users behaviour at susceptible sites (and around huts). He also observed people's behaviour at high use areas such as around huts, established stopping areas and camping spots. Photo points were selected mainly from areas where the track was across terrain too wet or muddy for transects to be of practical use.

A technique to record exactly where people walked across a track using a "trampleometer" was tried but found to be unsuitable for this survey.

A two-tier classification was used for visual rating of the track: constructed tracks (boardwalk, benching, steps, heavily gravelled) and natural (minimal or no construction). Both types of tracks were rated visually from 1 to 3 using defined criteria. This subjective rating system was used over the whole of the St James Walkway to fill in the zones between transects and photo points. A rating was taken at each transect which along with the photos helped to serve as a base reference for each of the points on the reference scale.

In the partial transects, ground cover (rock, stone, gravel, soil, humus), litter (twigs, leaves, etc) and vegetation were estimated and supplemented by oblique photos. Criteria were used to select sites for partial transects and point analysis was used. Criteria included no tracking visible, muddy or wet zones, areas where track development was expected, and areas of markers or cairns.

For full transects, track profile analysis measurements were taken over a sufficient length of the transect to cover the track and any potential track movement or widening. Oblique and near vertical photos were taken. Criteria were used to select sites for full transects including to monitor changes in track depth, shifting of track, general deterioration of both benched and unbenched tracks, and track widening.

Both types of transects required time and effort to set up, yet provided more objective results than visual assessment.

Tetteroo (1983) essentially repeated the methods of Nelson.

Scott (1965) developed a height frequency method of sampling tussock and shrub vegetation by using vertical sampling cylinders and measuring species frequency in each layer of vegetation by noting the presence or absence of a plant in small volumes within each layer. This method is less time consuming than point analysis that is not always suitable for New Zealand conditions. Control and impacted sites need to be compared because of seasonal differences in vegetation growth.

In Scotland, Lance *et al.* (1989) looked at techniques to measure footpath widening. They recommended overall width and width of bare ground as two useful parameters to measure along with statistical tests to estimate the number of measurements needed to detect a minimum change in path width. Paired t-tests were used to compare mean changes in width using the same fixed measurement points on successive occasions.

Overall, different methods have been used in New Zealand to measure impacts of trampling on vegetation but only Norton's monitoring of the impacts of a section of the track used in the Coast to Coast endurance event has continued for more than two seasons. The literature reviewed suggests that a combination of visual and more objective assessment is adequate. Visual assessment of indicators such as % bare ground or criteria such as those developed by Nelson (1982) can be combined with photo points with careful attention to details as outlined by Meurk (1989). This needs to be supplemented by more objective assessments at selected sites using permanent line transects and the height frequency method of vegetation sampling as suggested by Scott (1965) and the track widening methods of Lance *et al.* (1989).

(b) Soil erosion and compaction

McQueen (1991) correlated erosion with level of use and severity of erosion with the depth of erodible material. Erosion was not observed to be correlated with climate, slope or vegetation. At high levels of track use soils have the most influence on the level of impact. At an upper threshold, most degradation has occurred and there will be little further damage.

Clayton (1990) measured soil colour using a Munsell Soil Chart to allow comparison between control and impact plots. Rate of infiltration of water was measured using a ring infiltrometer. In the laboratory, % organic matter and % fines were measured.

Soil compaction in terms of penetration resistance, bulk density and infiltration capacity were measured by Beamish (1977).

Stewart (1985) measured bulk density, soil strength and infiltration rate. In addition topsoil and subsoil samples were analysed for upper and lower plastic limits, aggregate stability, organic and clay content of the soil and routine chemical tests. It is important to distinguish between organic and mineral soils because organic soils are not compacted but are wet and weak and severely damaged by trampling. Mineral soils have greater shear strength and load carrying capacities, making them more suitable for tracks. Stewart and Cameron (1992) recommend confining walkers to the track if possible to prevent lateral spread of the initial severe compaction that results from trampling.

In the United States, Cole (1987) found that the loss of organic horizons sufficient to expose underlying mineral soil only occurred at relatively high levels of experimental trampling. The amount of loss varied with the type of vegetation. Penetration resistance increased with amount of trampling but was influenced by the amount of resistance in the type of vegetation.

Bulk density, soil strength and infiltration rate are suitable indicators of soil erosion and compaction but the influence of type of vegetation on the severity of impact needs more study under New Zealand conditions.

3.2.1.2 Methods of measuring impacts of camping on:

(a) Vegetation

As the intensity of use of camping areas increases, vegetation and soils are affected. Bare ground increases, species diversity decreases, weed species increase, soil fauna is depleted, soils become compact, lose porosity and water run-off increases (McQueen, 1991).

McQueen *et al.* (1991) measured species numbers and diversity along with levels of use at campsites. Forest sites were sampled within 10 m x 5 m plots. All species of higher plants were recorded according to tiers and an estimate of % cover. Frequency of ground layer species, bare ground, litter, bryophytes and seedlings were recorded from 1 m^2 subplots located at random. Open camping areas of herbaceous vegetation were subdivided and their total area and vegetation cover estimated. Damage to woody vegetation was also recorded. Photo points were not used but were recommended as references to monitor site conditions and to evaluate restoration initiatives. Photography should be used in conjunction with other semi-quantitative methods. McQueen *et al.* (1991) suggest that if only one indicator of campground impact can be used, the area of the site with less than 50% grass cover would be appropriate. In the Able Tasman National Park, high impact occurs when tent sites are occupied for >50-70 nights per year.

Beamish (1977) carried out a subjective assessment of vegetation cover in camping areas.

Vegetation cover estimates were carried out by Nelson (1982) using transects from the corners of a hut, supplemented by oblique photos. Ground cover (rock, stone, gravel, soil, humus), litter (twigs, leaves etc) and vegetation were estimated and supplemented by oblique photos. Tetteroo (1983) repeated these methods.

Cole (1989) discusses the most effective methods for monitoring wilderness campsites. He points out that systems based entirely on photography are not accurate enough to assess impacts but can be very important for relocation of sites and to illustrate changes documented with field measurements. He concludes that photo points should be combined with semi-quantitative visual assessment methods.

As with impacts of trampling, subjective assessments of the impacts of camping need to be combined with objective measurements to enable comparisons to be made over time and by different people.

(b) Soil erosion and compaction

McQueen *et al.* (1991) measured soil properties including penetrometry, morphology, soil surface water entry, soil chemistry and measurements of bulk density and hydraulic conductivity. Abundance of soil fauna were also measured. A number of these properties are appropriate indicators of impact including increase in penetration resistance in topsoil, decrease in number of soil animals in sensitive orders, decrease in grass cover (>50% is easily seen visually), removal of forest understorey and presence of weeds.

(c) Habitat degradation

McQueen *et al.* (1991) studied the effects of camping on soil fauna using a 75 mm corer to sample the equivalent of a surface area of 900 cm^2 and a soil volume of 3,600 cm^3. The area with the highest number of soil animals had the lowest level of disturbance through camping.

In the UK, Duffey (1975) studied the effect of human trampling on the fauna of grassland litter and found a substantial decline in numbers of those species sensitive to treading. The invertebrate fauna appeared to be affected by levels of trampling much lower than those required to produce changes in the structure and species of living plants.

(d) Solid waste and litter

Beamish (1977) described refuse pits on the Routeburn, with open pits attracting opossums, keas and stoats. Refuse drums, that are flown out when full, had replaced the pits at some hut sites. Sewerage pits caused similar problems to refuse in that buried sewerage is accumulating in the National Park and construction is difficult in rocky areas, although seepage into the ground water is unlikely.

Cole (1989) reviews the work of Kitchell and Connor (1984) who rate human waste and litter (trash) from 1 to 4. Litter is assessed in terms of number of pieces present; human waste in terms of pieces of toilet paper and numbers of piles of faeces.

3.2.1.3 Methods of measuring impacts of rock climbing on:

(a) Vegetation

Swaine (1992) measured impacts of rock climbing on subalpine plant communities by measuring % bare ground, vegetation height, species numbers and cover abundance for each species along transects set up at 90° to the rock face and using a 0.5 m quadrat.

(b) Soil erosion and compaction

Trampling causes soil compaction; bulk density of soil increases 0.2-0.4 gm^{-3} higher than under undisturbed vegetation. Soil water content may increase as drainage is impeded, and smaller pore size decreases oxygen flow and diffusion through the soil which decreases the rate of organic matter decomposition. In the study on impacts of rock climbing, Swaine (1992) measured slope, using a clinometer, and soil pH but soil compaction was not measured. Altitude and aspect of the rock face were noted.

(c) Damage to natural features

Scrubbing of the rock face to obtain more friction for climbing removes mosses and lichens. Drilling a hole in the rock and inserting a bolt is used for climbing. Both these features are surveyed visually by Swaine (1992).

3.2.1.4 Methods of measuring impacts of visitors to caves:

Biophysical impacts of recreational visits to caves do not appear to have been studied in New Zealand. An Australian study (Manidis Roberts Consultants, 1995) has identified measurable indicators of environmental impacts including hydrology, carbon dioxide, temperature, evaporation/humidity, water quality, selected terrestrial and aquatic bio-indicators and physical damage. A system of co-ordinated monitoring of potential impacts is not yet in place.

3.2.1.5 Methods of measuring impacts of off-road vehicles on:

(a) Vegetation

Literature reviewed by Grant *et al.* (1977) indicates that vegetation removal by off-road vehicles compounds erosion problems by exposing the soil surface to water. Vehicles reduce the supply of plant litter and organic matter which in the long term will affect the soil structure and nutrient supply and reduce re-vegetation of the area.

(b) Soil erosion and compaction

Soil compaction by vehicles has serious long term implications for the environment. Soil tests were carried out by Grant *et al.* (1977).

3.2.1.6 Methods of measuring impacts of endurance events on:

(a) Vegetation

A problem for managers is the regular versus episodic use of tracks. Norton's New Zealand study (1989) is now an annual monitoring programme with observation, assessment of vegetation, track width measurements and surface movement on the track. Photo points are taken before and after each endurance event. At this stage the impression is that regeneration is taking care of the damage. The Countryside Commission for Scotland have attempted to monitor mass events on footpaths using observation and photos before and after the event but no quantitative studies have been undertaken (JW Mackay, 1990, pers comm).

(b) Habitat degradation

Norton (1989) observed the effect of runners in the Coast to Coast endurance event on populations of blue duck. Two pairs of blue duck with chicks were watched during the study.

(c) Litter

Norton (1989) recorded occasional litter on the track.

3.2.2 Studies of Impacts on Wildlife

3.2.2.1 Methods of measuring impacts of marine mammal watching on the whales:

MacGibbon (1991) used non-intrusive methods to measure seven behavioural parameters while the whales were on the surface. These were: respiration or blow interval; length of submergence; surfacing length; speed of movement on surface; orientation on surface; occurrence of "hasty" dives; occurrence of aerial behaviours.

Whales were observed from a research vessel and from several points on the shore. Photo identification was used. Individual whales were observed before the whale-watching boats arrived, while they were present and after they left the area.

Gordon *et al.* (1992) repeated MacGibbon's methods of observation and extended them to study acoustic behaviour by collecting and analysing acoustic data. Data was collected from a vessel that towed a hydrophone that was monitored every 15 minutes until a whale was heard. Where possible whales were followed through dives using passive acoustic techniques including in the proximity to whale watching boats.

3.2.2.2 Methods of measuring impacts of boating on wildlife:

Jeffs (1993) used a competent biologist to record observations of fish and bird behaviour around a glass-bottomed boat.

Montgomery (1991) counted all species of water birds daily before recreational users were about and later when recreational activity was at its peak. High and low recreational use sites were used. Recreational disturbance was assessed by counting the number of boats present, an estimate of engine noise, number of water skiers and number of shore parties. The results were analysed statistically.

3.3 Discussion

The gaps in Tables 5 and 6 indicate the limited number of studies carried out in New Zealand on the impacts of a particular activity on a particular aspect of the environment. The most useful indicators and methods are thus difficult to recommend, although a combination of objective measurements and subjective assessments have provided adequate coverage at some sites. A more comprehensive literature search could perhaps provide appropriate low cost monitoring methods in addition to the limited selection quoted in this Paper.

4 CONCLUSIONS AND RECOMMENDATIONS

This Paper provides a literature review and critique of research into visitor impacts on the New Zealand natural environment. The scope of the Paper was defined by the Department of Conservation as indicated in the Introduction.

4.1 Conclusions

- Research into visitor impacts on "hot-spots" (as defined in Ward and Beanland, 1994) is limited in terms of the areas studied, the type(s) of impact considered, and the length of study.
- There appears to be very little continuous monitoring or intermittent surveys being carried out.
- The relationships between baseline conditions, type and level of use, the type and degree of impact, and management objectives/responses have not been investigated.
- Most of the research has focused on terrestrial impacts, with very little having been undertaken with respect to impacts on natural features, wildlife, or environmental quality.
- Individual studies have focused on only one or two of the variables to be assessed (refer to Tables 1-3), and therefore do not provide a comprehensive coverage of tourism impacts at a particular site.
- The studies reviewed provide a basis for further research.
- However, the studies reviewed do not provide sufficient information to demonstrate the relationships between sites with similar biophysical, use and impact characteristics.
- Only a very limited number of research methods have been used in the New Zealand context.
- A limited search of overseas literature revealed some additional methods for measuring the impacts of trampling.

4.2 Recommendations

- In order to implement the second and fourth "priority actions" (Draft Visitor Strategy Discussion Document, DoC, 1995), the Department of Conservation must identify the gaps in the understanding of biophysical impacts and decide where information is most urgently needed.
- A more focused and comprehensive literature search of overseas initiatives in the development of appropriate indicators and the monitoring of visitor impacts needs to be undertaken.
- The Department needs to refer back to relevant research cited in Part 1 (Section 2.2) of this Paper prior to the development of indicators, and the design and implementation of site specific research/monitoring programmes. A number of researchers have made good comments that are worthy of further consideration.
- Long term, low cost monitoring of priority "hot-spots" should be undertaken.

- Monitoring programmes must be clearly linked to management objectives and responses.

- Information derived from these monitoring programmes should form the basis for site and visitor management.

- The purpose of any research/monitoring into visitor impacts needs to be explicit.

- Wherever possible, monitoring programmes should be comprehensive, ie, provide for the relationship between baseline conditions, type and level of use, the type and degree of impact, and management objectives/responses.

- Monitoring programmes must be cost-effective and practical, ie, aim to provide information about visitor impacts that assists both the tourism industry and the Department of Conservation in managing New Zealand's tourism and recreation resources.

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APPENDIX I
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APPENDIX II

Summary of the Twelve References from Booth and Cullen

Terrestrial Impacts - Soil and Vegetation

1) Beamish, SF (1977): *The Route Burn track: an application of environmental impact analysis.* Report for the Mt Aspiring National Parks Board. University of Otago.

Problem investigated:

To assess the environmental impact of trampers walking the Route Burn track.

Potential impacts considered:

- Track activity - effects of tramping
- Hut activity - effects of camping, cooking, washing and waste disposal

Variables chosen to assess impacts:

- Users - numbers, trends, patterns, characteristics
- Vegetation depletion
- Soil compaction
- Soil erosion
- Pollution
- Comparisons of light impact with heavy impact areas. Temporal and spatial variation assessed. The aim was the ability to predict trends.
- Daily rainfall

Methods used to assess variables:

- Users' survey
- Trampling:
  Ground survey of : Vegetation cover and regrowth
  : Soil compaction - bearing strength, bulk density, infiltration hydrologic relations
  : Soil erosion - track width-depth, sediment yields, induced stone movement
- Hut:
- Camping: vegetation cover
- Cooking: fuel
- Washing: waste water
- Waste disposal: refuse pits
- Results mapped and analysed

Researcher's findings and comments:

Several main areas of impact were identified where trampling and erosion have occurred. However these are of limited extent when compared with the total area covered by the track.

The track's ability to sustain present and future numbers of users is dependent on recognising acceptable thresholds of physical and aesthetic deterioration under current policy and management.

Variation in habitat and narrow extent of trampling over the track made it difficult to establish a threshold of an indicator such as % bare ground.

Future monitoring of photopoints may establish acceptable thresholds of track width and depth and % live plants in the vicinities of huts.

Several alternatives of regulating the future use of the track include educating users, limiting facilities during periods of peak use, limiting numbers of people on the track.

Recommendations include the monitoring of photopoints on a regular basis and examining trends, and further research on predicting environmental parameters responsible for track erosion.

Researcher:

Otago University student. Report for the Mt Aspiring National Park Board used as a University thesis.

2) Clayton, TO (1990): *Impacts of use of walking tracks in Tongariro National Park, New Zealand.* Unpublished MSc thesis, University of Auckland.

Problem investigated:

1. To determine whether a significant impact occurs due to the use of walking tracks in Tongariro National Park;
2. To identify environmental factors that are significant in determining the severity of impacts;
3. To evaluate the utility of a subjective estimate of the impact from use of walking tracks; and
4. To identify and discuss the implications for management of Tongariro National Park of the results of the above investigations.

Potential impacts considered:

Impacts of Recreational Trampling on Vegetation

- Seed germination and plant establishment
- Physiological and morphological effects on plants
- Photosynthesis and carbohydrate metabolism
- Effects on plant height and biomass production
- Effects on bloom and fruit production
- Effects on recolonisation (Kuss and Graefe, 1985)

Impacts of Recreational Trampling on Soils

- Increases in bulk density and penetration resistance as a result of soil compaction and subsequent changes in soil moisture, air flow and mass flow of nutrients (Cole, 1985).
- Major impact follows the destruction of vegetation when the soil is exposed to erosion. In such circumstances the soil particles are able to be lifted by frost heave and are then readily transported by wind and water (Grose, 1983). The susceptibility of Tongariro National Park soils to erosion once exposed may also reflect changes similar to those discussed by Cole (1985). Any decreases in the depth of organic horizons and infiltration rate of the soil are likely to promote erosion.

Variables chosen to assess impacts:

Plot:	• size • location • slope	• aspect • altitude
Track:	• litter	• modification and dispersion
Vegetation:	• % cover • species	• % each species and maximum height
Soil:	• colour • infiltration rate	• % organic matter • % fines

Methods used to assess variables:

The basic methodology used in this research is the comparison of control and impact plots. This approach was necessary as there is no baseline data describing in detail the characteristics of the communities and the soil present prior to the formation of the walking tracks.

At each plot, measurements were made with the aim of establishing, through statistical analysis, where there are significant differences between the control and impact plots.

Three separate areas were sampled during the course of the field work with selected characteristics summarised in Table 1. The intention prior to commencement of the field work was to sample from a range of different communities so that the results of the research would be as widely applicable as possible.

Table 1: Summary of selected characteristics of study areas

Characteristics	Study Area A	Study Area B	Study Area C
Altitude (m)	1450	1150	1150
Vegetation	Low Alpine	Subalpine Scrub	Subalpine Scrub
Aspect	Northwest	West	West
Intensity of use	Moderate	Heavy	Moderate
Track type	Unmodified	Modified	Unmodified
Soils (% fines)	6-28%	13-33%	20-29%
% organic matter	1-18%	4-22%	13-25%
Source: Field & Laboratory Data, 1990; Department of Lands & Survey, 1983, 1984.			

Researcher's findings and comments:

The statistical analysis of the field and laboratory data has produced the following results:

1. Analysis of variance (ANOVA) showed that the control and impact plots sampled during the field programme were not significantly different in terms of variables that are not affected by use of the walking tracks. Any differences detected in subsequent analyses are, therefore, assumed to be the result of the impact of trampling.
2. The ANOVA and discriminant analysis identified the variables total cover of vegetation, litter, number of species per square metre, percentage fines and percentage organic matter as potentially showing differences between control and impact plots.
3. Testing of each variable using a regression modelling procedure identified percentage organic matter and total cover of vegetation as the most robust indicators of impact.
4. A further modelling procedure showed that the variables altitude, percentage fines, slope, diversity and rate of infiltration are significant in explaining the variation of percentage organic matter and total cover of vegetation.
5. Examination of the utility of a subjective estimate of impact suggested that it may be useful but requires clear, rigorous criteria.

The author suggests that an increased number of observations would allow development of better models of variables such as number of species per square metre and, therefore, better prediction of values under control conditions. This, in turn, could lead to identification of more impact variables. Measurement of more variables in an extended sampling programme could also lead to identification of more impact variables. It is unlikely, therefore, that this research has identified all the variables that measure changes in the environment of Tongariro National Park due to use of walking tracks.

An obvious limitation of the study design is the restricted number of variables it was possible to measure. Additional field workers and resources would be required to increase the number of variables recorded. Particularly valuable would be more soil measurements such as a direct measure of soil compaction and soil bulk density. A measure of the intensity of use of each of the walking tracks would also be valuable although it has not proved to be essential.

Another limitation of the research as presented is the lack of an extensive analysis from a botanical viewpoint. Such an analysis is at present beyond the competence of the researcher but could produce useful results for management. For instance, it may be that particular species are reliable indicators of impact in Tongariro National Park as previous research has shown that some species are resistant to trampling and are often located adjacent to walking tracks (Bates, 1935).

The number of observations collected in the sampling is, as implied previously, less than would be ideal. This shortfall is partially offset by the relatively high degree of explanation of the statistical models presented in Chapter 3 and the robust methodology used in the statistical analysis. However, there must still be an element of doubt which suggests that it would be worthwhile repeating the analysis of the field data as part of an extended study.

In addition to an analysis from a botanical viewpoint and use of transects, the methodology used could potentially be improved by further statistical analysis. Experimentation would be required but it is possible that more complex multivariate techniques such as canonical correlation analysis could be useful.

Researcher:

MSc student, University of Auckland.

3) Grant, IJ; Crozier, MJ and Marx, SL (1977): *Off-road vehicle recreation study: Characteristics, demand and impact on the social and physical environment.* Prepared for the Wellington Regional Planning Authority by Applied Geology Associates, Wellington.

Problem investigated:

Effects of off-road vehicles (ORVs) used for recreation in the Wellington region.

The objective of this study was to provide factual information from which policies for planning, provision and control of off-road vehicle activities could be derived.

The Study had four sections:

1. Determination of the nature of demand
2. Definition of the nature of resource available to meet that demand
3. Determination of physical impact of the demand on the resource
4. Terrain sensitivity

Potential impacts considered:

Immediate vegetation cover:

- Soil surface form and change in structure, removal of vegetation and soil litter, decrease in porosity, lower the infiltration capacity of the soil.

Long-term vegetation cover:

- Decrease in soil litter, infiltration capacity, soil structural changes, overland flow, soil erosion potential.

Variables chosen to assess impacts:

- Number of vehicles in use
- Size of the area used
- Length of time the area is used
- Impact-making capabilities of the ORV and the activity engaged upon the sensitivity of the terrain to ORVs and their activity

Methods used to assess variables:

- Attendance at club competitions
- Visiting areas known to be used by participants
- Soil tests
- Photographic record

Review of previous studies, observation and measurement at competitive events, and by devising controlled experiments involving off-road motorcycles. The information resulting from these investigations is used to design a terrain sensitivity ranking for each of the Environmental Resource Units (ERU) within the Region. This information is depicted in its final form on the ERU Terrain Sensitivity Map.

Researchers' findings and comments:

Research into the literature, study of competitive events and popular areas for operating ORVs, and the execution of controlled experiments have led to the following conclusions.

Aspects of the physical environment subject to immediate impact:

- ***Soil*** -- Soil compaction has the most serious long-term implications to the environment. It has the potential for altering the hydrological regime of a catchment, inducing soil erosion, depleting available moisture for plants, and inhibiting root development, revegetation and microbe activity in the soil.

- ***Vegetation*** -- Vegetation removal by ORV also compounds the erosion problem by exposing the soil to the erosive effects of running water and by allowing overland flow to travel at higher velocities and hence with greater erosive competence. De-vegetation of the soil surface reduces the supply of plant litter and organic matter which, in the long run, will detrimentally affect the structure and nutrient supply to the soil and impede re-vegetation of the site. In addition, the exposed surface of the soil receives direct impact of raindrops and this will further decrease the infiltration capacity of the soil due to surface sealing.

- ***Recovery*** -- As long as the immediate impact of ORVs has not initiated widespread erosion and ORV operation has ceased, there is some indication that the environment may recover. Re-vegetation had taken place at an average rate of 80.2 m^2 per week and, at this rate, complete re-vegetation of the grass cover would occur approximately 17 - 18 weeks after the event. However, there was an indication that the species composition of the pasture had changed, with weeds, such as thistle, being more abundant on the track than in the surrounding areas.

The environmental factors which control variation in the type and degree of impact are: slope angle, soil texture, soil compaction (including clay mineralogy and organic matter content), soil density, soil moisture and seasonal conditions, and vegetation cover.

Researchers:

Applied Geology Associated accepted responsibility for the execution of the study. The personnel involved in this study were:

- Ian J Grant, Principal, Applied Geology Associates
- Michael J Crozier, Senior Lecturer, Geography, Victoria University of Wellington
- Sally L Marx, Graduate Student, Geography Department, Victoria University of Wellington

The study was based at the Geography Department, Victoria University of Wellington.

Ewen Henderson of the Wellington Regional Planning Authority monitored the research process.

4) McQueen, D (1991): *Environmental impact of recreational use on DoC estate: (1) Guidelines on track location, management and repair.* DSIR Land Resources Contract Report No 91/54 (Part 1) prepared for the Department of Conservation.

Problem investigated:

Need for guidelines on the best location of new tracks and monitoring environmental degradation through site indicators.

Potential impacts considered:

Track erosion.

Variables chosen to assess impacts:

Relationship of site factors (climate, slope, soils, vegetation, type and level of use) to track deterioration.

Methods used to assess variables:

Literature search of relationship between site factors and track deterioration, and systems for predicting and monitoring track deterioration. Case study of track deterioration in Tararua Forest Park.

Researcher's findings and comments:

Examples of prediction systems:

1. A classification from 1 to 5 which emphasised slope angle, soil type and drainage (Sumner, 1980).
2. A fragility classification for alpine areas with sites ranked from 1 to 3 (Knapik, 1978)
3. A New Zealand example based on rainfall and usage to estimate requirements for track construction (Young, 1985 - see later reference).

A prediction case study using only soil and topographic information to predict track problems and optimise track information enabled a generalised view of likely conditions to be encountered and would be useful at the feasibility study stage of track development. This approach would need to be augmented by a detailed soil survey.

Monitoring methods for track deterioration include: identification of representative areas, measurement of soil loss and visual degradation.

Methods for prevention of deterioration and repair of tracks include provision of cambered track surfaces, ditches and culverts and artificial surfaces.

Erosion was correlated with level of use and severity of erosion was correlated with depth of erodible material. Erosion severity was not observed to be correlated with climate, slope or vegetation.

Level of use and site characteristics control level of impact. At lower levels of use, major impact is on vegetation. At higher levels of use, soils have the most influence. A lower threshold exists above which impacts are not easily absorbed and are related to total use. At an upper threshold, most degradation has occurred and there will be little further damage. The thresholds depend on the features being examined.

Track deterioration in NZ appears to be higher for the same level of use than some other countries. There are systems available to predict and monitor track deterioration. Tracks should not be sited in sensitive areas: deep soft soils, unstable slopes, poorly drained zones. These areas can be identified by pre-track construction surveying.

Monitoring of track condition at selected points by detailed measurements is important to a certain rate and degree of deterioration and take remedial action.

Relationships established should be tested in other situations. Standards of unacceptable erosion severity and track deterioration need to be established.

Researcher:

DSIR scientist.

5) **McQueen, D; Williams, P and Lilley, G (1991): *Environmental impact of recreational use on DoC estate: (2) Effects of camping.* DSIR Land Resources Report No 91/54 (Part 2) prepared for the Department of Conservation.**

Problem investigated:

Need to quantify the effects of camping in order to provide managers with site indicators as to when campsite use is having unacceptably high environmental costs.

Potential impacts considered:

- Damage to or removal of vegetation
- Soil compaction and soil removal
- Reduced soil drainage
- Accumulation of rubbish
- Pollution of water supplies
- Attraction of weeds and pests

Objectives:

1. To measure environmental effects of low, medium and high camping levels as compared to a control situation and to measure recovery rate for an area where camping is excluded.
2. To assess severity of impacts and make management recommendations.

Variables chosen to assess impacts:

Objective 1:

- Soil properties (physical, chemical and waste disposal potential)
- Vegetation (diversity and quantity)
- Soil invertebrates (susceptible to this kind of disturbance)

Objective 2:

- A list of field based indicators of impact
- General recommendations for management to minimise ecological impact

Methods used to assess variables:

Levels of use were calculated as a ratio of bednights/area available for camping (specific use). The number of sites/camping area was estimated and assuming 2 persons/tent site occupancy/year was calculated. High and very high levels of use are given as 50-70 nights/year.

Three sites within Abel Tasman National Park studied.

Measurements of:

- Vegetation - species numbers and diversity
- Soil properties - compaction porosity, water movement, chemistry
- Soil invertebrates - abundance and identification down to order level

Researchers' findings and comments:

Vegetation changed markedly with increasing level of use. Removal of saplings and litter is followed by broken branches and the arrival of weeds.

Soil fauna are very sensitive to use with >50% depletion at high and very high levels

Soil penetration resistance in topsoils increased with use.

Higher levels of use lead to depletion of topsoil and volume of roots; more pronounced in open grassland than under trees.

Soils in camping area were deficient in nutrients, especially potassium.

Soils became compacted with use but still retained sufficient porosity so that movement and disposal of water was adequate. Ability of soils to retain water for plant growth was limited and drought potential was high.

Soils were weakly developed sandy Recent soils from beach sands and alluvium. They were found to be moderately suitable for camping.

Indicators of impact are:

- Removal of woody vegetation and litter
- Absence of seedlings
- Decline in soil fauna
- Decrease in native species diversity
- Increased presence of weeds
- Presence of bare ground
- Damage to trees
- Increased compaction of soils
- Thinned soil A horizons and loss of organic matter

Most changes occur at low use levels. Once a slight change occurs and management begins, reversal of change is more difficult. Deterioration is still reversible and recovery to "natural' condition is possible provided use levels are very low.

Recommendations:

1. Improvements in design of camping areas to distribute impacts more easily.
2. Management of grass species to increase cover.
3. Monitoring levels of use and impact and changes with time to assess the effect of management programmes.
4. Optimise site selection by prior assessment of site suitability.
5. Extension of study to other areas.

Researchers:

DSIR scientists.

6) Norton, DA (1989): *Environmental impact report on Mingha/Deception section of Coast-to-Coast endurance event.* Report prepared for Robin Judkins, Christchurch.

Problem investigated:

1. To assess the long-term environmental impact of the Coast-to-Coast;
2. To assess the specific impacts of the 1989 event and to comment on the likely impact if it were staged under adverse weather conditions; and
3. To assess the effect the event is having on other track users.

Potential impacts considered:

Track condition, some observations on bird life and litter.

Variables chosen to assess impacts:

Vegetation impact, track width, weather conditions, surface movement of track, blue duck, track usage.

Methods used to assess variables:

Three track visits, before, during and after the Coast-to coast event. Track inspection, photo points, track width measurements, vegetation impact, surface movement on track, bird observations, litter observations.

Researcher's findings and comments:

The extra use of the track does not appear to have resulted in any excessive deterioration in track quality. Environmental impact is inevitable but appropriate management will confine it to the track.

Boggy sections of the track could be controlled by good management. Boggy sections of the track immediately after the event returned to pre-event condition one month later. Board-walks have prevented track deterioration, even after heavy rain.

Impacts of the event on plants and animals are minimal.

Control is needed for litter and also for keeping contestants on the track in one section of the forest.

Track counters and regular track monitoring are needed.

Researcher:

Lecturer in the School of Forestry, University of Canterbury.

7) Simmons, DG and Cessford, GR (1989): *The St James Walkway study*. Occasional Paper No 1, Department of Parks, Recreation and Tourism, Lincoln University.

Problem investigated:

Environmental impact on the St James Walkway.

Potential impacts considered:

Track impact studies.

Variables chosen to assess impacts:

Descriptive studies of changes in track condition; physical impacts of use on different soils.

Methods used to assess variables:

Study of track conditions over three years: Nelson (1982) evaluated impact monitoring techniques and selected suitable ones for this study and established a baseline; Tetteroo (1983) and Hutchings (1984) largely repeated the methods of Nelson with small modifications. Mixture of objective measurements and subjective assessments used: full transects of track, partial transects, hut transects, photopoints, subjective track rating, observation of users behaviour.

Extensive study of physical impacts of trampling on soils by Stewart (1985) using different soil types, ridge and gully sites, backslope and toeslope positions or terrace and valley floor positions. Topography and soils recorded at each of 24 sites. Soil samples analysed for soil bulk density/porosity, consistence, aggregate stability, pH, nutrient status and organic carbon content.

Researchers' findings and comments:

Objective approach: Initially, emphasis was on gathering objective data to show use-induced change. Degree of change (usually track widening or deepening) was not great or of great extent. Sites of high rainfall, low drainage and organic soils were the most affected.

Stewart (1985) found initial effects of trampling on a new track caused loss of vegetation and top soil but often lead to more stable conditions with compaction of underlying soils. Exceptions were soils which were poorly drained or become water courses. Differences between organic soils and mineral soils are important. Organic soils are not compacted but are wet, weak and severely damaged by trampling. Mineral soils are most susceptible to erosion and tend to be compacted by trampling which increases soil strength but decreases water infiltration, leading to surface run-off and puddling.

Subjective approach: Use of this approach allowed identification of the reasons that track profile measurements showed change, assessment of how representative such changes were of the whole track, and which management actions should take place to prevent further undesirable changes. Subjective recognition of use-induced impacts allowed the general state of the track to be assessed over wider areas that those covered in the objective approach.

Overall, impacts from track use were low and generally confined to a small area. In retrospect, given the short period in which the track changes occurred during consolidation of the track, the objective measurement approach seems unnecessary. Subjective assessment of changes provided an adequate account of what changes were occurring, where and why. Objective approach most useful at particular sites where specific conditions are being considered. The soil study showed that tracks should avoid organic soils, areas of surface ponding and run-off along the track. Where possible, tracks should be sited on recent soils formed on river gravels.

Researchers:

Simmons is a Senior Lecturer in the Department of Parks, Recreation and Tourism, Lincoln University. The other researchers involved in this study were graduate (Cessford and Stewart) and diploma (Nelson, Tetteroo, Hutchings) students.

8) Swaine, C (1992): *Vandals in the temple: a study of the physical and cultural impacts of rockclimbing in Tongariro National Park, New Zealand, with emphasis on vegetation values.* **Unpublished dissertation for Part II, Fitzwilliam College, Cambridge University.**

Problem investigated:

The impacts of rock climbing on subalpine plant communities, rock and Maori cultural values.

Potential impacts considered:

Type and degree of climbing impact by comparing a highly used site with a lesser used site in the Mangatepopo Valley.

Variables chosen to assess impacts:

Bare ground, vegetation height, species numbers and abundance were assessed along with a discussion of impacts of bolts in the rock face and scrubbing the rocks.

Methods used to assess variables:

Measures were made of bare ground, vegetation height, species numbers and abundance along three transects at two sites in the Mangatepopo Valley. The impact of bolting to the rock face and scrubbing to remove moss and lichens are discussed.

Two sites at Parikarangaranga were also studied using the same methodology because of the vegetation and cultural impacts due to intensive use by climbers.

Researcher's findings and comments:

The two Mangatepopo sites were compared using t-tests and the results suggest that it is "highly likely" that the differences are due to the higher use being made by rock climbers of the more highly used site.

The Parikarangaranga sites are of concern to DOC as they provide a warning of the potential for Mangatepopo to be similarly affected. However the two locations were not directly comparable because of differences in site characteristics (altitude, climate, vegetation type) so statistics were not performed. There is clear evidence that climbing is having an impact on the vegetation and rocks at the highly used site.

It is recommended that apart from the parameters measured, other conditions likely to influence local patterns should also be measured such as slope, aspect and soil pH.

Recommendations:

1. Site specific research is needed to assess vulnerability or hardiness of a particular site; also regular monitoring of impacts.
2. One or two "sacrifice" sites need to be set aside for climbers.
3. Prohibit use of bolts and chalk.
4. Education of climbers to increase the awareness of negative environmental impacts; information boards explaining environmental and Maori cultural implications of climbing.

5. Map questionnaire distributed to climbers for them to mark their route, stopping places and activities at each site. This would help DOC to judge the use intensity of the sites.
6. Consolidation of existing tracks leading to Mangatepopo Cliffs to alleviate track erosion.
7. Revegetation of affected areas to recreate natural communities using seed from park communities.

At Parikarangaranga Scenic Reserve, additional recommendations for management are:

1. Prohibit the use of vehicles along the length of the crags.
2. Information boards under Scenic Reserve signs may increase climbers' awareness of environmental impacts and cultural values.

Researcher:

University student.

Wildlife Impacts - Marine Mammals

9) **Gordon, J; Leaper, R; Hartley, FG and Chappell, O (1992):** ***Effects of whale-watching vessels on the surface and underwater acoustic behaviour of sperm whales off Kaikoura, New Zealand.*** **Science and Research Series Report No 52, Department of Conservation.**

Problem investigated:

The behaviour of sperm whales on the surface, and the vocalisations they made under water were analysed to investigate the possibility that whales were being disturbed by whale-watching operations off Kaikoura, New Zealand.

Potential impacts considered:

- Short-term effects - avoidance and aggressive behaviour possibly resulting in short-term stress.
- Long-term effects of harassment on critical behaviours such as feeding, resting, and mating could result in a reduction in the biological fitness of a population.
- Biological significance of changes in behaviour.

Variables chosen to assess impacts:

- Sperm whale vocalisations
- Visual and acoustic behavioural parameters - such as shorter periods on the surface and shorter ventilation periods, clicking after diving

Methods used to assess variables:

The report includes specific descriptions of methods used in relation to the following indicators/activities:

- Collection of visual information:
  - Recording surface behaviour - visual and acoustic
  - Individual identification - photographs
  - Range estimation
- Analysis of surface behaviour
- Collection of Acoustic data
- Analysis of Acoustic data
- Acoustic behaviour summary parameters:
  - Parameters summarising initial clicks
  - Parameters summarising creaks
  - Parameters summarising interclick intervals
- Statistical analysis of visual and acoustic data

Researchers' findings and comments:

The effects of disturbance on surface behaviour seem to be relatively undramatic and effects on acoustic behaviour would seem to be restricted to the period directly after fluke up. However it may be premature to assume that these effects have little biological significance. In particular it should be noted that there have been no measurements of the long term effects of disturbance on these whales.

Behaviour of individual whales can be very different even when even when environmental conditions seem to be constant.

Some whales seem to be more tolerant of whale watching boats and these individuals are the ones to which most whale watching effort is directed. Such whales could be inherently more tolerant of boats or could have become habituated to them over time. Conversations with whale-watching skippers suggest that both of these processes could have played a part.

There were some difference in the behaviour of whales in the shelf and offshore zones. These may have been due to physical and biological differences between the two regions as well as to differences in the individual whales found in the two areas.

There were still occasions when whales were disturbed by tour boat operators in ways which were immediately obvious and could have been avoided. This was usually caused by particularly insensitive boat handling and often resulted in the whale submerging without fluking. This study suggests that there has been a reduction in the number of whales which were so obviously disturbed when compared to the observations by MacGibbon (1991).

No measures of the long-term biological effects of the changes in behaviour indicated by this study have been made. However, some comments on their possible nature can be made, based on what is known of sperm whale biology.

The decrease in surface time and reduction in blow number is the factor which is most likely to be of major biological significance. Feeding whales are at the surface to prepare for deep feeding dives. This study has shown a correlation between surface time and the length of subsequent dives; a relationship which would also be expected on physiological grounds.

It should be emphasised that during this study most of the whale watching was taking place with whales that were tolerant to whale watching boats. The findings, particularly as regards boat disturbance, may well not hold, if less tolerant whales became the subjects of the industry. The study also took place during the summer months. MacGibbon (1991) found that whales were more approachable in the summer than in the winter months.

Therefore, some immediately obvious effects of boats on whales have been observed, but note that there has probably been a considerable reduction of the degree of disturbance of whales by tour boat operators in recent years.

There are some additional effects on surface behaviour. These seem to be quite minor but it would be premature to assume that they had no biological significance.

Effects on underwater acoustic behaviour were only demonstrated in the bout of clicking immediately after fluke up. This could be taken to indicate that what effects there were on whale behaviour, occurred at or near the surface, and had limited effects on underwater behaviour.

Continuing monitoring would be advisable in order to investigate any long-term effects of this disturbance.

Researchers:

- Johnathan Gordon, Wildlife Conservation Research Unit, University of Oxford, Department of Zoology
- Russell Leaper
- Gillian Hartley, Department of Zoology, University of Bristol
- Oliver Chappell, Chappell Hydrophones, Bristol

Wildlife Impacts - Fish and Birds

10) Jeffs, A (1993): *The impacts of a glass-bottom boat operation in Goat Island Bay.* An independent impact assessment for the Department of Conservation on behalf of the Habitat Exploration Partnership, Auckland.

Problem investigated:

- Impacts on natural values of the marine reserve
- Impacts on other users of the marine reserve

Potential impacts considered:

- Fish behaviour around the boat
- Bird behaviour around the boat
- Marine life on the shore and near the mooring buoy
- Outboard motors on minute marine life

Variables chosen to assess impacts:

- Fish behaviour around the boat
- Bird behaviour around the boat

Methods used to assess variables:

The methods used in this study rely mainly on a qualified and competent biological observer recording observations of the effects of the glass-bottom boat operation on the natural values in the reserve.

Such an approach provided an expert appraisal of the nature of the impacts that were taking place, comments on the relative importance of the impacts and how they might be ameliorated have been provided in some instances.

This study did not attempt to provide any quantitative assessment of the observed impacts because many of these impacts would be extremely difficult to quantify with any confidence because of the nature of the impacts and the variability caused by other factors.

Researcher's findings and comments:

Fish behaviour -- The glass-bottom boat was found to be affecting fish behaviour. Assessing the relevance of these changes in behaviour to the ecology of the reserve would be difficult, if not impossible. Fish are highly mobile creatures that in the normal course of their daily lives must regularly avoid potential predators and follow moving sources of food. Therefore, it is unlikely that the operation of the glass bottom boat in the bay will create any long term impacts to the natural ecology of area. However, if this vessel does create any long-term impacts it would be unlikely that they would be significant when compared to other activities in the bay such as uncontrolled fish feeding by the public, other boat traffic, and the discharge of polluted water from the Whakatuwhenua Stream.

Bird behaviour -- The glass-bottom boat operation does not appear to be interfering with bird behaviour in the reserve in a manner that would create significant concern. Birds in general are highly mobile species that can, and will, move to avoid what they perceive as potential threats. Avoidance behaviour is only likely to cause a more serious impact if it interferes with a particular site that is of importance to the birds for some reason, such as roosting, nesting or feeding site. Recommendations have been made here on how possible impacts in potentially important sites to wild birds could be avoided by the boat operators.

Shore flora and fauna -- It was unlikely that shore organisms on the sandy beach were affected in any significant way by loading operations as sandy beach communities are by nature highly mobile and under continual wave disturbance. However, loading from the rocky-shore platform was observed to have some impacts on the shore life mainly from abrasion caused by foot traffic and from the loading operation itself.

The impacts on shore flora and fauna from the glass-bottom boat were limited in both the areas affected and the levels of impact on those areas. If it was thought to be necessary, these impacts could be reduced further; but encouraging passengers to wash their feet in rockpools before boarding the vessel or before leaving the shore platform; but installing permanent steel bollards on the shore to tie the loading pontoon on to in order to reduce movement on the gangway; by minimising the period for which the glass-bottom boat is tied alongside the loading pontoon as this accentuates the movement in the gangway.

The mooring buoy is having an effect on marine life -- Damage consists of abrasion to rock and seaweed from the chain. The operators have been advised of this concern and have already undertaken to remedy the situation.

Minute marine life is being affected by the running outboard motors -- It was unnecessary to attempt to observe the effect of the glass-bottom boat on minute marine life. Outboard motors would undoubtedly kill, injure or disturb small planktonic marine life through the movement of the boat, propellers through the water and through the uptake of cooling water for the motors. Any such impacts were likely to be small scale in comparison to the huge pool of planktonic animals living in the area and were unlikely to be any greater than for any other vessel moving through the reserve.

Researcher:

"The acceptance of the researcher as *a recognised and reputable independent party* was laid out in a letter from DoC dated 12 January 1993."

11) MacGibbon, J (1991): *Responses of sperm whales (Physeter macrocephalus) to commercial whale watching boats off the coast of Kaikoura.* Unpublished report, Department of Conservation, Wellington.

Problem investigated:

The effects of whale watching on sperm whales off the coast of Kaikoura.

Potential impacts considered:

Changes in whale behaviour.

Variables chosen to assess impacts:

While a whale was on the surface, seven behavioural parameters were recorded:

1. Respiration or blow interval: time (seconds) between any two consecutive blows (exhalations) of a single whale during surfacing.
2. Length of submergence.
3. Surfacing length.
4. Speed of movement on surface: assessed qualitatively as slow, moderate or fast. Any changes in speed were noted.
5. Orientation on surface: direction of movement and any changes.
6. Occurrence of "hasty" dives, that is any dive which was not preceded by the usual pre-dive sequence.
7. Occurrence of aerial behaviours such as spyhopping, side-fluking, breaching or lob-tailing.

Methods used to assess variables:

Non-intrusive research methods were used to observe the behaviour of the sperm whales found off the coast of Kaikoura in the presence and absence of commercial whale watching boats. Observations were made from several shore stations and from a research vessel. Photo-identification was used.

Data collection involved:

1. Observations from shore stations - initially undertaken with the purpose of forming a baseline of "normal behaviours" of undisturbed sperm whales, with which to make comparisons.
2. Observations from the research boat - initial search routes were non-systematic. An omnidirectional hydrophone was used to pick up the echolocation clicks produced by sperm whales.
3. Behavioural observations - surface behaviours were recorded by a single observer on observation sheets during both shore-based and boat work.

To control for individual variation, continuous observations of a single individual over a number of surfacings were conducted whenever possible. The whale was therefore observed before boats arrived, while they were present and after the boats left the area. Because of the long dive times and underwater movement of the sperm whales, it was necessary to use *photo-identification* to confirm observations of a single subject across dive sequences.

Researchers' findings and comments:

Several individuals were sighted repeatedly over the winter months and tended to dominate the attention of the whale-watching boats. The frequent occurrence of unsuccessful approaches by boats suggests that there is a group of whales that are shy of boats and were rarely sampled during the study. The presence of boats tended to be correlated with the occurrence of short submergence times, short intervals at the surface, and the absence of raising the tail flukes of tail flukes prior to a submergence.

The presence of boats was associated with an increase in speed or cessation of movement with increase in the amount of change in direction, rather than the normal slow unidirectional movement.

Researchers:

Jane MacGibbon, Postgraduate, Zoology Department, University of Canterbury. Supervised by Dr Ian McLean. Thesis never completed.

ntgomery, PJ (1991): *The effects of water-based recreational disturbance on water-rds at Lake Rotoiti, Rotorua.* A report for the Royal Forest and Bird Protection ociety, the Department of Conservation and the Ministry for the Environment, echnical Report Series No 14, Department of Conservation, Rotorua.

Problem investigated:

This report aims to give some preliminary indications of recreational effects (principally from boating) on water-birds and management directions needed for the benefit of our water birds.

On Lake Rotoiti, Rotorua Region, the impact of water based recreation was assessed on nine water-bird species. This was done by using three study areas, each with a high and nil or low recreational use site.

Potential impacts considered:

- Which species are most affected by recreational (principally boating) activities
- Different species' tolerance to disturbance by a slow moving motor boat

Variables chosen to assess impacts:

- Comparison of bird abundance and diversity at high and low recreational use sites
- Assessment of boat-bird disturbance distances at high and low recreational use sites.

Methods used to assess variables:

Data collection -- At each site, all species of water-birds were counted from a boat twice a day - soon after dawn when the day's recreational disturbance was minimal, and again midday-early afternoon when the recreational level was generally at its peak. The counts were carried out on Saturday and Sunday (when recreational level was generally moderate to high) and two days during the week (when the recreation level was generally nil or low). Thus it can be said that the weekdays acted as a control and that if differences in the bird counts were to occur due to an increase in recreational activity, the afternoon counts in the weekends would detect these differences.

The recreational disturbance level was assessed during each birdcount for each of the high recreational use sites.

Four numerical values were noted for each site:

1. Number of boats present at the site (included all craft except those at permanent moorings).
2. Boat noise (estimated using a scale from 0 = none to 5 = racing power boats).
3. Number of waterskiers skiing on the water.
4. Number of shore parties, eg an angler, a family picnicking.

These four values were then added together and applied to the following scale to determine disturbance level:

0	nil
1-2	low
3-5	medium
6+	high

Data analysis -- Using the GENSTAT statistical analysis program, the following variables were statistically analysed:

- The number of birds present for each species during an observation.
- The presence or absence of each species during an observation.
- The total number of birds of all species.
- The number of species present at an observation.

The analysis proceeded in three stages:

- The low recreational use sites were compared against the high recreational use sites.
- At the high recreational use sites, the effect of disturbance level was tested.
- Step 2 was repeated after first adjusting out the effects of study area and time (morning or afternoon observation) in the analysis.

Boat-bird disturbance distances -- The second method for assessing the impacts of boats on water-birds was to measure the distances at which they were disturbed by boats. As it was not possible to assess the disturbance distances for all water-bird species, four were chosen: dabchick, coot, scaup and little shag. These represented a cross-section of the rare and common native bird species and all four were consistently present in each of the study sites. These species also appeared to be within the range of disturbance distances common to most lakebirds (ie, they are not the most sensitive or the most tolerant species).

The disturbance distance measurements were taken from the same study areas as the first part of the study and they were assessed in the low and high recreational use sites separately.

Data analysis procedure -- All three study areas were treated together but the high and low recreational use sites were analysed separately. Thus for each of the four species the means of the (a) distance to alarm and (b) distance to flee in both the low and high recreational use sites were calculated.

Researcher's findings and comments:

During the field work it was observed that the disturbance distances are affected by two factors:

- How close the birds are to cover
- If the birds have young.

For this study, shags were the most sensitive of the water birds to boating.

Short Term Effects -- In addition to having an effect on the numbers and distribution of birds on individual waters, two of the most important short term effects are:

- Keeping birds off preferred habitat, be they food, rest or breeding areas
- Energy loss for the bird. Disturbance often results in a change of activity, from resting/roosting or feeding, to moving. During conditions of food shortage or high food requirements (ie: the breeding season) this may have a significant effect on the welfare of the birds.

Long Term Effects – The long term effects are much more difficult to demonstrate or even theorize on. Ultimately only factors which cause a decrease in breeding success or an increase in mortality levels will have a long term impact. These factors include any which either limit the habitat available or the duration of its use by water-birds in the long term. In New Zealand, the most serious effects boating and associated recreational activity could pose to water-birds in the long term is the impact on breeding success. This can happen by a variety of mechanisms. Disturbance can result in increased predation of nests and chicks by mammalian predators such as rats, mustelids and cats or by avian predators such as pukeko, harrier and black-backed gull.

Wave wash from boats has the ability to destroy nests, particularly those of grebes (such as dabchicks) which are usually floating structures. In terms of rareness and limited distribution, the potential threat to dabchicks from boating causes some concern.

In general, too little is known about the current status and population trends of dabchick. They appear to be rarer than the North Island kokako, yet at present the species receives only a small amount of research and no management.

Direction for future research:

- A longer term repeat of this study:
  (a) for assessing the impact of boating on bird numbers and diversity, the study would need to start well before the peak holiday season of Christmas/January. The design and methods developed for this study could be used again, as they proved suitable. The distribution of water-birds within each high recreational use site should be assessed (ie, refuge and non-refuge areas). The number of broods or young of each species should also be recorded and analysed if comparing high and low recreational use sites.
  (b) At the same time some further disturbance distances should be assessed. Firstly adults with young and secondly adults of species not assessed in this study, especially shags; (For each species 20 observations minimum, 50 preferable);
  (c) If practical, an assessment of how far birds travel when disturbed-to-flee could be included.

- Shags: Effect of recreational disturbance on breeding success

- Dabchicks:
  (a) a literature review and compilation of unpublished data covering breeding success, population trends and current status of the population;
  (b) effect of recreational disturbance on distribution of adults, distribution of breeding adults, and breeding success.

- If any habitats of particularly high wildlife values are zoned to exclude boats, then this zoning change should be monitored in terms of bird numbers, diversity and breeding success.

The Report then makes some specific conclusions and recommendations in relation to effects, how to manage them and future research. Of particular interest are:

- On Lake Rotoiti coot, scaup, dabchick and little shag became noticeably disturbed by a slow moving motorboat at distances averaging between 30 and 70 metres. These same species were forced to flee, on average, when the boat came within 26-62 metres.
- Of the four species assessed, coots were the most tolerant of and little shag the most sensitive to a slow-moving motor boat.
- Coot, scaup and little shag showed greater tolerance of a slow-moving motorboat in high recreational use areas.
- Shags (little, little black and black) were the most sensitive of the water-birds to recreational activity - principally boating. This results in detrimental short-term effects on shags (ie: displacement and increase in flying time).
- The diversity of species present at a site is reduced during times of high recreational disturbance.
- The ability of the water-birds to accommodate recreational activities also depends on there being quiet refuge areas of high value water-bird habitat with good cover within high recreational use areas. This is an essential consideration to take into account when formulating management plans and assessing development proposals.
- With the exception of the above conclusions, recreational activity - principally boating - has had a minimal effect on the water-birds in the areas studied.

Researcher:

Study acknowledged DoC staff, Rotorua, Eastern Region Fish and Game Council, and FRI with funding from Royal Forest and Bird Protection Society and Ministry for the Environment.

APPENDIX III
Additional New Zealand Studies

Reference:

Howard-Williams, C and Davies, J (1988): The invasion of Lake Taupo by the submerged water weed *Lagarosiphon major* and its impact on the native flora. *New Zealand Journal of Ecology 11*: 13-19.

Problem investigated:

To assess the distribution, abundance and growth forms of the waterweed *Lagarosiphon major* and to assesss the effect of this plant on the native aquatic vegetation (see following study by Johnstone *et al.* (1985) for the role of boats in dispersal of aquatic weeds).

Potential impacts considered:

The effect of five growth forms of *L. major* on native macrophyte communities including characean meadows. Also, indirect effects of the weed beds on birds and invertebrates are discussed

Variables chosen to assess impacts:

Whole lake survey down to 7-10 m recorded aquatic plant species composition and abundance. Detailed analysis of 42 sites for vegetation structure and selected environmental variables including fetch, sediment type and slope.

Methods used to assess variables:

All field work was conducted by SCUBA divers. Sediment samples were size fractionated and % organic matter determined.

Researchers' findings and comments:

The introduced aquatic plants directly displaced native flora over large areas of the lake littoral zone.

They also attracted large herbivors such as swans and detritivors such as crayfish which adversely affect the native flora and compound the effect of the introduced plants.

Every care should be taken to prevent the intoduction of these exotic plants to the few remaining lakes where they do not occur, such as a few Northland and Westland lakes and Lake Christobel, to preserve the existing remnant populations of native plant communities from further degradation.

Researchers:

Taupo Research Laboratory, DSIR, Taupo.

Reference:

Johnstone, IM; Coffey, BT and Howard-Williams, C (1985): The role of recreational boat traffic in interlake dispersal of macrophytes: a New Zealand case study. *Journal of Environmental Management 20*: 263-279.

Problem investigated:

Dispersal of introduced aquatic macrophytes and measures to control their spread.

Potential impacts considered:

The association of the distribution of aquatic weeds with boating and fishing activities, bird dispersal and wind.

Variables chosen to assess impacts:

Distribution of five submersed, long-stemmed, vegetatively reproducing aquatic weed species in 107 North Island lakes was examined in relation to boating, fishing, birds and wind.

Methods used to assess variables:

Lakes were surveyed by boat and SCUBA and water quality data obtained. Boats and their trailers (565) were inspected for weed fragments and boat operators interviewed. Each lake was monitored once a week. Fragments of each weed species were measured and survivorship after 4 weeks was noted. Data was analysed and expressed as frequencies.

Researchers' findings and comments:

Plant distribution was significantly associated with boating and fishing activites rather than with natural vectors such as wind and birds. Boat inspections of 14 lakes showed that 5.4% of the boats entering the lakes carried vegetative fragments, and that, of those, 27% had come from another lake.

Boats leaving lakes carried weed fragments only when the haul-out area was near weed beds suggesting that weed control near haul-out areas would greatly reduce the probability of boat-mediated interlake dispersal.

Biotic factors such as lateral bud frequency, internode length and resistance to desiccation, may affect dispersal ability.

A model for predicting the frequency of interlake dispersal of macrophytes by recreational boat traffic was developed which can help with management decisions. For example, the probability of interlake weed dispersal by boats in the study area decreases very rapidly as the distance between lakes increases, and is extremely small beyond distances of about 125km.

Researchers:

- IM Johnstone: NZ Electricity, Hamilton
- BT Coffey: Ruakura Research Centre, MAF, Hamilton
- C Howard-Williams: Taupo Research Laboratory, DSIR, Taupo

Reference:

Nelson, D (1982): ***Environmental impact analysis on the St James Walkway.*** **Unpublished dissertation, Department of Parks, Recreation & Tourism, Lincoln College.**

Problem investigated:

- To establish and evaluate suitable techniques for monitoring environmental changes and impacts on the St James Walkway.

- To make a limited measurement of the impact of trampers on the track and surrounding environment during the summer of 1981/82.

Potential impacts considered:

Impacts on tracks and camping spots.

Variables chosen to assess impacts:

Measurements of track quality and width, impacts on camping areas; qualitative assessment of users behaviour

Methods used to assess variables:

Full transects, partial transects, oblique and vertical photopoints, subjective assessment of track quality between transects, track users behaviour at susceptible sites (and around huts).

Observations of people's behaviour at high use areas such as around huts, established stopping areas and camping spots.

Photo points selected mainly from areas where track was across terrain too wet or muddy for transects to be of practical use.

A two-tier classification was used for visual rating of the track: constructed tracks (boardwalk, benching, steps, heavily gravelled) and natural (minimal or no construction). both tracks were rated visually from 1 to 3 using defined criteria. This subjective rating system was used over the whole of the St James Walkway to fill in the zones between transects and photo points. A rating was taken at each transect which along with the photos helped to serve as a base reference for each of the points on the reference scale. Cattle impact was found to obliterate all sign of human impact on some sections of the track.

This system could possibly be used to determine if a section required maintenance.

In the partial transects, ground cover (rock, stone, gravel, soil, humus), litter (twigs, leaves, etc), vegetation was estimated and supplemented by oblique photos. For hut site transects, similar estimates were made. Criteria were used to select sites for partial transects.

For full transects, track profile analysis measurements were taken over a sufficient length of the transect to cover the track and any potential track movement or widening. Oblique and near vertical photos were taken. Criteria were used to select sites for full transects.

Researcher's findings and comments:

The short time frame of the study (one summer) limited the repetition of the measurements in most cases. Consideration of the methods indicates the usefulness of photo points providing there is no interference with the marker pegs. The transects required more time and effort to set up but provided more objective results. It is important to decide what type of information is required and how it can be used for future maintenance and management. There is a need to discover whether the track and vegetation recovers over the winter period.

A technique to record exactly where people walked across a track using a "trampleometer" was tried but found to be unsuitable for this survey.

Researcher:

Diploma student in the Department of Parks, Recreation and Tourism.

Reference:

Rich, JW (1991): ***Management strategies for the riparian zones of the Manganuioteao River.*** **Unpublished MApplSc thesis, Lincoln University.**

Problem investigated:

To summarise the possible impacts of various recreational activities on the river's natural environment from the literature; to evaluate recreational management options for the riparian zone.

Potential impacts considered:

Literature search: vandalism (swimming, picnicking, barbecuing, camping, see Ch4), careless use of fire (camping), blue duck (camping, dogs, angling, rafting especially commercial, canoeing, tubing), decrease in trout numbers (angling).

Variables chosen to assess impacts:

Desktop study.

Researcher's findings and comments:

A variety of recreational opportunities exist around the Manganuioteo river and to date there are only minor environmental impacts (vandalism, fires) except on the blue duck population. A voluntary blue duck rafting pact has worked well whereby rafting companies had an agreement with DOC not to raft the river during the blue duck breeding season.

There is a problem of preservation versus use for managers with potential increased recreational use. Most riparian zones of the river are not actively managed. Recreational management strategies are needed to minimise impact of multiple recreation activities and to provide interpretive opportunities and education of recreational users of the value and significance of the river. Information is needed on blue duck, camping areas, fires, fishing, and permission to enter private property.

Researcher:

MApplSc student, Lincoln University.

Reference:

Stewart, DPC (1985): ***Effects of trampling on the soils of the St James Walkway, Lewis Pass.*** **Unpublished BAgSc(Hons) thesis, Lincoln College.**

Problem investigated:

To survey the soils and quantify the effects of trampling on these soils.

Potential impacts considered:

Comparison of trampled and untrampled soils in six soil regions, four sites per region.

Variables chosen to assess impacts:

Bulk density, soil strength, infiltration rate. Topsoil and subsoil samples were analysed for upper and lower plastic limits, aggregate stability, organic and clay content of the soil and routine chemical tests.

Methods used to assess variables:

Cores were used in the field. A variety of laboratory techniques used.

Researcher's findings and comments:

Trampling increased bulk density by 0.2 $g.cm^{-3}$ and soil strength by 9 kPa and reduced the infiltration rate by 1069 mm.hour-1. The podzolised high country yellow-brown earths had the largest increases in these variates. Organic soils had low soil strengths, further reduced by compaction. Little difference occurred between topographical treatments. The upper and lower plastic limits were highest for the podzolised high country YBEs and these were related to content of clay and organic matter.

Trampling greatly affected podzolised high country yellow-brown earths, yet their subsoils were resistant to compaction. High country YBEs and recent soils were less compacted.

Organic soils, although not compacted, are wet and weak and severely damaged by trampling. Tracks should avoid these soils where surface ponding and run-off along the track occur.

Researcher:

Lincoln College Honours student.

rence:

roo, R (1983): *St James Walkway research project, 1982-83 (Year 2).* Unpublished dissertation, Department of Parks, Recreation & Tourism, Lincoln College.

roblem investigated:

Continuation and reassessment of St James Walkway environmental impact analysis.

Potential impacts considered:

Impacts on tracks and camping spots.

Variables chosen to assess impacts:

Measurements of track quality and width, impacts on camping areas; qualitative assessment of users behaviour.

Methods used to assess variables:

All full, partial and hut transects re-measured and methods reassessed. New transects established in areas showing physical impact. Installation of a "light beam" type trail counter. to carry out track rating procedures as Nelson (1982).

Slight modifications to Nelson's methodology were made.

Researcher's findings and comments:

Generally low impact of users on the environment in the second year of use of the track. Some areas were found to be sensitive to physical impact. These need to be upgraded to avoid long term deterioration.

Researcher:

Diploma student, Department of Parks and Recreation, Lincoln College.

Reference:

Ward, JC and Stewart, ID (1989): ***An approach to lake management: Ecology, values and conflicts at Lake Alexandrina.*** **Unpublished report. Centre for Resource Management, Lincoln University.**

Problem investigated:

To study a high country lake over a period of seven years to estimate the value of the lake as a natural resource which provides benefits to people, and to indicate how future management may reduce problems of conflicting uses.

Potential impacts considered:

Impacts of recreation (and agricultural use) on lake ecology and nature conservation values and management of these effects.

Variables chosen to assess impacts:

Aquatic birds were counted, breeding success of southern crested grebe recorded, recreational users observed and surveyed. Water quality sampled. Spawning habitat and sewage discharge to the lake are discussed.

Methods used to assess variables:

Birds counted each morning; recreational users surveyed twice a day; water quality analysis undertaken.

Researchers' findings and comments:

Observed and reported incidents showed that birds were being harmed and on some occasions killed by recreational users. Black teal and swans were displaced by recreational activity while grebes and ducks were not. Changes in bird distribution on the lake with season did not appear to be correlated with disturbance by people. Breeding success of grebes did not appear to be affected by the density of recreational use but further study is needed to confirm this. Increased recreational pressure may affect bird populations.

Facilities for day visitors and campers were limited and the high landscape values of the area may be compromised by new holiday homes. Increased visitor numbers may result in the need for sewage facilites to ensure water quality does not further deteriorate through increased nutrient flow to the lake.

Wetland areas around the lake margin provide important bird and plant habitat and are potential areas for nutrient uptake from the surrounding land. These need to be managed to restrict stock and recreational access to allow regeneration of vegetation.

Researchers:

- JC Ward: Centre for Resource Management, Lincoln University
- ID Stewart: PhD student, Centre for Resource Management, Lincoln University

Variables chosen to assess impacts:

Essentially desktop exercise.

Methods used to assess variables:

The report includes some suggestions for monitoring techniques:

- Periodic interpretation of photographs
- Debris basin surveys to determine erosion rates
- Soil surveys to determine thickness and composition of remaining soil
- Vegetation surveys to determine viability of native vegetation and intrusion of exotics (if in native forest/regenerating area)
- Stream channel surveys to determine channel changes
- Water quality measurements
- Sampling plots

Researchers' findings and comments:

Evaluation of all areas within the region where use is allowed, based on the 1977 study (Grant *et al*) and ROS carried out by DoC in 1991. Some guidelines for site assessment, including specific environmental factors for consideration in site selection, planning considerations and monitoring are included.

Researchers:

This report has been prepared by Wellington Regional Council. The report is based on three studies of off road vehicle recreation:

- Applied Geology Associated (January 1977): Off Road Vehicle Recreation Study. Wellington Regional Planning Authority.

- Bartrum, I (December 1985): A Study of Trail Biking in the Wellington Region. Unpublished study, Wellington Regional Council.

- Whitmore, A (February 1988): Off Road Motorcycle Land Opportunity Study. Unpublished study, Recreation Department, Wellington Regional Council.

Whitmore's and Bartrum's studies were undertaken as student holiday projects. They have not been fully completed but contain relevant information, much of which has been included within this report.

Bartrum identified the main areas in the Wellington Region which are used by casual trail bike riders, but he did not identity those which would be most suitable for regular use.

Whitmore used the areas identified by Bartrum, plus several more, in a process of site evaluation. Using recreation potential, terrain sensitivity and social sensitivity as selection criteria she identified those sites which may be suitable for use. These are listed in this report.

Reference:

Young, JR (1985): *Erosion control on New Zealand walking tracks.* Unpublished BAgSc thesis, Lincoln College.

Problem investigated:

Survey the principles, methods and success of erosion control on walking tracks in New Zealand.

Potential impacts considered:

Methods and materials suitable for erosion control.

Variables chosen to assess impacts:

Track slope, waterbars, culverts, ditches, surfacing, drainage dips, steps, retaining walls, curduroy, rock fill, planting, rafts and boardwalks.

Methods used to assess variables:

Questionnaire to NZ Forest Service and Department of Lands and Survey staff: a census of erosion control techniques used on five South Island tracks.

Researcher's findings and comments:

For erosion control, four principles are involved: drain water from track surface, remove water from track environment, provide an erodible track surface, increase stability of trackbase and of track environment.

There are three broad categories of track environment: low rainfall, high rainfall and unstable soils.

Different techniques are needed for routes, tracks and walks as intensity of use increases. There are three track classes: high rainfall-high use, high rainfall-low use, low rainfall-high use.

Techniques are recommended for each of these classes.

Use of local materials is important aesthetically and economically.

Researcher:

University student.

Reference:

Wellington Regional Council. 1992. *Trail bike riding in the Wellington metropolitan area.* Attachment to report 92.617, Wellington Regional Council, Wellington.

Problem investigated:

This Report:

- reviews previous work done in this area;
- identifies the requirements of trail bike riders;
- identifies those factors which cause conflicts between trail biking, other users of a resource and residents;
- identifies areas in the Wellington metropolitan area currently used for trail bike riding;
- identifies and discuss areas of public land within the Wellington Metropolitan area which have potential for development of trail bike riding opportunities;
- draws conclusions and make recommendations concerning the provision for and future management of trail bike activity in the Wellington Region.

This Report draws heavily on the earlier report by Applied Geology Associates (Grant *et al*, 1977).

Potential impacts considered:

Report alludes to some potential impacts, including:

- formation of bogs
- erosion channels
- soil compaction
- destruction of vegetation

The visual character of these impacts (particularly exposed soil tracks), if within sight of residential areas or in sites of high landscape quality, is often a major issue.

Environmental factors (impacts) listed for consideration in site selection include:

- Soils
  - Compacting and disruption of surface soil
  - Destruction and dispersal of surface stabilisers
  - Reduction of infiltration capacity
  - Increased frequency and intensity of run-off
  - Concentration and channelling of run-off
  - Increased erosion and sediment yield
  - Increased wind erosion and fugitive dust.
- Water quantity - in relation to soil compaction, erosion & loss of plant cover.
- Water quality - as affected by chemical (petrol/oil) and biological contamination and added sediment.
- Plants
- Wildlife - vertebrates, invertebrates & birds