Methodologies for Measuring Thresholds of Change from Tourism Impacts on New Zealand Natural Assets

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Chapter 1
Introduction to the Visitor-Natural Asset Interaction Problem

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1.1 Overview

The demand to see and the level of diverse use made of natural assets by tourists is increasing and a methodology is needed to measure change in the condition of these assets and whether or not that change is acceptable to users and managers. A preliminary framework for the integrated management of natural assets used for tourism was developed and applied by Ward *et al.*, (2002). This framework included:

1. A simple and applied system for tourism natural asset classification;
2. A framework for sustainable management of natural assets incorporating management and monitoring guidelines; and
3. A Decision Support System to integrate the above requirements.

More recently further work on the integrated management framework has been undertaken by Hughey and Ward (2003) and Hughey *et al.* (in press) who found that despite the benefits that the classification framework apparently offered, feedback from stakeholder consultations showed that it failed to allow for many of the site-specific differences that determine an asset's priority for management. These differences may relate to a range of factors such as the ecological value of the asset, its rarity or distinctiveness, its history of use, or its value to local Maori and other such cultural, social, and economic factors. In some instances, certain asset types have attributes such as these clearly defined in policy to determine their importance and management priority (e.g., caves, vegetation and bird species). Accordingly, a further revised framework was developed and the classification of an asset's level of management was replaced with an assessment of its importance. Through this method, guidelines could be developed and allocated in a manner compatible with existing policies and criteria for individual asset types. Hughey and Ward (2003) and Hughey *et al.*, (in press) then proposed the use of 'fragility' as a counter-complement to 'importance' within the management framework. The revised approach incorporates three key components which can be summarised as:

1. A simple and applied system for tourism natural asset classification;
2. A framework for sustainable management of natural assets incorporating management and monitoring guidelines that emphasised the importance of the asset and the fragility of the asset. Examples in Hughey and Ward (2003) include application to monitoring and management of birds, seals/sea lions, caves and dune/beach systems; and
3. A set of Environmental Performance Indicators for natural assets used for tourism consistent with other sets being developed by the Ministry for the Environment.

The approach to tourism natural asset management presented in the revised classification and management framework continues to be specifically focused on tourism in the environment that is attraction based, and grouped around the three main attraction *types*: wildlife, physical and vegetation (Ward and Hughey 2003, Hughey *et al.*, in press). For each asset *type* there is a number of broad asset *classes* and generic indicators of visitor impacts for each class that have been developed along with associated management guidelines. While the approach developed here is useful because it meets the needs of tourism operators and managers to be easily used, it also highlights the challenge as to how to measure thresholds of change in a natural asset visited by tourists. Current literature on this subject is outlined in brief below and the subsequent case studies and generic approach further addresses what has been identified as a most obvious gap in terms of defining 'thresholds of unacceptable environmental change' in the assets being managed (Hughey and Ward, 2003:3).

An annotated bibliography on the biophysical impacts of tourism was provided by Crawford *et al.*, (2001). The 478 articles reviewed were based on the framework of Ward *et al.*, (2002) in which the common indicators of change used for monitoring impacts were classified into wildlife, vegetation and the physical environment. The wildlife indicators included changes in behaviour, displacement, decreased abundance and breeding success. Indicators used for monitoring vegetation included loss of cover, change in species composition and regeneration capacity. Indicators of impacts on the physical environment include changes in soil compaction, bulk density, chemical composition, hydrology, rate of erosion and extent of pollution. A review of tourism and related literature in search of tools for monitoring user impacts on tourism assets has demonstrated little new material in this context (Hughey and Coleman, 2004).

More recently in New Zealand, research has been undertaken on fur seals at Kaikoura (Boren, 2001). Observations and controlled approaches were used to study the effects of tourist activity on fur seal behaviour. These controlled approaches were made from land on foot, from a kayak and from a motorboat while recording the fur seal's response and distance at which the seal responded. Habituation can take place such as recorded by Boren *et al.*, (2002) for fur seals in areas of high tourist activity. Some further work on penguins, e.g., Seddon (Yellow-eyed) and Ling (Antarctic) (2004 on radio) is underway. The White Heron colony on the West Coast, the Royal Albatross colony in Otago and New Zealand Dotterels in the Waikato are all under continued monitoring for impacts of tourism by the Department of Conservation (Ward and Beanland, 1995).

Barringer *et al.*, (2002) reported on models to describe relationships between visitor numbers and the impacts of these visits using key indicators for each asset type and asking experts to determine probable relationships between visitor numbers and impacts on West Coast tourism assets. It was found that some assets such as the White Heron (*Egretta alba*) colony on the West Coast are reaching biophysical capacity while others such as the Fox and Franz Joseph glaciers are not.

While based on expert knowledge these simplified models had problems. Some, for example, glacier impacts, were very hypothetical. One, white heron, was based on empirical data from Kazmierow (1996) but the changing relationship between increases in tourism numbers and disturbance was not modelled. Others, especially regarding caves, contained some empirical data re visitor numbers but very little quantitative impact data. Overall, no generalised approach was defined to gathering data for modelling the tourist-impact relationship, a research question left to be further explored by this study.

Given that the Department of Conservation and others wanted an approach that was simple to use yet robust for a range of management purposes, such as monitoring and concessions, our approach to developing a methodology for measuring change involving natural tourism assets was as follows:

- From the wildlife and physical asset categories, one asset from each was selected for study: seals and caves;
- Instantaneous and cumulative effects were measured;
- Models were developed;
- Rates of damage and key inflexion points were predicted; and
- From all of above, as applied to both seals and caves (Chapters 2 and 3 of this report), a process is suggested that can be used for other assets generally (Chapter 4).

It is intended that the approach derived from the above process will be used by tourism asset managers to standardise and improve the management response over time.

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Chapter 2
Wildlife Assets: Visitor – Fur Seal Interaction Modelling

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In order to develop a methodology to measure thresholds of visitor-induced change in wildlife assets fur seals were chosen for a case study. The main intention of this work is that it contribute to development of a generic approach to wildlife asset management in general.

2.1 Introduction

Viewing wildlife in its natural environment is a significant component of the growing eco-tourism phenomenon. Rates of tourist visitation to New Zealand are predicted to grow considerably over the next decade, and a significant proportion of these visitors are eco-tourists seeking interaction with wildlife in natural surroundings. Eco-tourism and nature tourism both involve visiting nature attractions, but eco-tourism is differentiated by an underlying desire to achieve some level of environmental or social protection (Kiss, 2004). With this motivation and the sustainability of the industry in mind, managers of eco-tourism need to ensure that the "environmental protection" achieved through the venture outweighs any possible impacts the tourists may have on the target wildlife or ecosystem. Human disturbances can have significant impacts on wildlife, affecting breeding success and population survival (Giese, 1996), even though a species might appear to tolerate visitation (Higham, 1998). One means of predicting future impacts may be to combine predictions of visitor numbers with models that describe the degree of impact visitors have on a natural attraction (Curry *et al.,* 2001).

Marine mammals appeal to tourists world-wide due to their charismatic nature and are thus a common target for eco-tourism ventures (Constantine *et al.,* 2004). New Zealand offers a unique opportunity for marine mammal observation due to the presence of a large number of species, often in localised areas, that are easily accessible to the public. Eleven species of cetacean (whales and dolphins), and two species of seals (NZ fur seal and sea lion) are encountered on a regular basis within New Zealand; while four other cetacean species and two other seal species may be observed on rare occasions (Constantine, 1999).

Pinniped-focused tourism is increasing in popularity and value with seals being viewed at more than 79 sites in the Southern hemisphere (Kirkwood *et al.* 2003). Locations such as the Kaikoura Peninsula in New Zealand, are attracting more visitors every year, with at least one million visitors in 2003 making it one of the three most visited tourist attractions in New Zealand (Experience Kaikoura, Oct. 2003). Seals lend themselves to tourism activities by being a colonial species, that is ashore reliably and predictably throughout the year (Barton *et al.,* 1998), and that exhibits interactive and "playful" behaviour that appeals to the public

(Kirkwood *et al.* 2003). However, their popularity as a tourist target and their accessibility also makes them a useful a model for investigating tourist impacts on marine mammals.

The accessibility of seals, in comparison with cetaceans, tends to result in seal tourism activities being less well regulated. For example, whale watching requires access by boat, and the majority of people who view cetaceans do so through commercial operators who must follow strict guidelines with respect to limiting the impacts on the target species. In contrast, numerous seal colonies are located on the coastline in places that are readily accessible by the general public, and so are subject to more uncontrolled observation.

The greater accessibility of seals versus cetaceans also simplifies the study of their behaviour. Seal behaviour can be observed from a distance, without the need of a boat, so their behaviour both with and without tourists present may be observed with little to no observer interference. In comparison, behavioural observations of cetaceans are limited to "at-surface" behaviour (C. McFadden pers. comm. 2002) and such studies may be frequently confounded by observer affects. What is more the biology and life history of seals have been well studied (Stirling, 1970; Miller, 1975; Mattlin, 1987; Carey, 1989; Harcourt, 2001). Seals may therefore be a useful species to monitor the affect of eco-tourism on biotic resources.

Seals come ashore for body maintenance, to rest, give birth, and mate (Taylor *et al.,* 1995), departing to sea to forage. Fur seals are a polygynous species where one male holds a territory over several females (Stirling, 1970; Carey, 1989). Males begin to come ashore and claim a territory in early November. Females come ashore to give birth in late November, and pups are born from late November to early December (Stirling, 1970). Mothers remain with their pups for approximately the first week after birth, re-mate, and then begin to alternate between making foraging trips to sea and coming ashore to feed their pup. Due to the relatively small size of fur seal females, they must forage during lactation in order to maintain condition and nurse their young (Boness and Bowen, 1996). Cows initially make short trips to sea but these gradually get longer, with cows spending up to 8-15 days away from the rookery near weaning (Miller 1975, Oftedal *et al.,* 1987, Harcourt *et al.,* 1995, Mattlin *et al.,* 1998), which occurs approximately 300 days post-partum (Stirling, 1971; Harcourt, 2001).

New Zealand fur seals show a high degree of site fidelity (Stirling, 1971) meaning that they repeatedly return to a preferred site. Breeding sites are characterised by large rocks and crevices that enabled pups to hide, also proximity to food sources, and degree of human disturbance may influence site selection in fur seals (Bradshaw *et al.,* 1999). With increasing tourist numbers fewer seal colonies have low degrees of human disturbance and breeding colonies including those in the Kaikoura region are now being exposed to higher degrees of human disturbance. Because fur seals show high degrees of faithfulness to sites, which provide appropriate terrain for rearing pups, and are close to a reliable food source, they are less likely to be displaced by increasing tourist encounters and this makes them more susceptible to detrimental long-term impacts.

Tourism may impact seals by forcing them to modify their behaviour. This may result in decreased resting (Constantine, 2004), increased energy expenditure (Barton *et al.,* 1998), trampling of pups (Mattlin, 1978), or the appearance of unnatural behaviours through habituation (Connor and Smolker, 1985). The peak in the New Zealand fur seals' breeding season (December/January) is a crucial time when mother/pup pairs form a bond before the cow leaves for her first feeding trip. This bond is vital as it enables the pair to reunite upon the mother's return (Phillips and Stirling, 2000). An outside disturbance may result in the female altering her foraging cycle and thus the rate of milk transfer to the young (Boren, 2001). If the separation were to occur prior to the formation of the bond the consequences would be much more severe and may result in the death of the offspring (Edington and Edington, 1986).

New Zealand fur seals may be especially vulnerable to the effects of eco-tourism, as the prime months for tourism in New Zealand, November to February, are also the key months in the fur seal reproductive cycle. These few months are vital for the population must produce and rear enough young to compensate for adult mortality, or it will decline in numbers. The pressures placed on seal populations during this summer period by eco-tourism operations may be highly detrimental to the long-term survival of target populations.

Recently several studies have set out to investigate the impact of eco-tourism operations on seals and habituation and significant behavioural changes have been observed. Breeding and non-breeding colonies of New Zealand fur seals, and Australian sea lions, and New Zealand sea lions have shown signs of habituation to tourists (Barton *et al.* 1998; Wright, 1998; Shaughnessy *et al.,* 1999; Boren, 2001; Orsini, 2004; TJ. Arianna-Lovasz pers.comm.). However, other studies have documented an increase in vigilance and decrease in resting behaviours in Australian sea lions (Orsini 2004), harp seals (Kovacs and Innes, 1990), grey seals (Lidgard, 1996), and harbor seals (Henry and Hammill, 2001). Decreased female attendance was observed in grey seals exposed to tourists, as was a preference for breeding in areas of low disturbance (Lidgard, 1996). Similarly, Arianna-Lovasz (pers. comm.) found that densities of Australian sea lions exposed to tourists were lower during the breeding season, suggesting that females might be selecting less disturbed areas in which to pup.

Many studies suggest that the current guidelines for viewing are not adequate to minimise tourist disturbance and that further investigation into the potential long-term effects of tourist disturbance is required, along with the need for stricter management of the target populations (Barton *et al.,* 1998; Shaughnessy *et al.,* 1998; Boren *et al.*, 2002; Orsini, 2004). With the increasing value of pinniped-focused tourism, the sustainability of the industry requires an understanding of the relationship between seal responses to tourists and increasing tourist numbers.

Therefore the objectives of this study were to:

- Determine whether there is a relationship between visitor density and New Zealand fur seal behaviour in order to derive a visitor-impact model; and
- Quantify the effectiveness of site management designed to lessen visitor impacts.

2.2 Methods

2.2.1 Sites

Observations of visitor numbers and activities and seal behaviour were made at two sites on the east coast of the South Island, near Kaikoura; Lynch's Reef seal colony and Ohau Point seal colony. The sites differ in visitation rates, guidelines for viewing seals, and the extent to which visitor behaviour is regulated.

Lynch's Reef is located just off the Kaikoura peninsula, approximately 4 kms from the Kaikoura township. The proximity to town and ease of access means visitor numbers to the peninsula are high. The areas observed are described here and shown in Figure 1. The car parking area (CP) is separated from a coastal rock platform by a low wall. There are steps from the wall leading down to the rockflats (RF), as this is the northern starting point of what is known as the Kaikoura Peninsula coastal walk. CP and RF are accessible to tourists by land and during the summer months no more than about ten seals may be viewed in these areas. Lynch's Reef (LR) is located across a channel from the rockflats. The reef is made up of a long, thin, jagged reef where the majority of seals in this area form a small breeding colony, and a large flat area to the north. This northern area (North) is a haul-out to approximately 20 seals. The seals on LR and North are accessible by foot, snorkelling, kayaking and boating, and a guided walk operates at these two areas. Additionally, about 10-50 seals haul-out on a set of large boulders (South) in the water to the southeast of LR, these boulders are only accessible by snorkelling, boating, and on a very calm day, kayaking.

Figure 1
Diagram of Lynch's Reef Area

There is one educational sign in the CP, along with three regulatory signs, while one regulatory sign was erected on the RF, and one was erected on LR. The educational sign still states the pre-1998 minimum approach distance for land-based tourists of 5m. Between 1998 and 2003 minimum approach distances on the Kaikoura peninsula were as follows: land-based - 10m, kayak - 10m, motor boat - 20m, and snorkelling - 10m. Since 2003, the guidelines have been changed to 20m for all approach types except snorkelling, based on the study by Boren *et al.,* (2002). These new guidelines were not yet enforced at the time of this study.

The Ohau Point seal colony is located 26 kms north of Kaikoura and is approximately 0.75-1km long positioned immediately alongside SH1. Because of it's location between Blenheim and Kaikoura, many travellers stop and view the seals on route to their destination. At the southern edge of the colony a lookout platform was built for safe seal viewing at what was once a non-breeding portion of the colony, there is also space to park several cars and tour buses at the lookout. On the northern edge of the colony there is a carpark and a bench seat where seals can be viewed. There are also a number of places along the length of the colony where the seals are relatively accessible. Entry into a breeding colony is prohibited. However, it is not an uncommon sight to see tourists climbing down to get a closer look at the seals.

Currently there are no regulatory or educational signs at the northern edge of the colony, and there are no regulatory signs on the south edge of the colony. When the lookout was first designed approximately four regulatory signs were placed at the southern end of the colony, along with one informative sign on the lookout. These were originally placed at a non-breeding portion of the colony, designed to keep tourists viewing seals in an area where their impacts should be minimised. In late 2003, the regulatory signs were removed leaving only one informative sign to aid tourists. Since the signs were erected, the colony has been expanding and now pups, lactating females and territorial bulls are in view to both the lookout and the northern edge of the car park. With tourism increasing over the last five seasons and colony expansion more tourists are walking the length of the colony on a narrow, treacherous stretch of road and, where possible, climbing into the colony.

Meteorological data (air temperature and solar irradiance) corresponding to the periods of observation for Kaikoura were retrieved from the national Climate Database.

2.2.2 Observation Methods

For the first study objective, observations were made between 20th November 2002 and 20th December 2002 on the Lynch's Reef seal colony and its surrounding haul-outs. The method initially involved scanning the area every 30 minutes, and then was changed to every 15 minutes to increase the chance of observing tourist seal interactions. During every scan the observer counted the number of vehicles in the CP, the number of visitors in the CP or on the RF, and the number of tourists kayaking, snorkelling or on the guided seal walk. The observer also recorded the number of seals, their location and their behavioural response. Seal behaviour was classified according to Table 1. A change in seal behaviour over the course of a scan was analysed using a Chi-squared test for goodness of fit. If the behaviour change was found to be significant, it could then be compared with the tourist data at that time to see if there was a direct link. The most likely change to occur in the event of a tourist disturbance would be an increase in the proportion of seals exhibiting "active" behaviour. Relationships between seal numbers, tourist numbers, seal behaviour and climate were analysed using multiple regressions and one-way ANOVA's.

Table 1
Classification of Seal Behaviour

Behaviour	Description
Resting	Lying down with eyes closed; also includes 'supine' lying down with eyes open.
Comfort	Grooming, scratching, shifting position/weight, active thermoregulation including waving flippers and lying in a shallow pool.
Interaction	Interaction with another animal.
Active	Sitting up aware, alert or moving, including territorial vertical display of neck.
Swimming	Seal mostly submerged in the water; diving and loafing included.

For the second study objective, observations were made between 6 January 2003 and 18 February 2003 at both the Lynch's Reef seal colony and Ohau Point seal colony. All visitor-seal interactions were monitored, recording the time of the interaction, the number and location of visitors and seals, the visitor activities and the seal responses. An interaction was defined as each incidence of a visitor or group of visitors stopping at the site and actively observing the seals. It was noted whether or not visitors complied with regulations and guidelines with regard to crossing barriers, proximity to seals and behaviour near seals. Also noted was any seal behavioural responses to the visitor interaction, responses were classified according to Table 2.

Table 2
Classification of Seal Responses to Tourist Activities

Response Rank	Definition of Response Rank
Interaction (I)	Non-aggressive movement towards stimulus
Neutral (N)	No apparent response
Change Behaviour (C)	Change in behaviour including looking up, becoming alert
Avoidance/ Aggression (A)	Vocalise, threat, enter water, flee

2.3 Results

Days of Observations
From the 20th of November to the 20th of December seals and tourists were observed on 18 days weather permitting at LR and surrounds. From the 6th of January to the 18th of February, tourist compliance and behaviour was observed on 24 days weather permitting at both LR and Ohau Point seal colony.

Within Site Trends - Seal Numbers and Behaviour at Lynch's Reef and Surrounds
A significantly greater number of seals were observed on LR than on the North and South haul-outs of the reef ($P < 0.001$). On average, there were 47 seals on LR, eight on North and nine on South. There was no difference in the proportion of seals that were active between localities in the site ($P = 0.17$). On LR around 7 per cent of seals displayed active response behaviour on average, with 7 per cent and 5 per cent showing active responses on North and South, respectively.

Within Site Trends -Tourist Numbers and Behaviour at Lynch's Reef and Surrounds
Significantly more tourists viewed seals from the RF than from other means ($P < 0.0001$). At a given time there was an average of 11 tourists viewing seals from the RF and approximately eight from the CP, however, the number of tourists viewing from these locations ranged up to 60 and 32, respectively. The number of tourists on the guided seal walk (SW) was the highest of the three commercial viewing methods with an average group size of nine and a maximum of 15 tourists at any one time. Seal swimming (SS) took average group sizes of four with a maximum of seven tourists, while the guided kayak trips (SK) took and average group size of three vessels with a maximum of four vessels observed. Because these trips ran based on sea conditions, tide level and level of interest, these groups were not sighted as commonly as private tourists on the CP and RF. As a result, their actual average number of tourists per scan time is much lower than their trip averages at 2.083 (SW), 0.378 (SS), and .0171 (SK) compared with those previously mentioned for RF and CP.

Seasonal Trends - Relationships Between Seals and Tourists
Over the four-week period of observations for the first study objective, the number of seals on Lynch Reef and surrounding rock flats increased from around 40 to nearly 100, with a mean seal population of 64 (Figure 2). The proportion of seals that exhibited active behaviour varied between zero and 60%, however, there appeared to be no obvious trend in seal activity in relation to time of the season, air temperature or solar irradiance (Figure 3). During this same period, the average number of visitors at the site was 22, and varied between zero and 90 but did not show a systematic increase or decrease with time.

Figure 2
Number of Visitors and Seals Observed at Lynch Reef

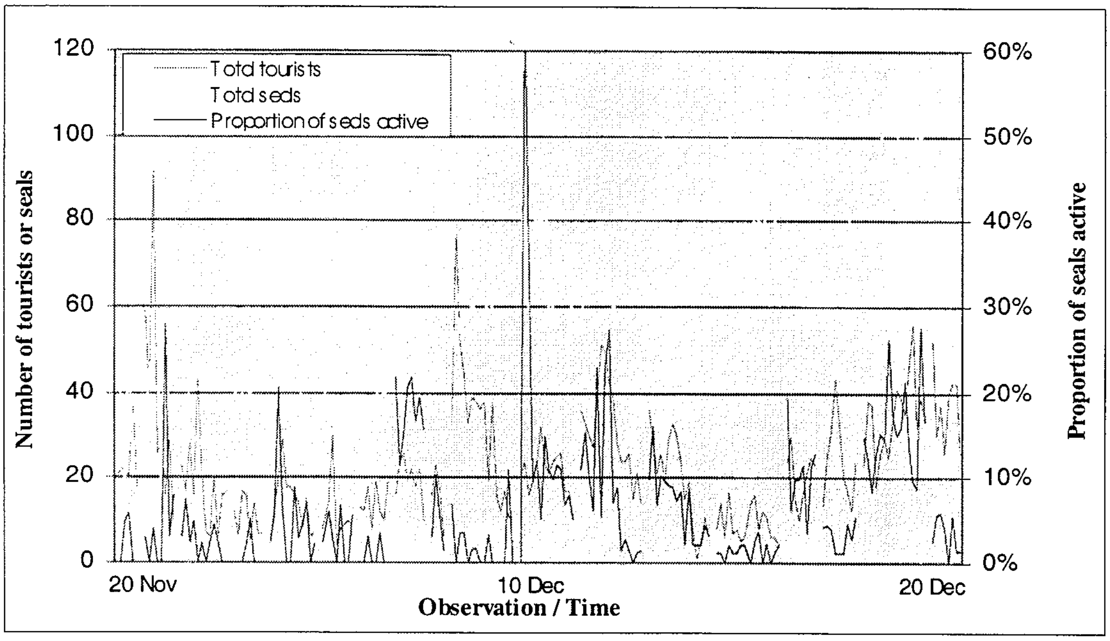
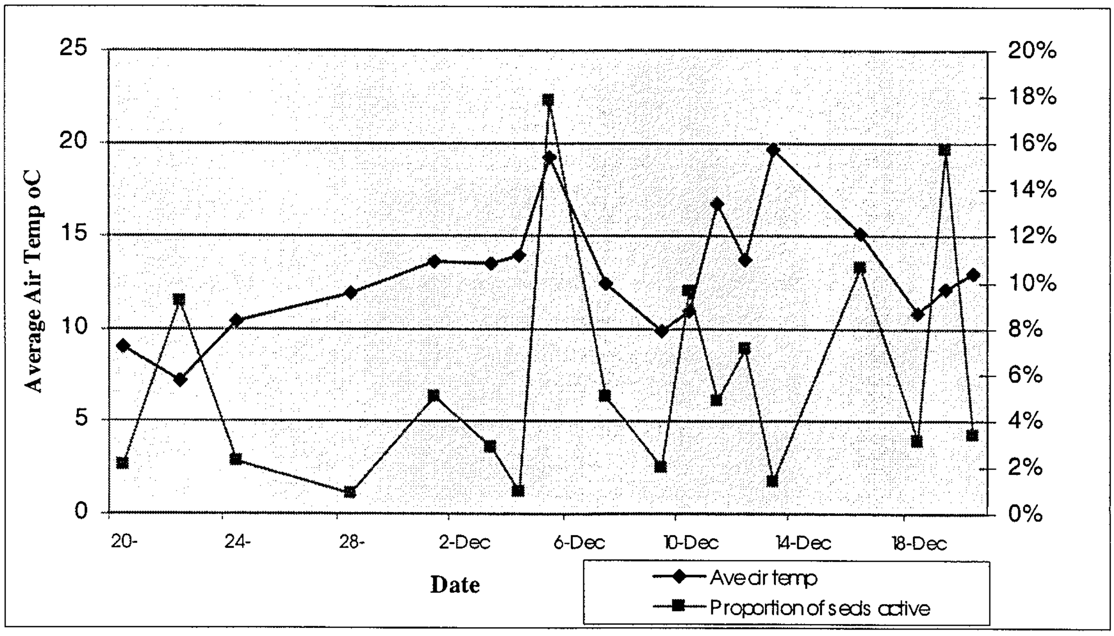
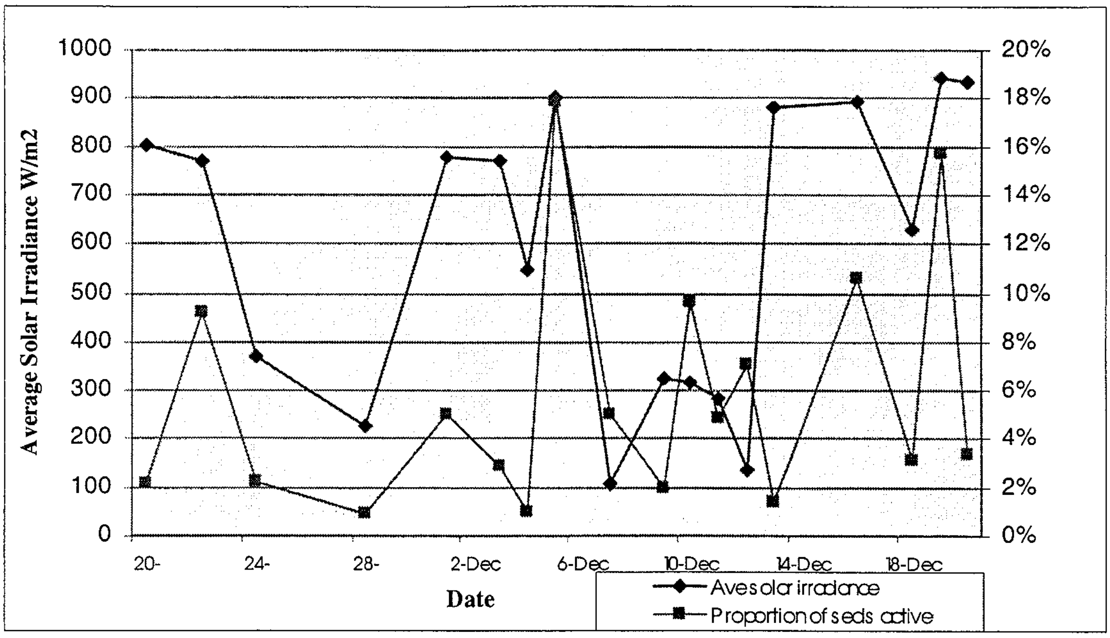


Figure 3
Average Air Temperature and Solar Irradiance

(a) Average air temperature (°C) over the course of the data collection period compared with the proportion of seals active.



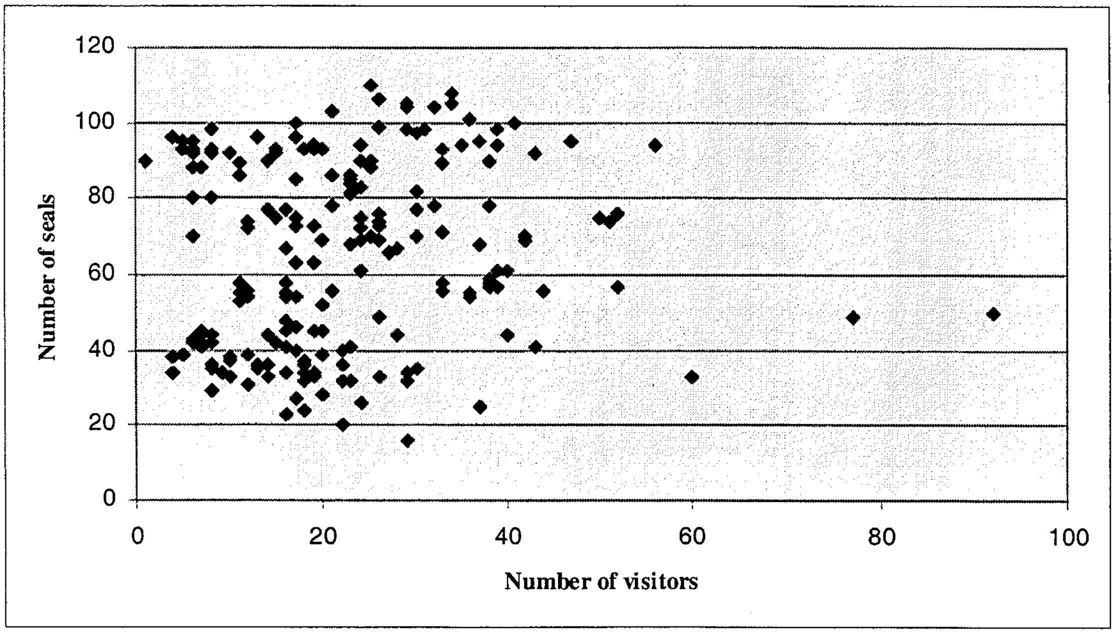
(b). Average solar irradiance (W/m^2) over the course of the data collection period also compared with the proportion of seals active.



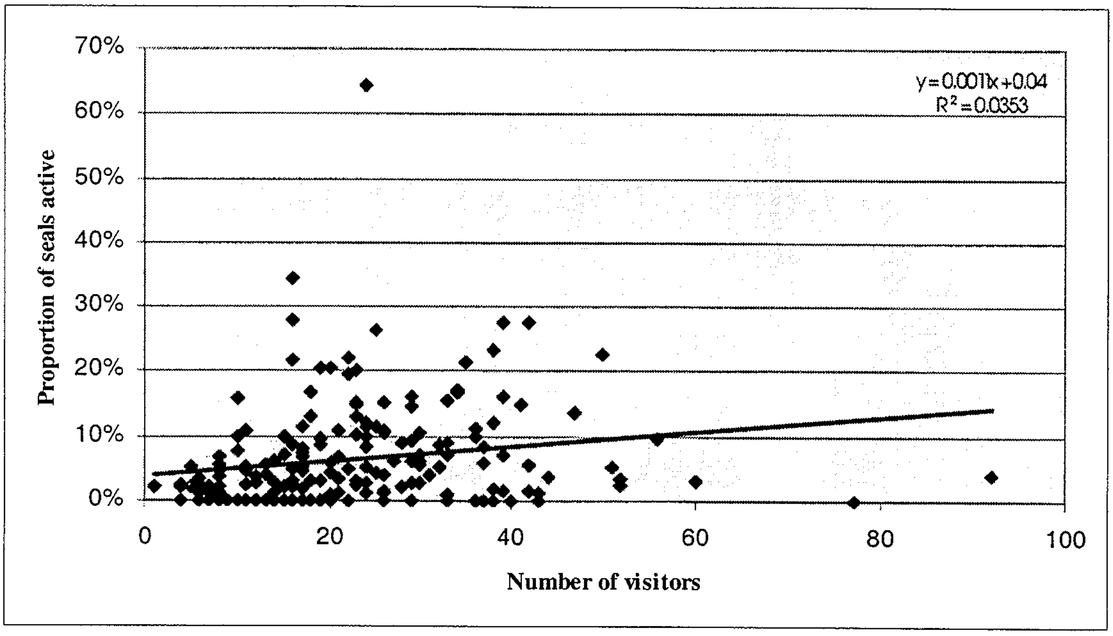
There was no significant correlation between instantaneous counts of the number of visitors and the number of seals at the site. There was a weak though significant (P = 0.009) linear relationship between the number of visitors and the proportion of seals that were active (Figure 4 a,b).

Figure 4
Seal Numbers

(a) Instantaneous counts of number of seals plotted against number of visitors at Lynch Reef and surrounds.

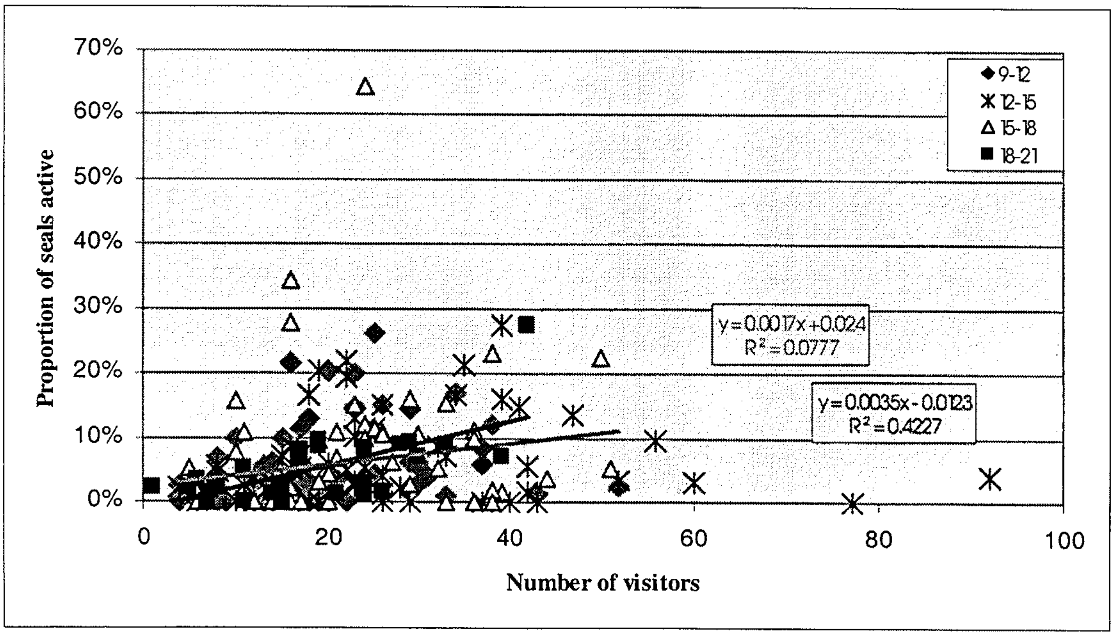


(b) Instantaneous counts of proportion of active seals plotted against number of visitors at Lynch Reef and surrounds.



Daily trends- relationships between seals, tourists and climate
Classifying the instantaneous observations according to time of day indicated that there may be a greater sensitivity of seals to visitors during morning and early evening (Figure 5). Linear regressions between visitor number and active seals for data during the morning (0900-1200 hours) and evening (1900-2100 hours) are significant (P = 0.037 and 0.032, respectively), but are not significant during early and late afternoon. The relationship between visitor numbers and seal active behaviour was strongest during the evening (1900 – 2100 hours), although the number of observations was lower in this time period than the others.

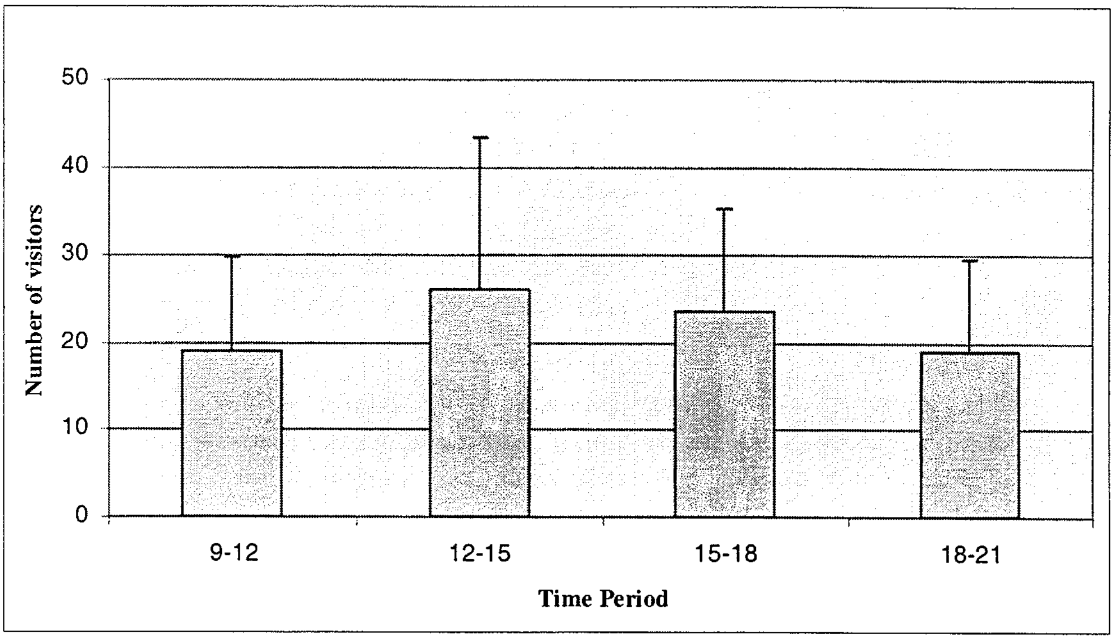
Figure 5
Instantaneous counts of the number of visitors at Lynch Reef and the proportion of seals that (were active). Data are classified according to time of day. Only regressions that are significant (*P* < 0.05) are shown.



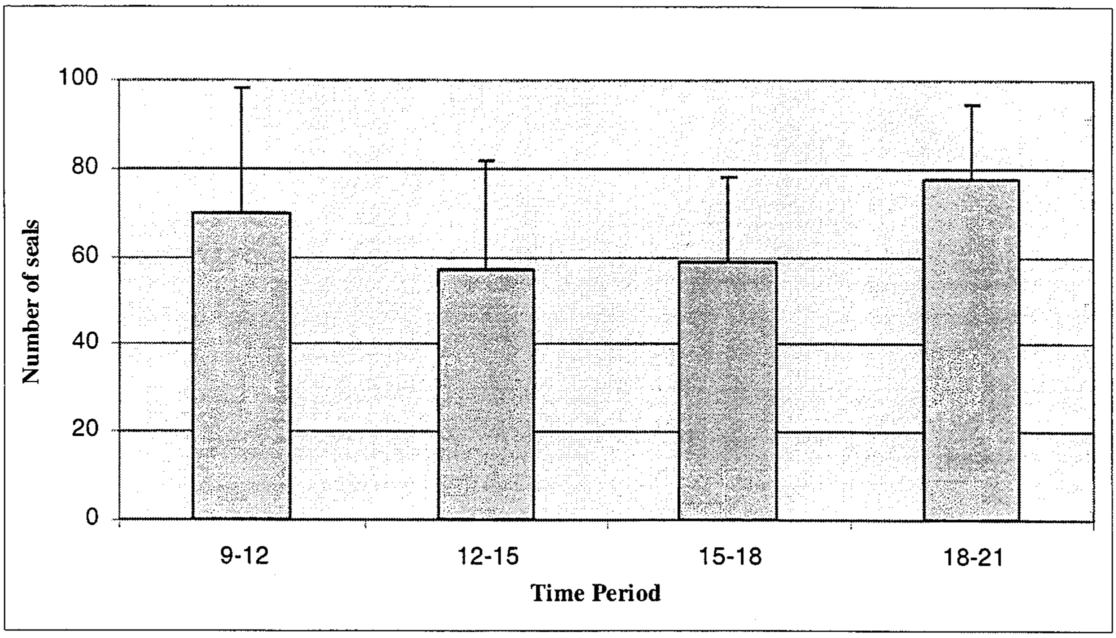
Time of day has a significant influence on both the mean number of visitors and the mean number of seals observed (P = 0.014 and 0.003, respectively) (Figure 6a,b). There are generally more visitors and fewer seals between mid-day and late afternoon, with fewer visitors and more seals in the morning and evening. Time of day did not have a significant effect on the proportion of seals showing an active behavioural response (Figure 6c).

Figure 6
Average Visitor and Seal Numbers
Error bars represent standard deviations of the means.

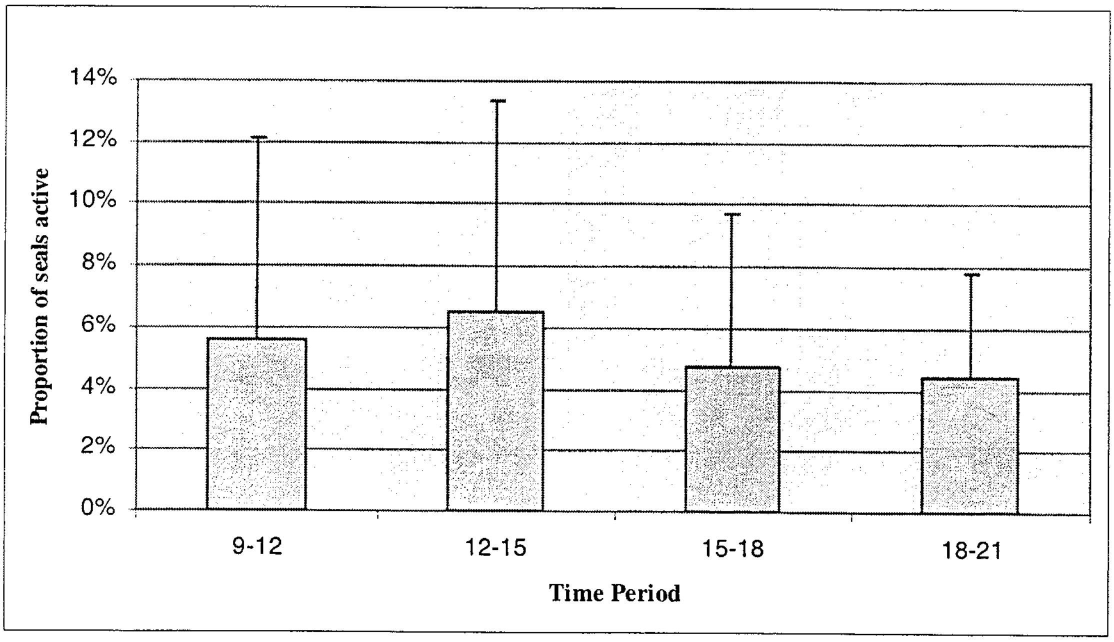
(a) Average Visitor Numbers



(b) Seal Numbers



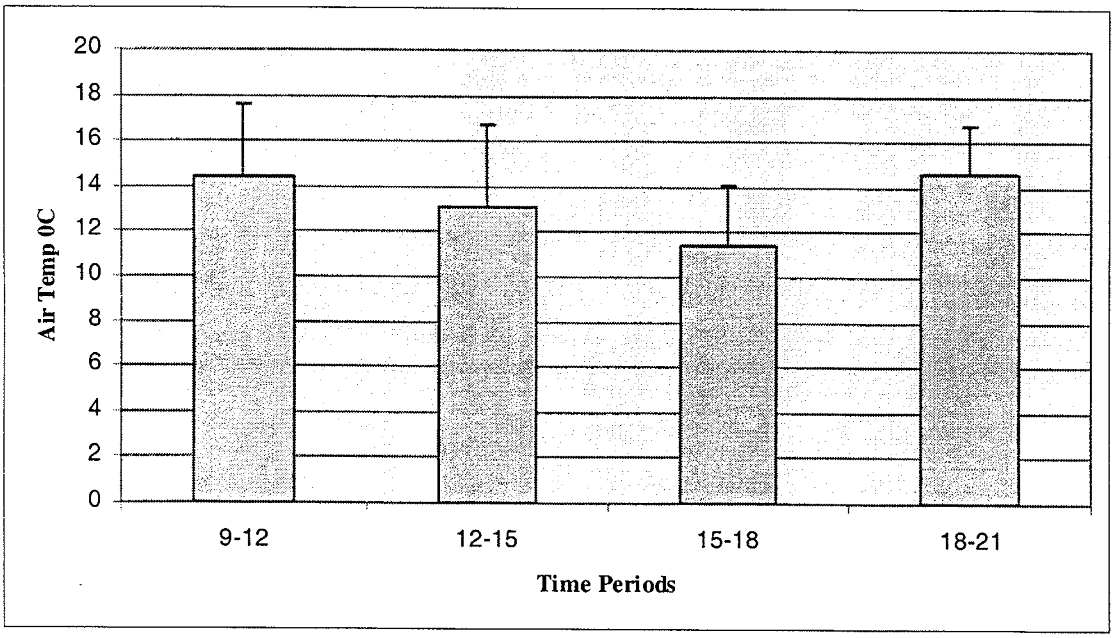
(c) Proportion of Seals that are Active Classified According to Time of Day.



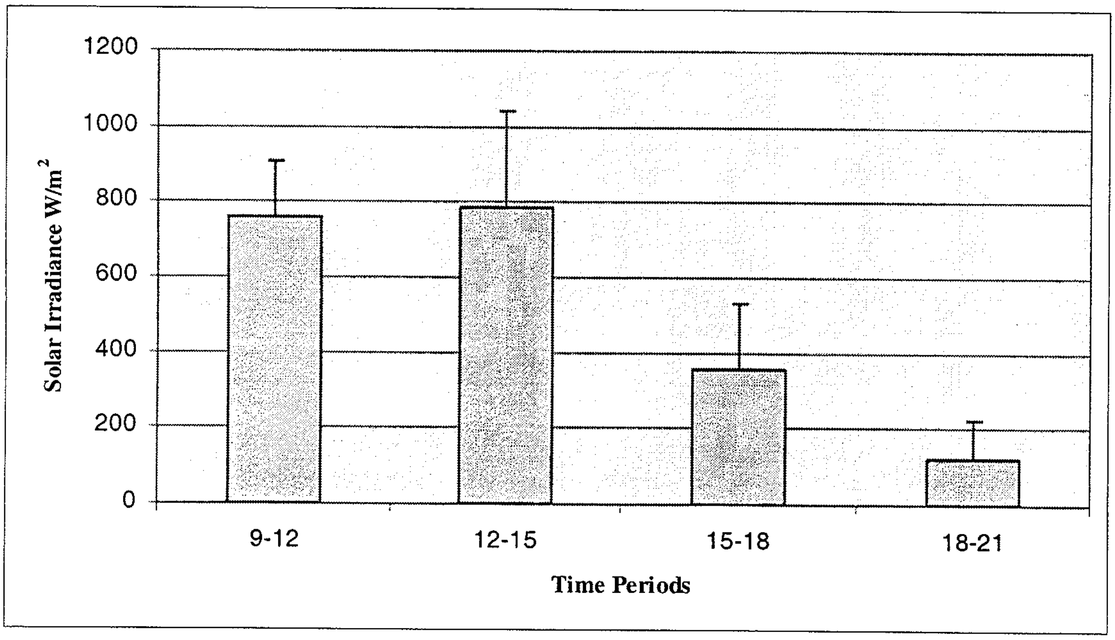
Air temperature and solar irradiance during the hours of observation were also analysed by time of day. Air temperature was significantly higher in the morning and evening hours, 14.4 and 14.6°C respectively, than in the early and late afternoon, 13.1 and 11.4°C respectively ($P < 0.0001$). In contrast, solar irradiance was significantly highest during the morning and early afternoon, moderate in the late afternoon and lowest in the evening ($P < 0.0001$) (Figure 7a,b). There was no relationship between air temperature and either seal numbers or seal activity when analysed by time of day.

Figure 7
Average Air Temperature and Solar Irradiance Classified by Time of Day.
Error Bars Represent the Standard Deviations of the Means.

(a) Average Air Temperature



(b) Solar Irradiance

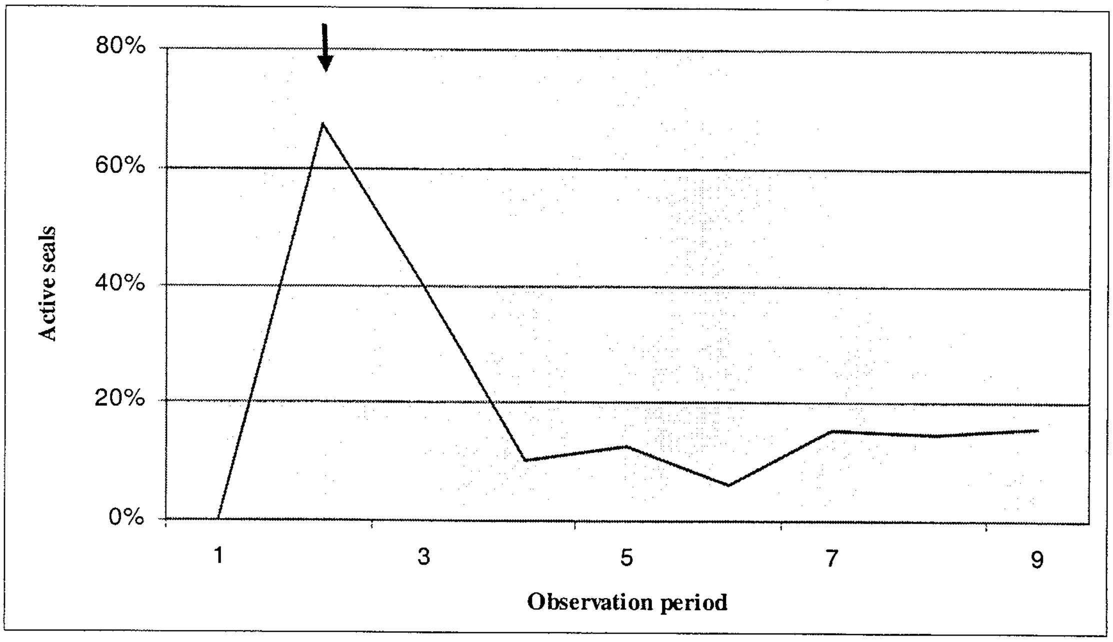


Specific Disturbance Events

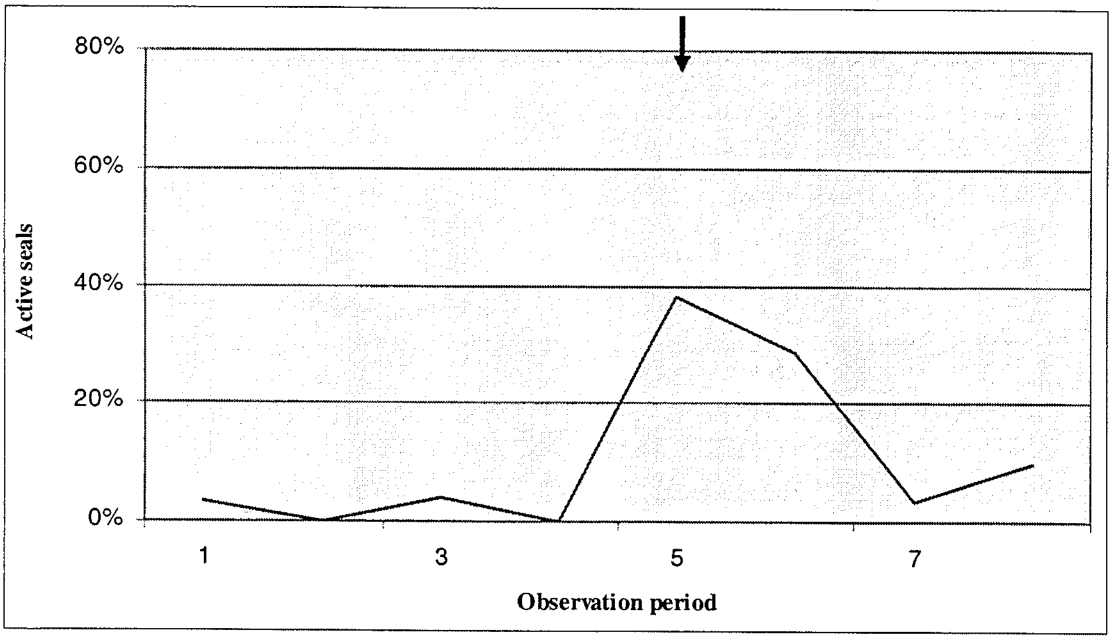
On five out of 18 days of instantaneous scans disturbance events occurred that were associated with human activities near the seal colony (Figure 8). On two occasions multiple groups of tourists approached seals on the reef to within 10-20 m (Figure 8c, d). Seal behaviour during these two observation periods fit the assumptions to perform a Chi-squared test of goodness of fit and the observed changes in seal behaviour were significantly different from normal ($P < 0.001$ and $0.001 < P < 0.005$). Two other cases of disturbance did not fit the assumptions of the test, however, the proportion of seals that were active increased dramatically from an average of 0 to 67 per cent on one occasion (Figure 8a) and from 0 to 38 per cent on the second occasion (Figure 8b). In all situations the colony returned to a normal level generally within 60 minutes of the disturbance event. One isolated disturbance also occurred on the 24th of November, when a seal swim group approached a single seal hauled out on the RF. The seal was active for the scan when the group approached but was seen resting in the following scan after the seal swim departed.

Figure 8
Significant disturbance events associated with human activity close to the colony

(a) Research observer approaches colony.

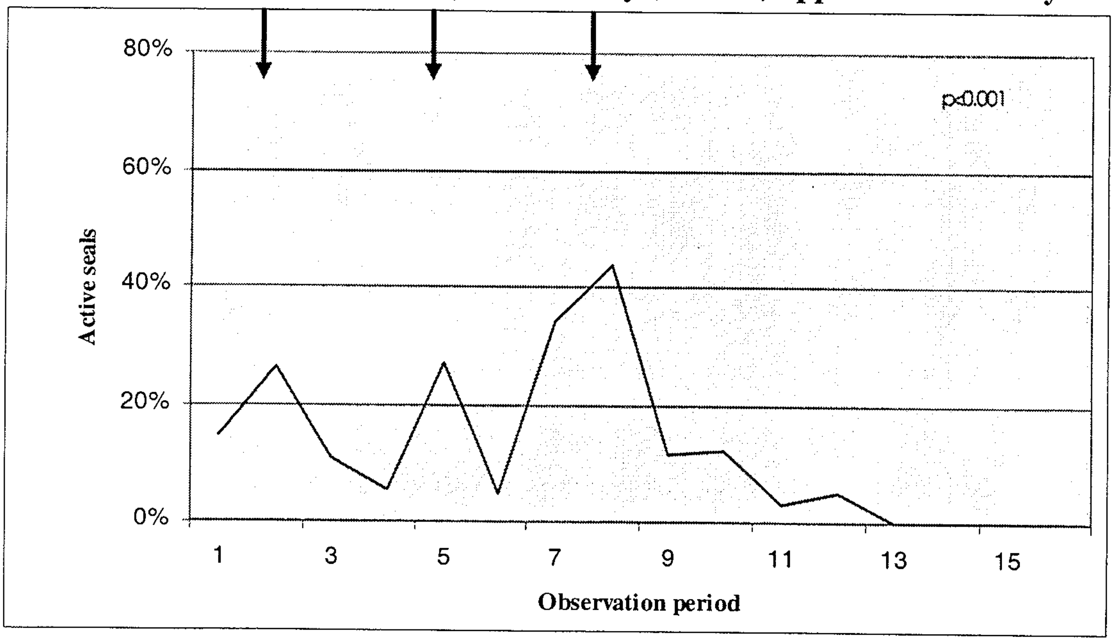


(b) DOC[1] personnel working with a jackhammer near Lynch Reef.

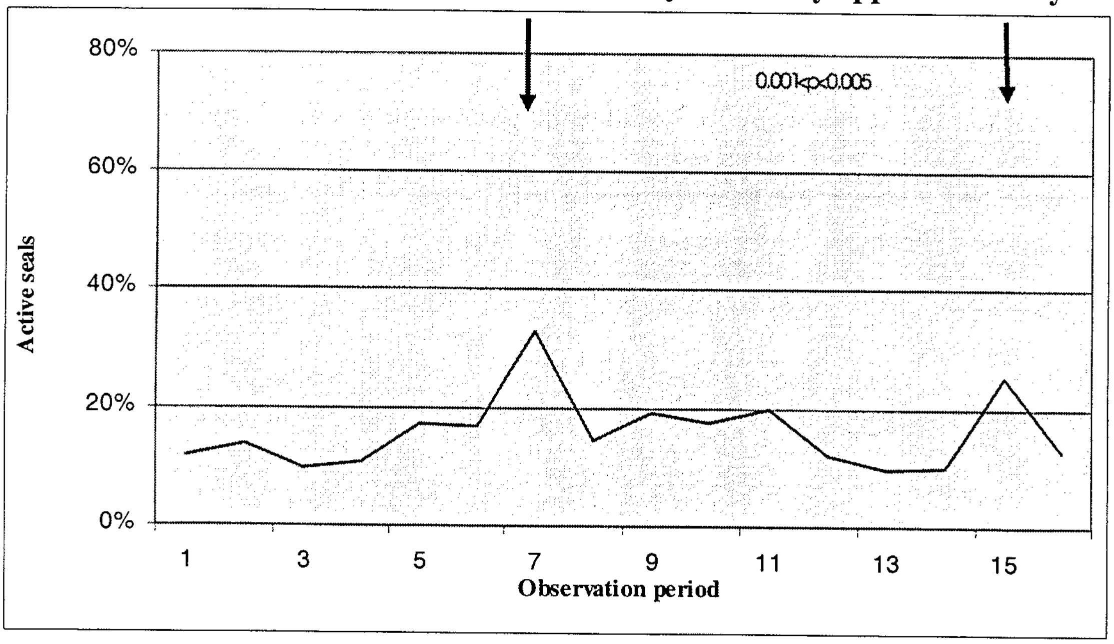


1 Department of Conservation

(c) Guided seal walk and kayakers closely (10-20m) approach the colony



(d) Guided seal walk, private tourists and kayaks closely approach colony.



Visitor Compliance and Seal Disturbance

The average size of visitor groups observing seals at Lynch Reef and Ohau Point were not significantly different (Table 3). The majority (94.3%) of visitors who interacted with seals at Ohau point complied with signposted guidelines and regulations. In contrast, over half (52.5%) of those visiting at Lynch Reef did not comply with guidelines, and either crossed barriers, approached too close to seals or displayed inappropriate behaviour toward seals. At Ohau Point only 3 per cent of interactions resulted in a disturbance. However, one-third of the disturbances were caused by compliant interactions. At Lynch's Reef, 26 per cent of interactions resulted in disturbance, and of these, 23.9 per cent were caused by compliant interactions.

Table 3
Statistics of Visitor Compliance and Seal Disturbance at Ohau Point and Lynch's Reef

	Ohau Point	Lynch's Reef
Mean number of visitors/interaction	3.7	3.4
Total number of tourist interactions	642	924
Compliant interactions	606 (94.3%)	439 (47.5%)
Non-compliant interactions	36 (5.6%)	485 (52.5%)
Total number of disturbances	18	238
Compliant disturbances	6 (33.3%)	57 (23.9%)
Non-compliant disturbances	12 (66.6%)	181 (76.1%)
Disturbances per interaction	3%	26%

2.4 Discussion

To determine the usefulness of modelling the impacts of increasing tourist numbers on seal behaviour, trends in seal numbers, behaviour and tourist numbers were compared. The topography and function of the sites within the area, and the accessibility of these sites can explain trends seen in seal and tourist numbers within the Lynch's Reef (LR) area. LR is the only suitable terrain for breeding in this area (Bradshaw *et al.,* 1999), while the remaining four areas in which seals could be found are all non-breeding, of these, only North and South have restricted human access. Tourists can view seals in low numbers (<10) from the CP and RF sites without wading, kayaking, swimming, or attending the guided seal walk. However, to see the seals at LR, North or South, access to isolated areas is required, and most tourists go through commercial ventures, which are subject to availability, sea and tide conditions. The increase seen in seal numbers over the four-week period of observations at LR is a consequence of the onset of the breeding season (Stirling, 1970). No difference in mean seal activity level was observed over the course of the month. With previous measures of seal activity within a colony averaging around 16.6 per cent (Boren, 2001), activity was not expected to increase dramatically, unless there was an outside disturbance, e.g. close tourist approach, therefore it was not surprising that mean tourist numbers also remained static.

In this study, seal activity was more closely related to tourist numbers in the morning and evening, suggesting that seals might be more sensitive to tourists at these times of day. Observed seal numbers were also highest in the morning and evening, while tourist numbers showed the opposite trend. While this could look as though increased numbers in tourists lead to a decreased number in seals it is unlikely. Fur seals do most of their foraging at night (Harcourt *et al.,* 1995) so the increase in numbers seen in the morning could be from animals arriving from the sea. The reduced numbers in the middle of the day and subsequent increase in the evening could be related to the number of seals moving off the reef to thermoregulate/swim in increasing air temperatures (Wright, 1998). If elevated counts of seals are primarily related to seals moving on and off the reef for thermoregulating or foraging, one would expect to see a corresponding elevation of seal activity at the times of increased seal numbers. This did not hold true in this study, where no difference was found in seal activity throughout the day. Similarly, a study of male breeding behaviour at Ohau Point seal colony during the same time frame found no difference in activity levels according to time of day. However, seals were slightly more active at low tide (A. Caudron, unpub. data). The number of seals on the site and their behaviour can depend on a number of factors, including some not analysed here; moon phases, prevailing weather, sea conditions, and food availability. Due to the array of factors that can influence seal behaviour, it is very difficult to make a direct link between tourist numbers and seal activity.

There was a much greater incidence of seal disturbance at Lynch's Reef (26%) as opposed to Ohau Point (3%). Barton *et al*,. (1998) also showed a high incidence of seal disturbance resulting from visitor interaction at Lynch's Reef, where c. 60 per cent of visitor interactions caused seals to respond, with 33 per cent becoming 'active' as defined in the present study. Although disturbances at Ohau Point are minimal, under present guidelines, visitor interactions are still causing disturbances at both populations as seen by the proportion of disturbances occurring even when visitors complied with guidelines: Ohau Point (33.3%), and Lynch's Reef (24%). The same conclusion was reached by Barton *et al.,* (1998), where 55 per cent of seals responded to approaches in compliance with the minimum approach distance of 5m. While increasing the minimum approach distance to 20m was recommended, a final distance of 10m was decided upon. Using a novel experimental approach to this issue, Boren (2001) found that on average 33.6 per cent of seals were still responding to land approaches by tourists that followed the recommended 10m guideline. Furthermore, at distances of 20-30m, 29.8 per cent of seals responded to controlled land approaches, suggesting the new minimum approach distances were still too close (Boren *et al.,* 2002). Consequently, the minimum approach distances were again revised, to 20m.

The minimal relationship seen in the current study between tourist numbers and seal behaviour is most likely due to habituation of seals at Lynch's Reef and surrounds. Habituation has previously been shown in NZ fur seals in Kaikoura, wherein fur seals at Kaikoura respond less often and less dramatically to a disturbance than seals at sites not exposed to frequent human visitation (Boren *et al.,* 2002). Similar habituation has been observed in Australian sea lions at Kangaroo Island, where no behavioural difference was noticed between sea lions at visited and non-visited sites. This dramatic lack of response is potentially due to several decades of sea lion viewing at this site (TJ. Arianna-Lovasz, pers. comm.).

2.5 Conclusions

Relationships between visitor density and seal behaviour are weak (Figures 4,5). The scatter in the data reflects the complexity of the interactions, including tidal cycles, climate, food availability and previous exposure to tourists. It is possible that certain visitor actions at a low visitor density could have just as large an effect on seals as other actions at higher visitor densities as was observed through specific disturbance events where humans either approached too close or acted in ways that disrupted the seal's behaviour (Figure 8). Because of the complexities of seal behaviour and the potential for habituation, modelling of tourist impacts using seal behaviour is not plausible. Modelling based on a physiological indicator could show a stronger relationship, however, to obtain physiological data, the invasiveness of the data collection may cause more stress to the animal than a tourist approach. As a result, scientists have been looking at potential non-invasive ways of collecting physiological data, for example, measuring the level of cortisol in faeces. This method also runs into problems, as the sample size required is very large and habituation of seals will decrease the amount of cortisol released during a tourist encounter (Caudron *et al.,* unpub. data).

While Kaikoura fur seals appear to be habituated, the guidelines at the time of the study (10m) were not enough to minimise disturbance to the seals, and over 50 per cent of tourists visiting Lynch's Reef are ignorant of, or, ignore the guidelines. Although, investment into visitor control structures and interpretive signage may help reduce the amount of disturbance, the largely self-regulating nature of seal viewing means that individual visitors may still behave in ways that negatively impact on seals. Barton *et al.*, (1998) found that many visitors perceive their impact on seals as nil or minimal, and did not understand the potential implications of seal disturbance. This indicates that while additional investment in visitor education should reduce the incidence of inappropriate visitor behaviour, it will not eliminate it. While modelling the impact of increasing tourists on fur seal behaviour might not be practical, there are behavioural methods used to determine the effectiveness of current management practices and developing adequate minimum approach distances. Such methods would be useful in evaluating current management practices for eco-tourism ventures on other species.

2.6 Implications for a Generic Approach to Other Wildlife

The methods used in this study would also be applicable to other marine mammals and birds where behavioural change due to numbers and behaviour of tourists are recorded through observation and statistical analysis.

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Chapter 3
Physical Assets: Visitor – Cave Impact Modelling

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In order to develop a methodology to measure thresholds of visitor-induced change in physical assets caves were chosen for a case study. The main intention of this work is that it contribute to development of a generic approach to wildlife asset management in general.

3.1 Introduction

Caves in New Zealand were first used for recreation as early as 1849 (Lipyeat and Wright, 2003). Currently, adventure caving is a fast growing tourist activity whose growth is expected to continue with the predicted increase in tourists visiting New Zealand. As finite environments, caves have well-defined boundaries and often contain fragile and often unique ecological communities (Wilde, 1981; Bunting, 1998). Invertebrates, pollen and fossil remains of extinct birds of high scientific significance are present in many New Zealand caves (Wilde, 1981; McLachlan, 1993; Worthy, 1993; Bunting, 1998). Unfortunately, recent research on tourist caves has shown a decline in biological diversity and a general reduction in experience by tourists over time (Huppert *et al.*, 1993). Other studies have shown significant effects on carbon dioxide levels (Dragovich and Grose, 1990; Baker and Genty, 1998), temperature (Williams, 1987; Calaforra *et al.*, 2003) and for many caves, increasing irreversible physical damage (Bunting, 1998).

In New Zealand, concerns about visitor impacts on caves have been voiced by the Department of Conservation (DoC) as well as cavers (Wilde, 1985) but little has been done to quantify these impacts (Bunting 1998). In response to increasing recreational use of a limited resource, some researchers have adopted the concept of *environmental carrying capacity* (Stankey *et al.*, 1990; Department of Conservation, 1995). The environmental carrying capacity concept can be expanded to include Levels of Acceptable Change (LAC) proposed by Hendee *et al.*, (1990) where a level of change or impact is identified as manageable or able to be maintained (Bunting, 1998). Bunting (1998) proposed that when applying this LAC framework, cave managers need to answer three important questions:

1. In what condition do we want our caves in the future?
2. What levels of damage are managers and cavers prepared to accept? and,
3. How will these conditions be managed over time?

The answers to these questions are pivotal to the management of New Zealand's cave resources if they are to be maintained in an acceptable condition for visitors to enjoy for future generations. It is clear the answers to such questions will depend on data obtained from sampling and monitoring programs.

To measure changes to physical structures, photo-monitoring has been used in some caves of high conservation significance such as the Honeycomb Hill caves, Karamea (Abel, 2001). While this method is very useful to assess damage within small areas, assessing larger areas is very time consuming. Furthermore, difficulties marking photo-points and achieving consistent lighting, depth of field and continuity in film colour, can reduce the value of photo-monitoring attempts (Bunting, 1998). Bunting (1998) developed a Cave Impact Assessment Rating System (CIARS) that could be used to visually assess impacts of recreational cavers on the floor, ceiling and walls of caves. In his 1998 study, Bunting surveyed sections of Honeycomb Hill cave and Gardner's cave in the Waitomo cave area in the Waikato, and rated impacts as: not visible, light, moderate or severe using his CIARS method. He compared his CIARS method with the Visitor Area Impact Mapping (VIM) method (Hendee *et al.*, 1990). Bunting (1998) found the CIARS method was superior as it assesses the levels of impacts on all surfaces of the caves, whereas the VIM only gives a pictorial assessment of the cave floor. Since this study, few additional data have been collected on which to base management decisions.

To protect natural assets used by tourists, clear guidelines and monitoring requirements are crucial. New tools are needed by managers to assist cave monitoring and management. The purpose of the present study was to collect and analyse data on visitor impacts in cave systems on the West Coast to determine the relationship between visitor numbers and physical impacts. Both the data collection and analysis methods were intended to provide managers with a practical tool to monitor changes in cave systems and to model and predict future visitor impact.

More specifically, the study aimed to:

- Carry out a pilot survey and exploratory data analysis of physical impacts in caves caused by visitors;
- Devise a sampling plan to quantify or index impacts in a cave;
- Use the sampling plan to collect data over a range of cave types;
- Use the data to model the visitation/impact relationship; and
- Evaluate the utility of the model in light of current management practice.

Two caves were visited in 2002 to carry out a pilot survey designed to evaluate initial sampling plans designed to quantify and monitor tourism impacts in caves. The caves were Honeycomb Cave - Restricted Area, Karamea that receives few visitors, and Metro Cave, Charleston that has a large number of visitors. Based on data collected from the pilot survey a final sampling plan was devised and further caves sampled. These additional caves were: Fox River Tourist Cave, The Cavern and Babylon located at Punakaiki and Te Tahi, Winchhead and Hole in the Cliff, located at Charleston.

3.2 Sample Sites

Fox River Tourist Cave, Punakaiki
Fox River Tourist Cave is classified as "open access" (Wilde and Worthy, 1992). Constant local visitation for over 100 years has damaged this cave to a level where further visitation is considered to have little impact (Wilde and Worthy, 1992). This cave is popular with visitors in the region. While many stalactites and stalagmites are damaged, DoC still actively manages the cave because they consider there is still much potential for damage. In addition, DoC staff periodically undertake cleaning to mitigate the effects of mud and silt being tracked throughout and covering formations. This cave is a winding passage, approximately 200m in length.

Punakaiki Cavern, Punakaiki

This is a robust, large, inactive sea cave made up of two main chambers and is classified "open access" (Wilde and Worthy, 1992). It is the most accessible of all the caves in this study due to its close proximity to the highway and has a very high visitation rate.

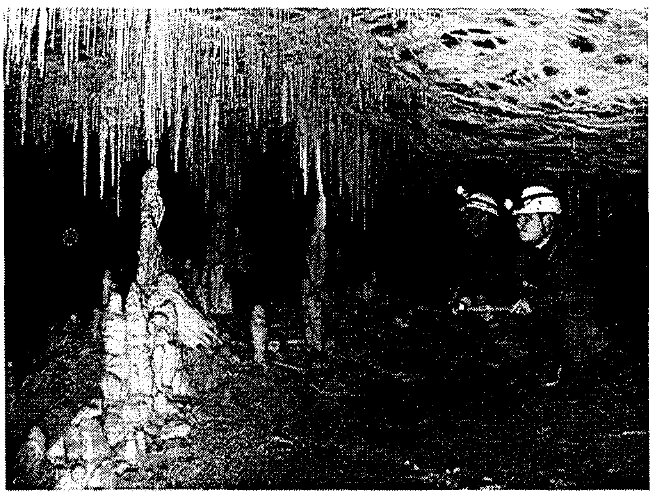
Babylon, Punakaiki

Babylon is a large resurgence cave with spectacular passages (2400m in total) and arguably the best speleothem decorations of any cave in the West Coast Conservancy (Wilde and Worthy, 1992). Access to the decorated areas is currently gated. Babylon is not easily accessible or well known to the general public and has a low visitation rate. The cave proper has a large open robust cavern that slopes steeply underground with the floor largely covered in rock fall. The sample was taken in a side passage, The Passage of Toth that is limited access and very different from the main cavern with many delicate formations. The cave contains biokarst in the entrance zone, significant fossil deposits and a rare aquatic troglobite giving it national significance (Wilde and Worthy, 1992) (Worthy 1990). Entry into "Restricted and Limited Access" areas is by permit only and sensitive areas are protected by taped routes (Wilde and Worthy, 1992).

Honeycomb Hill Cave, Karamea

Honeycomb Cave opened 1984 and has international significance because of its fossil deposits. In addition, it has national significance due to its geomorphology. This cave is a multi level complex maze system containing 14 km of passages (third longest in NZ) covering an area of 1000 x 800 m (Wilde and Worthy, 1992). Honeycomb contains a significant population of the protected spider *Spelungula cavernicola* (Wilde and Worthy, 1992). The sample was taken in the restricted access gated portion of this cave that receives few visitors annually. The gated section is closely monitored and managed by DoC staff and is an extremely sensitive area with many significant fossils and sensitive formations (Worthy, 1993). Local residents and cavers, however, are known to have used other entrances to gain access to this section (Abel, 2001).

Metro Cave (Te Ananui), Nile River, Charleston



Metro is a large extensive cave with over 8 km of passages and contains very significant geomorphological features. Metro has a diverse range of substrate types, cave fauna, significant fossil bones and speleothems (Wilde and Worthy, 1992). These natural values combined with its tourism and recreational values make it a nationally significant cave (Worthy, 1990). It has large robust caverns as well as more sensitive and vulnerable areas. The cave is gated and entry is by concessionaire or permit only. Metro is a tourist cave with a high visitation rate due to heavy concession use in some areas. Accumulated impacts due to recreational caving are evident in many areas.

Te Tahi Cave, Nile River
Te Tahi contains 2200m of surveyed passages with nationally significant Oligocene fossil whale bones (Worthy, 1990) and is highly valued by recreational cavers. It is a tourist cave with one concessionaire. This 'sporting cave', was the most challenging of those assessed in this study. Te Tahi requires a higher level of fitness to negotiate its passages. This cave contains many areas of delicate speleothem and other cave formations.

Winchhead, Nile River
This cave's 1325m of surveyed passage makes it one of the more locally significant of its region (Wilde and Worthy, 1992). Winchhead is less physically challenging than Te Tahi with tall rift passages that close down as one proceeds through the cave. Areas of sensitive formations are more localised. Winchhead is visited by about 140 recreational cavers each year.

Hole in the Cliff
This cave is located between Four Mile Road and the Nile River. Hole in the Cliff is a low energy cave with some significant speleothem formation at the rear. This cave is a large open rocky caverns as an entranceway. The cave is visited by a small number of recreational cavers each year.

3.3 Methods

Several standard sampling plans were considered before commencing this study. However the geodiversity of the cave and multivariate nature of the measurement necessitated a review of the initial sampling plans. In the pilot survey, the types of impact caused by human activity were identified and recorded on data sheets (Appendix 1). For Honeycomb cave, nine 25m line transects were located systematically every 100m from a random starting point (in this case 71m from the cave entrance). Impacts were recorded within visibility distance either side of each transect every meter. Out-of-transect impacts were also recorded and compared with the sample estimates of impacts per meter. It is worth noting that while we refer to the samples as line transect samples, they do not conform to the more formal line transect surveys based on using a maximum visibility distance (Krebs, 1989). Standard line transect surveys could not be used because of the variability of the width of passage. The width of a normal cave passage can vary between zero to 30m between the track and the walls and can change suddenly along the transect length. A similar method was used to assess damage in Metro cave. An initial exploratory analysis of the pilot survey data indicated that the recorded data required simplification (Appendix 2) such that samples could be standardised and impacts more precisely quantified. Categories of impacts were created and all subsequent samples in all other caves used the categories of impacts outlined in Appendix 2.

Preliminary data analysis investigated the use of similarity/dissimilarity coefficients to categorise the characteristics of the impacts in caves (Table 1). The rationale for using these indices is that such measures are often used to compare or monitor changes in systems that consist of components, some of which may be shared and others that are not, for example communities of species (Krebs, 1989) and aspects of the genetic composition of species. Caves are systems that can share certain characteristic impacts that could be compared using such indices. Changes to these indices or more particularly comparison of the index for an individual cave with a reference cave could provide an effective monitoring tool. The rationale is that the degree of similarity with the reference cave might indicate a requirement for management action, depending on the value of the similarity coefficient. Other studies that measure similarity or dissimilarity use a simple correlation coefficient. The correlation coefficient was also investigated in this study for its utility to measure changes in caves. Of most interest is the sensitivity of each index to differences between caves and thereby their usefulness.

Table 4
Significance Rank, Vulnerability and Access Class (modified from Worthy 1990; Wilde and Worthy 1992) of the Surveyed Caves

Name	Significance Rank	Vulnerability	Access Class
Fox River	National	Low	Open
Punakaiki Cavern	Local	Low	Open
Babylon	National	Medium High	Open Permitted
Honeycomb Hill	International	High	Permitted access
Metro Cave	National	Medium	Permitted
Te Tahi	Regional/national	Medium	Open
Winchhead	Local	Medium	Open
Hole in the cliff	Regional	Low	Open

The data collected was then analysed to determine the relationship between visitor numbers and impact rates as measured by the all samples collected. Where several transects were measured in each cave, the impacts per metre were totalled over the transects and divided by their total length. The estimated impacts per meter are an index of the true impacts in the cave. There was no attempt in this study to achieve the degree of precision usually required in more traditional samples. Such levels of precision were considered not practicable because of the geodiversity of the cave system and the multivariate nature of the physical impacts. Visitor numbers were estimated by DoC workers and in some cases, gathered from various reports, and DoC's Visitor Access Management (VAMs) database. Where several estimates or measures of visitor numbers existed for a cave, an average estimate was used. It should be noted that these estimates have a low level of accuracy but give a relative quantitative assessment to establish an initial model that relates impacts to visitor numbers.

3.4 Results

Exploratory Data Analysis
The data recorded within each transect (Appendix 1) for the pilot survey was too complex for clear analysis and interpretation so the original transect records of the Honeycomb and Metro samples were simplified by assignment of impacts to categories (Appendix 2). It became clear that in some caves management creates deliberate modification to minimise damage, for example, installing bollards and roping off areas, as well as digging deeper tracks to clear the cave roof. Such practices can result in considerable compaction, so this category was dropped from the analysis. Categorisation of impacts allowed impacts per meter to be calculated (Table 5). All caves could be directly compared using similarity/dissimilarity indices and also

compared with the cave with the lowest impacts as a reference cave. Hole in the Cliff was removed from the analysis because of:

1. Its different geology compared with the other caves,
2. The failure to obtain enough data for this cave for valid comparison and,
3. The greater uncertainty of visitor numbers.

Table 5
Visitor Numbers and Average Impacts Per Metre for the Caves Surveyed in this Study

Cave	Visitors	Total Impacts	Metres Surveyed	Impacts/ Metre
Babylon	30	75	56	0.75
Honeycomb (restricted area)	50	19	225	0.08
Winchhead	140	148	45	3.29
Te Tahi	400	202	48	4.21
Metro	3700	422	75	5.64
Fox River	5000	155	50	3.1
Punakaiki	8500	188	50	3.76

To compare the similarity/dissimilarity of the types of impacts in caves, Table 6 shows two similarity coefficients and one dissimilarity coefficient for caves compared with Honeycomb restricted area. The distance coefficient (which is a measure of dissimilarity) scales from 0 (caves are identical) to infinity. In other words, the greater the distance, the more dissimilar the caves are. The Percentage Similarity (or Renkonen Index) was calculated. The Renkonen index ranges from 0 (no similarity) to 100 (complete similarity).

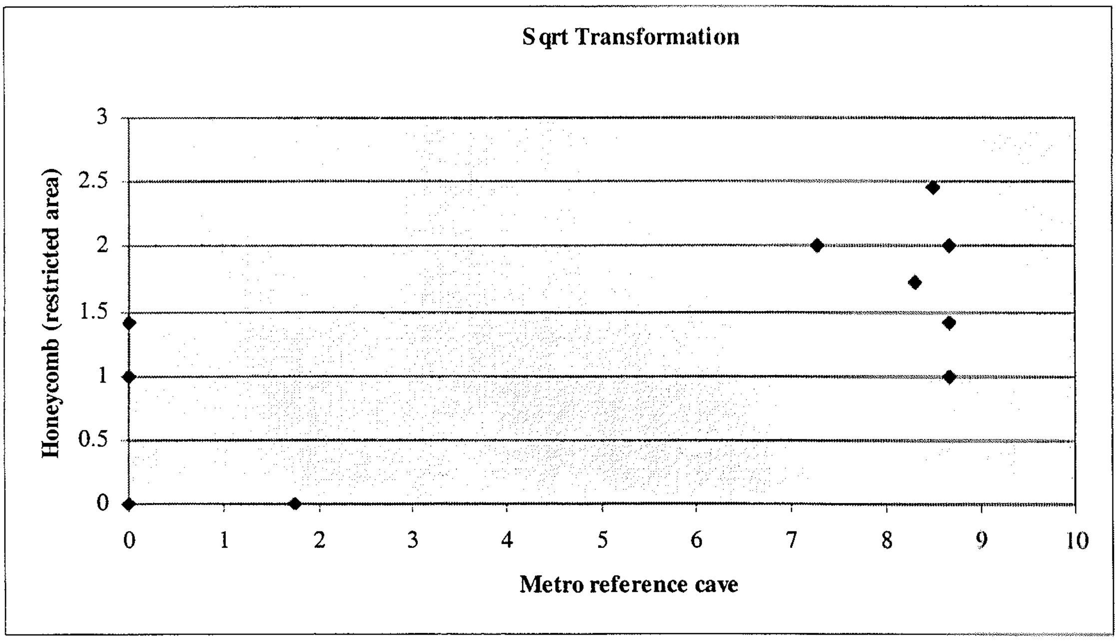
Table 6
Measures of Dissimilarity (Euclidean Distance) and Similarity (Per cent Similarity) of the Caves Surveyed with Honeycomb Cave – Restricted Area

	Euclidean Distance	Per cent Similarity
Babylon	0.15	64.6
Winchhead	0.32	42.9
Fox River	0.46	50.1
Punkaiki	0.51	38.3
TeTahi	0.57	40.2
Metro	0.73	34.5

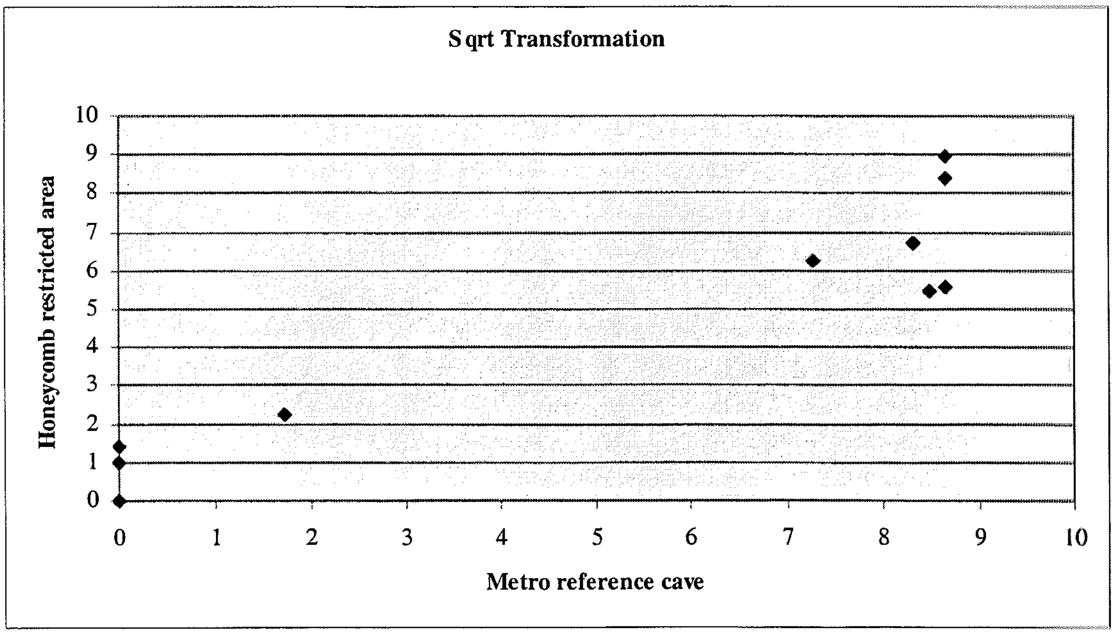
The Euclidean distance and Per cent Similarity show that Babylon is most similar to Honeycomb Restricted Area, that has the least estimated impact per metre, and Metro is the least similar to Honeycomb Restricted Area. To contrast the two extreme caves with regard to types of impacts, Figure 9a shows a correlation analysis between the data from Metro and Honeycomb for a square root transformation of impacts per metre. Figure 9b illustrates what the correlation between Honeycomb and Metro would look like if they became more similar.

Figure 9
Correlation Analysis

(a) Correlation analysis using the square root transformation between Metro reference cave that has the most impacts/meter and Honeycomb that has the least (r = 0.67).

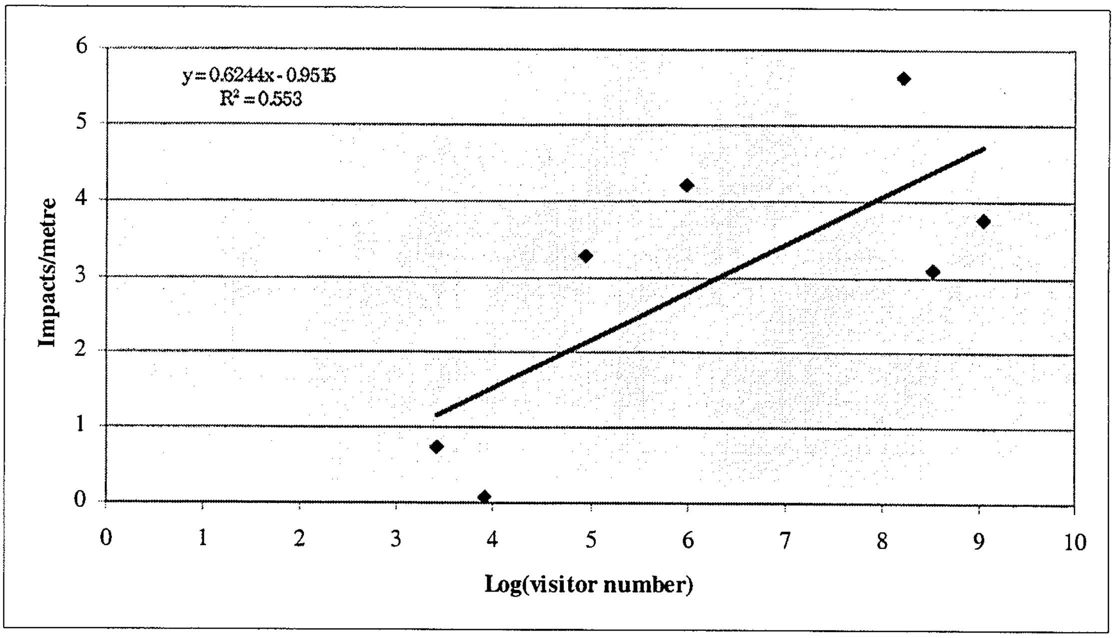


(b) The data is changed to make the caves more similar (r = 0.94). (Note that % damage and compaction are included in this analysis).



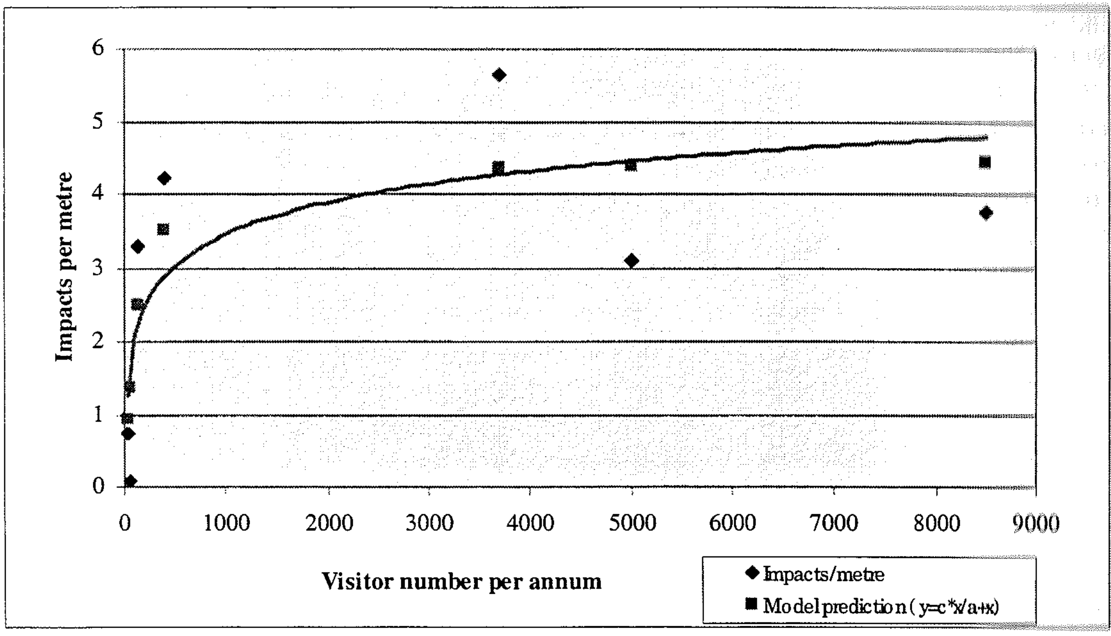
Regression Analysis
To establish a predictive model that can be used by managers to guide decisions, a regression analysis was carried out on the data in Table 5. The regression analysis showed that there is a significant relationship (significant at the 10% level, F = 6.18; P = 0.055; R^2 = 0.55) between log (visitor numbers) and impacts per metre (Figure 10). This relationship can be used to estimate rates at which impacts accumulate and the number of visitors that would result in a determined level of impact in a cave system.

Figure 10
Impacts Per Metre Versus Log (visitor number)



However, the untransformed data (Figure 11) clearly depicts a rapid rise of impacts in relation to increasing visitor numbers to reach an asymptote or plateau. This relationship can be described by the model first proposed by Bunting (1998, after Wood, 1985) and expressed by the equation y= cx/a+x. In this study, y represents the impacts per metre, c is a constant that represents the maximum damage that may occur, x is the number of visitors per annum and a is a constant that represents the number of visitors per annum required to reach half the maximum impact. The nonlinear curve fitting procedure NLIN of SAS (SAS Institute 1992) was used to estimate parameters a and c for the model. A significant fit was obtained (F = 27.4; df = 1, 6; p < 0.002; R^2 = 0.70). The parameters of the model were estimated as c = 4.49 ± 0.72 SEM, and a = 113 ± 88.6 SEM. In other words the estimated maximum damage is close to 4.5 impacts per metre and an annual visitation rate of 113 people on average, is all that is required to reach half the maximum impact.

Figure 11
A Two Parameter Hyperbola, y = cx/a+x that Describes the Relationship Between Impacts Per Metre and Annual Visitor Number



3.5 Discussion

During the surveys it became clear, that early cave explorers have been responsible for much accidental damage in many caves. Furthermore, they were responsible for deliberate damage by moving off track to improve access to passages. Some caves have an allocated concession and therefore high numbers of tourists are guided through specific areas. It was noted, however that much damage can occur outside of the areas used by the concessionaires through recreational caving. In every cave there was much evidence of cavers not keeping to tracks in sensitive areas in their attempts to find or establish new routes. In general, the amount of damage is often reflected by the type of material on the floor of caves. The more severely impacted caves were those with clastic (sand, silt and mud) floor material compared to rock fall deposits. Fragile cave areas with low ceilings or narrow passages often had very high impacts consistent with observations made by Bunting (1998).

Preliminary Analysis: Similarity/Dissimilarity Coefficients
Because caves differ in their morphology, robustness and management, the use of a reference cave does not appear to be very useful. However baseline data for each cave system would enable comparative changes using any of the similarity or dissimilarity coefficients proposed above.

Models that Relate Impacts to Visitor Number: Implication for Cave Management
The simple linear regression analysis appears to provide a useful relationship for predicting a relative rate of impact in relation to visitor numbers. Clearly, this model would be improved as more data is added. However, the untransformed data fits the rectangular hyperbola model ($y = ax/c+x$) proposed by Bunting (1998) surprisingly well. This model is useful for practical management as it gives an estimate of the average maximum impact ($c = 4.49$) that caves surveyed, can sustain. Of more interest is the parameter a that estimates the number of visitors per annum required to sustain half the maximum rate of impact. In this study, a was estimated as 113 ± 88.6 visitors per year. This parameter has a very high standard error of the mean and consequently its confidence interval would be wide. Nevertheless, the full model

gives some quantitative guidelines where none existed previously. For example, accepting that some damage is inevitable, managers might decide to accept that a certain cave should have no more than one quarter the maximum impact ($c/4$) estimated for caves in the area. The number of visitors per annum should be restricted to $(c/4) = (c*x)/(a+x)$. Solving for x, the number of visitors per annum, we find that $x = (c/4*a)/(c-(a/4)) = (1.1225*113)/(4.49-1.225)$ $= 38.9$ visitors per year. Conversely, if caving permits to a particularly sensitive cave (or part of cave) need to be limited, managers could use the model to determine the annual allocation of permits. For example, if managers decide to issue permits at a rate of 50 permits annually, then the amount of damage to expect from this level of activity is, $y = (4.49*50)/(113+50) = 224.5/163 = 1.38$ impacts per metre.

Certain assumptions are implicit in the models presented here. First, there is the assumption that accumulated impact over periods of time that vary among caves is somehow related to current estimated annual visitation rates. Since it is impossible to be precise about the timing of visitation or the measured impacts, it is assumed that the estimated annual visitation rate is a good proxy variable for true visitor numbers that have been responsible for the level of impacts in the caves. As the authorities responsible for managing the caves collect more data then more reliable measures and estimates can be made.

Impact Sampling: Implications for Cave Management

This study has highlighted that it is difficult to develop a generic measure that can be taken from cave to cave and that simplicity is the key to a successful management programme. There is limited time available to managers so it is important to get the monitoring/management ratio correct.

DoC is currently assessing the specific features of each cave. They are also establishing indicator sites to monitor as indicators of change. These often involve photographic points. Clearly, photo-points are useful over longer periods of time but need to be carried out and interpreted by experienced cavers or at least workers very familiar with the cave in question. Photo-points still involve subjective judgements concerning changes within the cave. If damage is witnessed in some sites and not in others it is still difficult to judge the implications for the whole cave system. Photo-point monitoring and counters maintained for each site over time would definitely give managers better information on which to base decisions. Measuring the intensity of damage or impacts is one of the most difficult factors to assess. Photo-points would be very useful measures of the intensity of damage.

A combination of approaches could be valuable. By quantifying changes, a sampling scheme as carried out in this study could be a useful additional method of measurement to photo-points. For example, if over a period of time the average impacts per metre change from three to five, then clearly, the manager would be inclined to suggest that significant change had occurred. It is important to recognise that both photo-points and sampling require experienced workers, especially those who can distinguish between natural and human impacts.

Weaknesses of the Sampling Method Used

While the sampling method used in this study proposes to be a practical tool for monitoring impacts in caves it has certain weaknesses that need to be recognised. Damage occurs in proportion to what is present in the cave. For example, the more formations present, the more will be recorded as damaged. Not only that, the types of damage recorded are related to the nature or character of the cave. For example, if the cave has a rock floor then compaction is not a problem and will not be reported. If there are a lot of formations close to the track then there will be a lot of formation damage. To correct for the number, position and vulnerability of formations within and between caves, relative areas would have to be measured. The extreme spatial geological variability and multivariate nature of the cave system means that such measurement is not practicable and certainly was beyond the scope of this study. Even stratification of the sample to areas with and without certain features is impossible because of the extreme variability in the system. However, stratification of the cave into broad categories based on fragility so that they can be sampled separately, is possible.

Improvements

Double counting may occur with increasing track presence and appearance of footprints off track. Better definitions or merging of the two categories would eliminate this particular problem.

The heterogeneous nature of the cave environment makes it important to do sufficient sampling to realistically represent the 'health' of the cave. For some caves it might be possible to simplify the sampling method even further and record simply the presence or absence of impact within the sample unit. The proportion of sample units (metres) with impacts could then be used to compare caves or more usefully monitor changes over time. Such a scheme would allow more sample units to be recorded and therefore greater precision. Many caves however, have some sort of impact in virtually every square metre and reduction of the sampling method to the simple presence or absence of an impact in each metre of length would lack sensitivity and thus be of little use.

It is important that caves are categorised in terms of their fragility as this quality determines how much damage is potentially possible to occur. In extremely complex caves, we recommend that cave managers use their knowledge of cave size so that each cave, or section of cave, whichever is of most interest, can be sampled in proportion to its size.

3.6 Conclusions and Recommendations

This study has presented methods and data that can be used to help answer the three questions posed by Bunting (1998):

1) In what condition do we want our caves in the future?
2) What levels of damage are managers and cavers prepared to accept?
3) How will these conditions be managed over time?

A practical sampling scheme is proposed that quantifies and relates physical impacts in caves to visitor numbers:

- Determine the size of the cave and plan to sample it in proportion to its size (e.g., a minimum 20% its length);
- Use strict random placement of transects if the cave is not well known by the managers;
- For well categorised caves, stratify the cave based on assessments of fragility and sample each stratum in proportion to size;
- Taking care not to overlap with the previous sample unit, record the presence of each category of impact (Appendix 2) within each metre of the transect and within visibility distance;
- Total all impacts and divide by the number of metres to calculate impacts per metre;
- Use the data in the model equations to make management decisions or to refine the model.

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Appendix 1

Cave: Honeycomb (Eagles Roost, Gypsum Passage etc.) 4/09/02

Transect Number	Photo	Impact Description	Number of Impacts	Biota
1		Minimum damage to rock path	0	
2	11:47 a.m.	Several track diversions off main track Deep erosion on main track	2	
3	11:52	Deep erosion (400mm on track	1	
4	11:58	Low level erosion of silt stone floor. Some evidence of footprints but have been brushed Erosion in side of bank down to stream bed	3	1 live spider
5	12:15 12:16	Footprints beyond tape in mud Disturbed silt off track Poke hole and scratches caused by some instrument	3	1 Harvestman
6	12:26	Track diversion and track presence on mud patterns Extensive damage to mud castles off track	2	1 harvestman 1 eggcase
7	12:43	Foot traffic erosion	1	
8	12:55 12:57 12:59	Hydro magnicide covering on floor removed Damage to cave coral formation Silt moved off silt mound	3	
9	1:15	Slotting and wearing away of track Bones moved by foot traffic and tampering	2	1 weta 1 weta 1 spider
OUT of Transect	**Impacts**			
Transects 1-4	11:07	4 erosion impacts Natural and accidental damage to stalactites	5	
Between t5-t6		Deep erosion on path Moon-milk rubbed off rocks	1	
Between t6-t7	12:35	Trampled fossils	1	1 spider
Between t7-t8	12:52	Foot traffic through silt off track Major damage by foot-traffic in mud (2) Hydro-magnicite? Removed	4	1 carabid body
Between t8-t9		Foot traffic through mud pool Deer's head crushed Rocks knocked down into rimstone? Pools Formation breakage	4	

Cave: Metro

Transect number	Photo	Impacts	Number of Impacts	Biota
1	12:57 12:59 1.04 1.05	Many footprints/alternative tack Crust broken in many places Main track erosion (dug out) Underground nova coil Excavated crust + crushed by tyres Gravel swept over flow stone Broken stalactites 70% damage	8	
2	1.29 1:30	Carbide waste left off track Moon-milk on rock trampled to smooth Broken rock on track Extensive silt transfer from boots Erosion off track Knobs of moon milk broken off Old track damage 65% damage	8	
3	2.05 2.12 2.18 2.20	Gravel knocked off, eroded, Silt compacted (2) Trampling off track (2) Rocks moved (2) Stalactites broken off Diversion of main track Obvious scratching and scuff marks on ceiling Carbide marks on ceiling Hand prints +dog prints Side of track eroded 40% damage		
4	2.21 2.23 2.45 2.46	Carbide waste (2) Graffiti in silt Silt tramped over moon milk Old tracks 80% damage		
5		Excavated track (80 cm deep) Rubbed sides of tunnel Excavated silt Stalactites tipped Flow stone broken Spade marks Scuffing Graffiti Carbide (2) Litter Compacted silt Spoil from excavations 90% damage		
6		Many footprints Stalactite tipping Erosion Silting Stalagmites damaged 80-85% damage		
7		Trenched throughout Crushed cave coral on floor Crushed cave coral on ceiling Damage to floor by bollard Carbide waste Broken crust in many places 85% damage		

Out of Transect Damage				
1		Lighter covering a stream pebbles Erosion from digging trenches Much sediment over tracked Extensive track presence Deep erosion off track from tubing visitors Moon-milk scraped off many areas Rocks shifted Rope marks Fossils moved 85% damage		
2	1.44 1.45	All stalactites above track with broken tips Some earthquake damage Silt on stalactites thru handling Numerous broken stalactites Bad foot erosion Alternative tracking 80% damage		
3	2:23 2:25	Trenches Silt from track piled up Hand and footprints in silt Marks on stalactites Boot-prints on structures Concrete bollards breaking surface Large gouges out of track from tires Holes dug in silt Many footprints Many tipped stalactites 90% damage		
4	2:52 2:53	Graffiti on wall carbide burn (arrow) 1000s of stalactite tips broken Nails from operators left Stalagmites attached to rocks removed and placed elsewhere Needles broken Rocks placed up on bank Litter under ledge (flash bulbs / carbide waste) Much tracking thru restricted areas Climbing damage up face Organ pipes broken 80-85% damage		
5		1000s of footprints Scuffing on walls Tipping 80-85% damage		
6		Broken edge on rock to allow easy access on track Finger prints on rocks Graffiti in silt Carbide waste (2) Broken cave coral Silt worn throughout Wooden box left Spoil either side of track (40cm high) Shawls broken off Graffiti (carbide arrow) Litter (red plastic) 85% damage		

7		Silt tracked over speleothems Rocks moved Scuffing and erosion along track edge Rocks broken to allow access Muddy footprints across flow stone Mud tracking from wet areas over stalactites Tracking out of roped area Stalactites broken Gravel shift by foot traffic 80% damage		

Types of damage
Categories are assessed every meter

Damage to cave formations[1] (broken, crushed, rubbed)
Footprints/fingerprints
Erosion from foot traffic
Compaction
Increasing track presence
Tracking of silt or mud
Deliberate modification to tracks or structures to allow access or activity
Tracking of silt
Graffiti
Litter (carbide waste etc.)
Damage or loss of fossils

[1] Stalactites, needles, moon-milk cave coral, mud formations etc

Appendix 2

CAVE: METRO
Marker : **Date:**
Protocol: *x* transects of approximately 25 metres (depending on the topography of the cave) are examined every hundred metres starting from a random starting point. Impacts are assessed within each metre of the transect, and marked present if recorded within the metre sample unit. An impact is a permanent impact or one that requires a management action. Note that the distance between transects can be easily adjusted to cave size.

	TRANSECT											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**		**Total**
TRANSECT LENGTH	**6**	**19**	**25**	**25**								**75**
TYPES OF DAMAGE												
Damage to cave formations[1] (broken, crushed, rubbed)	///// /	///// ///// ///// ////	///// ///// ///// ///// /////	///// ///// ///// ///// /////								75
Footprints/fingerprints Rubbing and scraping	///// /	///// ///// ///// ////	///// ///// ///// ///// /////	///// ///// ///// ///// /////								75
Erosion from foot traffic	///// /	///// ///// ///// ////	///// ///// ///// ///// /////	///// ///// ///// ///// //								72
Compaction												0
Increasing track presence	///// /	///// ///// ///// ////	///// ///// ///// ///// /////	///// ///// ///// ////								69
Tracking of silt or mud or gravel	///// /	///// ///// ///// ////	///// ///// ///// ///// /////	///// ///// ///// ///// /////								75
Deliberate modification to tracks or structures to allow access or activity	///// /	///// ///// ///// ////	///// //	///// ///// ///// ///// /								53
Litter (carbide waste etc.)	///											3
Damage or loss of fossils												
Graffiti												
Total Impacts	39	114	132	137								422

[1] Stalactites, stalactmites, speleothems, needles, moon-milk cave coral, mud formations etc.
Impacts/m = 422/75 = 5.64

Chapter 4
Overall Approach to Measuring Thresholds of Change

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4.1 Discussion

This section discusses the possibility of outlining a generic approach to managing tourism assets from the lessons learned from the two case studies. Hughey and Coleman (2004) reviewed recent literature on the range of monitoring tools available within the asset classes of physical, wildlife and vegetation (as outlined in Chapter 1 of this report). While they found a wide variety of tools in use and some useful developments occurring there was nothing in the literature that conflicts with the findings in either of the case study chapters on seals and caves reported here.

4.2 Tourism Impacts on Wildlife Assets

Wildlife research has shown that responses to tourism vary both between and within species. Habituation can take place in birds and mammals such as recorded by Boren *et al.* (2002) for fur seals in areas of high tourist activity. Responses during times of breeding can be more marked than at other times (Ward and Beanland, 1995). Therefore, we would expect to find variable responses to tourists by different species and at different times and locations of the same species.

The methods used to study tourist impacts on fur seals, in which observations of behavioural change due to tourists and tourist behaviour is supported by statistical tests, would also be appropriate for other marine mammals and birds. The observations would need to be tailor made for the particular species and situation but the general concept used in this study plus the controlled approaches as used by Boren *et al.* (2002) can easily be adapted. Controlled approaches involve randomly selecting an individual mammal or bird that may be alone or part of a group and quietly approaching on foot or by water until it responded and recording or estimating the distance. Methods to measure disturbance would need to be supported by statistical tests such as Chi-square test and regression analyses. This method is consistent with the behaviour of tourists or other visitors and is therefore appropriate as a measure of impact.

4.3 Tourism Impacts on Physical Assets

Tourism impacts on physical assets differ from wildlife in that the asset is normally in a fixed location. As demonstrate in Chapter 3 research has shown that robustness or fragility of a physical site will affect the results, even within a particular asset class such as the caves studied here.

Standard line transects to record impacts of tourists on caves were modified in this case study to allow for impairment of visibility which occurs in caves. However, the line transect method would be applicable to other physical sites such as tracks, lakes and glaciers. Methods to measure disturbance or impacts caused by tourists could use transect methods and visitor counts as described in this report for caves. By calculating the average impacts per metre as shown in this report and monitoring the change in this average number over time, managers are provided with quantitative information on which to make management decisions. A simpler method would be to record the presence or absence of impact rather than trying to quantify it. Photo points could also be used to record longer term changes in the intensity of the impacts.

The actual parameters measured will naturally depend on the particular tourism asset; these might include compaction, litter, change in biodiversity, erosion etc. Both the sampling and the photo points require experienced workers. Simple linear regression analysis provides a useful tool for predicting the relative rate of impact in relation to visitor numbers. In addition, the rectangular hyperbola model, explained in the cave case study, could be useful for estimating the average maximum impact that a physical asset could sustain.

4.4 Tourism Impacts on Vegetation Assets

Although impacts on vegetation due to tourist activities were not selected for a case study, the methods used would be similar to those of the physical impacts with line transects recording parameters such as loss of vegetation or change in species composition along a transect. The average impacts per metre would need to be calculated for some assets along with the use of photo points. Numbers of visitors using the asset will also need to be measured.

4.5 Conclusions

Overall, the methods used to measure thresholds of change need to be simple and user friendly. Even if they provide rather coarse results and may lack some statistical accuracy, this is preferable to expensive monitoring methods that may not be used at all.

Further research is needed to confirm these findings for other assets.

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