DEVELOPMENT OF AN ENVIRONMENTAL EFFECTS AND TOURIST FLOW DATA MANAGEMENT SYSTEM

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Abstract:

There is increasing concern about the environmental sustainability of tourism based on natural attractions. We have developed a preliminary computer-based data management system that integrates information about tourists and their use of natural assets with information about how indicators of asset health respond to increasing visitor numbers. First, we collected data on tourist flows between demand (natural attractions) and supply (visitor nodes) sites for the West Coast of New Zealand. Second, we studied a variety of natural asset types in an attempt to develop models describing relationships between visitor numbers and impacts from these visits. These data were then combined to produce the environmental effects and tourism flows data management system for the West Coast. We modelled tourist flows to a range of assets, including the Franz Josef and Fox glaciers, Lake Matheson, the Okarito white heron colony, Pancake Rocks, the Cape Foulwind seal colony and a range of caves in the Buller area. Some assets, e.g., the white heron colony, are already nearing biophysical capacity, while others are not, e.g., the glaciers.

Application/Implications:

The system allows us to simulate potential environmental responses to increasing tourist numbers and/or changing composition of tourist flows. This information is needed for tourism planning at national and regional scales to ensure that natural assets are managed sustainably. Future developments include refinement of the impact models, and scaling-up to the national level.

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INTRODUCTION

Recent concern about the sustainability of tourist use of natural assets provided impetus for a project funded by the Foundation for Research, Science and Technology (FRST) to determine indicators and limits of acceptable change for natural assets that are also important tourist attractions, and to quantify the impacts of current and potential future visitation rates on those assets.

A review of recent research, both in New Zealand and internationally, indicates quite a rich literature of case studies of tourist-related environmental impacts for specific sites or asset types (Simmons and Cessford 1989; Cole and Bayfield 1993; Manning 2002), activity types (e.g., Cessford 1995), ecological communities or animal species (e.g., Curry et al. 2001; Steiner and Parz-Gollner 2002), and more global environmental issues such as energy consumption (e.g., Becken 2001). Studies of tourist behaviour and movement are also common. These include agent-based modelling (e.g., Itami et al. 1999; Gimblett, Daniel, and Meitner 2000; Bishop and Gimblett 2001; Itami et al. 2002), cost surface or friction surface modelling (e.g., Gullinck and Dumont 2002; Lynch 2002), and network-based modelling (e.g., Forer and Simmons 2002; Hinterberger, Arnberger, and Muhar 2002). However, amongst this profusion of literature there is very little that integrates tourist activity and environmental impact at a regional or national scale to facilitate policy development and management of natural assets.

This paper describes the development of a prototype computer-based environmental effects and tourism flows data management system (DMS). The system integrates knowledge from the three elements of our project. These elements have a) identified indicators of environmental impact at several types of natural asset (e.g., bird colonies, caves or scenic tracks), b) quantified impact as measured by these indicators in relation to the number of visitors occurring at each site (Johnson, Ward, and Hughey 2001), and c) determined how tourists "flow" around the available natural assets using the available road and track infrastructure (Forer 2002; Forer and Simmons 2002; Forer, Simmons, and Chen 2002).

METHOD

Tourist Activity Data
Tourist flows on the West Coast of New Zealand were analysed from diaries and retrospective questionnaires (recording itineraries of visits to the West Coast) administered between December 1999 and January 2001 (Forer 2002). Sample size for this survey was 2743 final respondents. From these data we extracted tourist visitation rates at key "demand" sites (natural attractions), as well as intermediate stopovers and "supply" sites (major visitor accommodation sites or entry points to the region). Some 750 different stop locations were identified on the West Coast, and 256 locations for overnight stays. For this analysis 230 of these stops and nine supply sites (e.g., Hokitika and Haast township) were used for modelling. These data provided a snapshot of visitation rates at key sites of interest relative to total tourist flow. We also queried the International Visitor Survey (IVS) and Domestic Tourism Monitor (DTM) data in the Tourism and Migration 2000 Reference Reports at the Statistics New Zealand web site to

estimate total tourist numbers visiting the West Coast annually (approximately 1 million). By scaling the detailed survey data to the total number of tourists visiting the region, we derived an estimate of total tourist visits at all sites recorded in the West Coast survey. This methodology has since been refined using combinations of IVS and DTM (Forer 2002).

We also extracted subgroups' visitation patterns from within the West Coast survey data. We focused on country of origin, but the survey also provides information on age group, length of visit, and mode of transport for each tourist questioned. Although the small sample size presents some problems (i.e., zero returns for some attractions/sub-group combinations), such data present an opportunity to investigate how tourist visitation rates at key sites vary between groups within the sample population.

Preparing a Transport Network
We established a road-and-track network for the West Coast region based on the Land Information New Zealand 1:50,000 scale Topobase dataset and augmented by reference to tourist and alpine guide books (Fig. 1). Intersections or end points in the resultant road/track network are called nodes. A proportion of the nodes in any network are not destinations in their own right; they are simply places where roads or tracks meet and travellers must make a choice of travel direction. However, other nodes represent destinations, some of which are the attractions that tourists want to visit. To simplify the network as much as possible, we matched the 230 stopping locations identified from the West Coast survey with an appropriate node in the network. Parts of the network deemed irrelevant to our analysis were deleted. These included dead-end roads or tracks where there was no tourist data for the end node, and parts of the road/track network that had no tourist activity recorded and did not offer a viable alternative route between known attractions. While we removed parts of the network to simplify it, the remaining road or track segments retain their original shapes since any attempt to use automatic GIS functions to "generalise" the road network can lead to errors in connectivity where adjacent unconnected road segments may unintentionally be joined, creating spurious nodes. The final network had approximately 2100 nodes in total, of which 239 (approximately 11%) represented sites of tourist activity. We also identified from these 239 sites some 17 iconic sites that we considered represented key tourist attractions due to popularity (e.g., Pancake Rocks, Fox and Franz Josef glaciers), or because of their environmental significance (e.g., white heron colony and Honeycomb Hills cave). This subset of iconic sites is the focus of our research relating tourist visitation rates to environmental impacts.

Within the GIS network model both road/track segments and nodes are provided with attributes that help to estimate the interaction between the sources of tourists and the destinations to which they are being attracted, which is described below. Specifically, the visitation data derived from the West Coast survey (Forer 2002) provided an indicator of the attractiveness of these nodes to visiting tourists, and road and track segments were given an impedance value that determined the "cost" of traversing that segment of the network. Our impedance data are based on an estimate of time to traverse a segment of network given the type of road or track being traversed and its length.
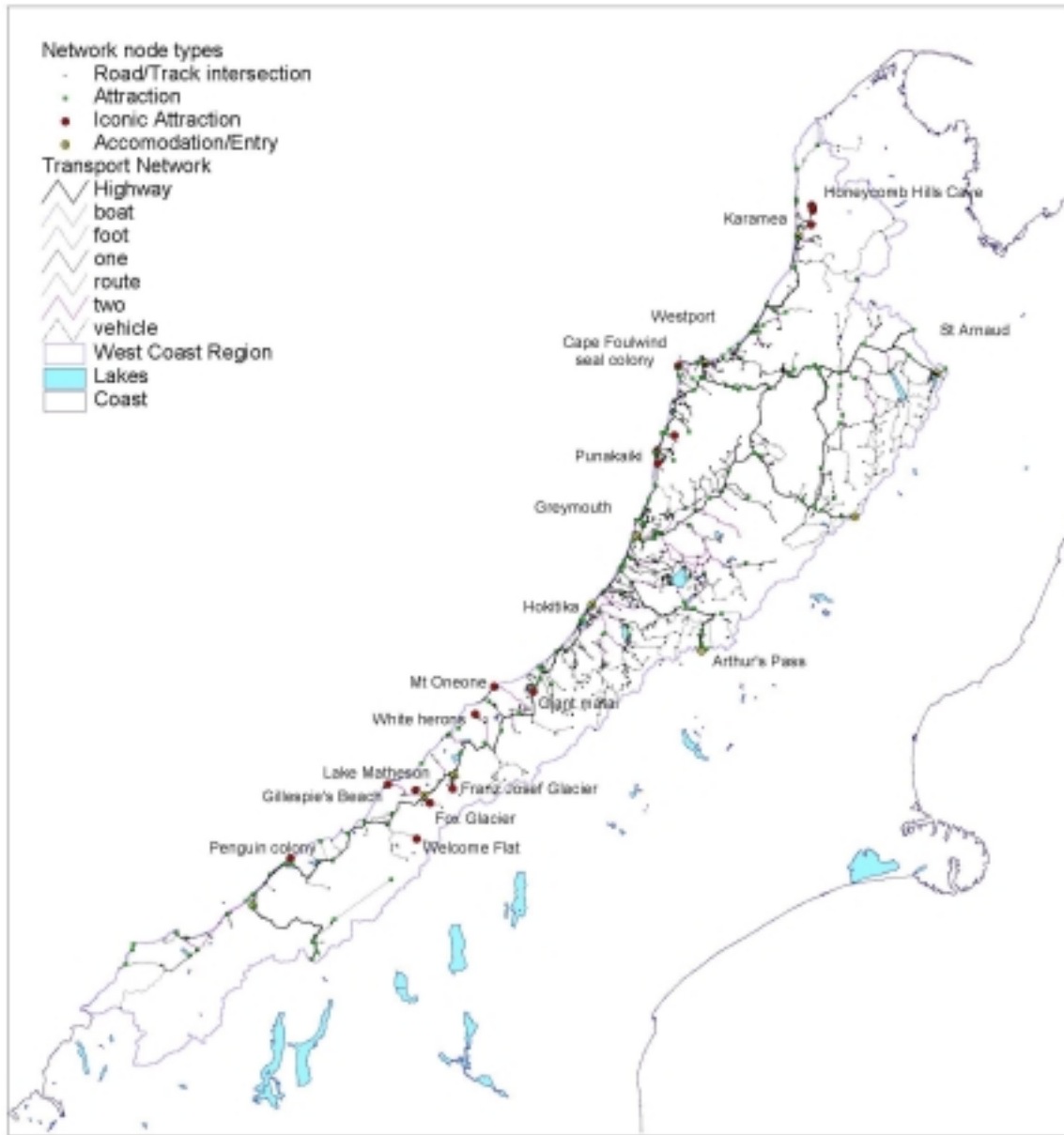
Figure 1: Overview of the transport network and nodes representing attractions or accommodation centres.

Because of the linear geometry of the West Coast transport network, many visitors travel either northwards from Haast or southwards from St Arnaud or the Lewis or Arthur's passes. As a result most tourists in most cases **must** traverse State Highways 6, 7 or 73 as part of their itinerary, so we chose to give these highways zero impedance since they did not represent a true impediment to the traveller in respect of specific site visits on the Highway. For example, if travelling from Hokitika to Franz Josef, the traveller **must** traverse that section of Highway 6 between those two accommodation nodes. Attractions on this section incur no extra visitation costs, and the question is, which attraction (e.g., white heron colony or giant matai tree at Lake Ianthe) results in a break in their trip?

Modelling Tourist Flow
To model tourist 'flow' (activity) for each natural attraction we used the standard gravity interaction model implemented with Arc/Info 8.2 (ESRI 2002). The interaction model generates a matrix of interactions between origins and destinations, the interaction between each origin and destination being computed as follows:

$$\frac{\text{tourist ``production'' of origin} * \text{attractiveness of destination}}{\text{cost}^{\text{distance decay exponent}}}$$

Three conditions must be present for interaction to occur. These are complementarity, transferability, and the absence of a critical intervening opportunity. Complementarity means that the supply and demand between two nodes must be for the same thing (e.g., tourism). Transferability means that it must be feasible to transfer the supply (tourists) to the demand location (attraction). Both these conditions are generally met in this application. Of more interest is the condition of intervening opportunities (Fig. 2). This refers to the notion that for two complementary locations to interact, there must be no intervening opportunity, or at least that any intervening opportunity will reduce potential interaction between two complementary locations.
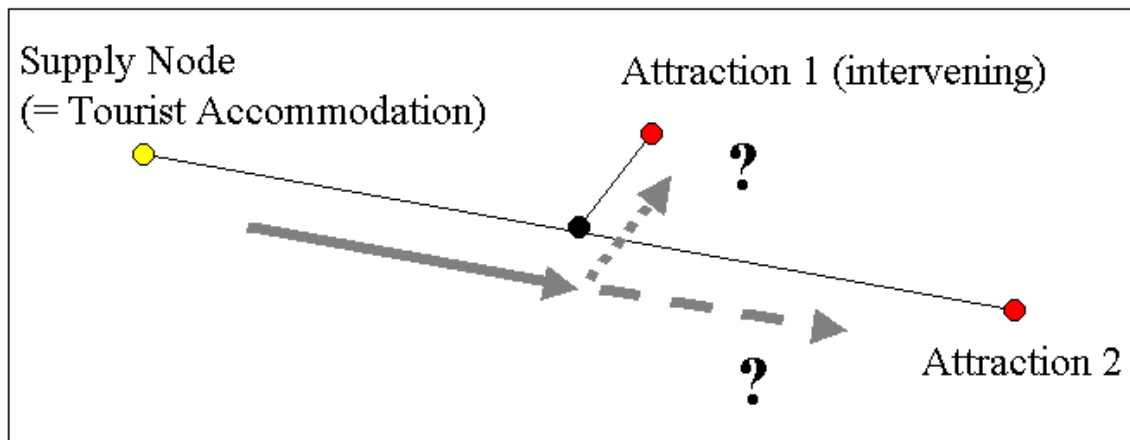

Figure 2: Intervening opportunities represent situations where tourists must decide whether or not to pass one attraction in order to reach another.

The distance-decay exponent in the interaction calculation is used to control the impact of intervening opportunity and effectively calibrate the model for the type of interaction being studied. If the exponent is small, then interaction with more distant destinations increases at the expense of nearer destinations; while increasing the exponent increases interactions with nearby destinations at the expense of more distant destinations. The interaction model permits interactions to be calculated as production-constrained (total number of tourists available at supply nodes determines total number of visits that can be made), supply-constrained (predicted number of trips to a destination equal the attraction of the destination), or doubly constrained interactions, where both production and attraction values are consistently balanced.

Modelling Visitor Impact
We focused on several types of natural attraction from the 17 iconic sites identified from the West Coast survey to develop models to describe the relationships between visitor numbers and impacts from these visits. The aim was, for each type of asset, to identify a key indicator of environmental change/impact and relate the observed level of impact at the site to the number of visitors.

The visitor impact relationships take the form of mathematical curves (Fig. 3). For each asset type a key indicator was identified (Table 1), and experts from the Department of Conservation, tourist operators, and environmental experts were approached to determine probable relationships between visitor numbers and impact. In each case we assumed that zero visitors equates to zero impact. We asked the experts to estimate the maximum number of visitors that could be sustainably accommodated at that site under two scenarios: a) the existing management practice, and b) the best management practice they could conceive of for that asset type. On a scale of 0 to 1 for impact **under best management practice**, we arbitrarily assigned the maximum sustainable impact under current management to 0.6, and that under best management to 1. This simplified impact model makes the assumption that impact is greater under the best practice management than under present management. This is not true, since the maximum level of impact is independent of the management regime. However, the level of impact for a given visitation rate is a function of management, and would presumably lower as management improved. Our simplified impact model treats impacts under two (or more) different management regimes as one continuous curve, assuming that as visitation rates approach or exceed the sustainable level for existing management, improved management will be implemented so that visitation rates can rise eventually to their maximum under optimal management. If impact exceeds the maximum level we assume that the tourist activity would be unsustainable and the asset would be seriously degraded. We also asked the experts to rate the level of impact at the current visitation rate and management regime, if it differed from the above information (i.e., the asset was currently operating at below maximum sustainable level for existing management). The experts' "data" points for each asset type were averaged and plotted graphically and a curve fitted through them. The mathematical equation for that curve was used as our preliminary model relating tourist numbers to impact.
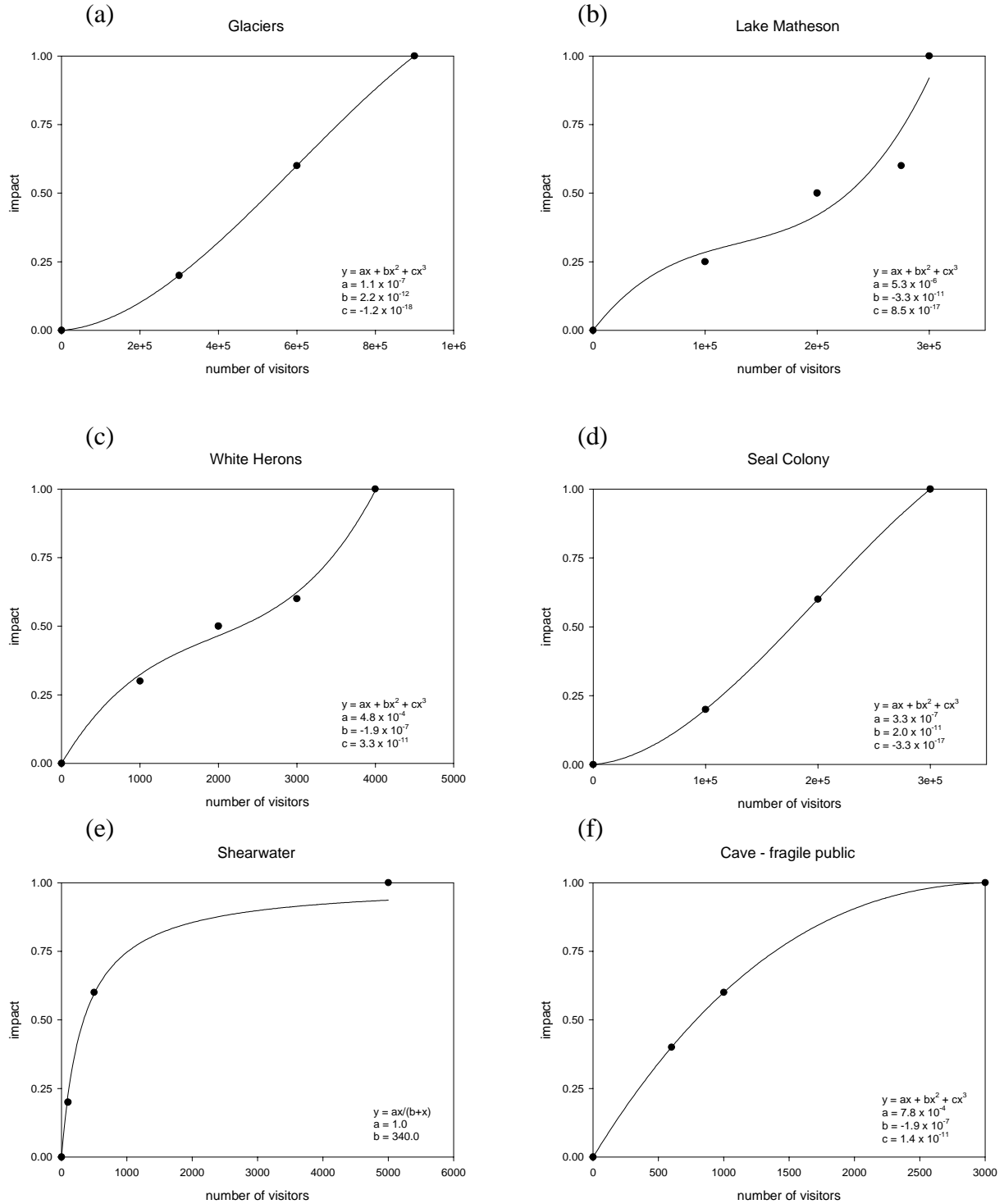
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Figure 3: Visitor impact curves for: (a) Fox and Franz Josef glaciers; (b) Lake Matheson; (c) Okarito white heron colony; (d) Cape Foulwind seal colony; (e) sooty shearwater colony; and (f) fragile public access caves.

Table 1: Asset types and key indicators of environmental impact.

Asset	Indicator
Fox/Franz Josef glaciers	Pollution of water bodies/streams
Lake Matheson	Water quality (turbidity) of lake
White heron colony	Disturbance/bird numbers
Seal colonies	Disturbance/numbers/change of behaviour
Penguin colonies	Disturbance/occupied nesting sites
Welcome Flat hot pools	Erosion of edges of hot pools
Giant matai tree	Damage to tree roots/track erosion
Punakaiki/Pancake rocks	Off-track damage (photo points)
Caves (all types)	Speleothem breakages

Developing an Environmental Effects and Tourism Flows Data Management System
The transport network, visitor behaviour data, and visitor impact modelling were combined to produce the environmental effects and tourism flows DMS for the West Coast. This GIS application was developed as an Arc macro language (AML)-based Menu system within Arc/Info 8.2.   It uses a menu-based user-interface for the DMS that enables the user to assess tourist flows and impacts under existing or different (user-specified) scenarios of tourist activity regimes. The DMS then assesses the number of visitors to each asset under the selected scenario using the GIS-based interaction model, and displays a map of the iconic sites. When one of the sites is selected, a graphic is generated that shows the visitor impact curve along with the calculated impact under the given visitation scenario. The scenarios are generated using a series of "sliders" that allow the user to vary the total number of tourists and/or to vary the ratio of tourist numbers according to nationality.

RESULTS

Modelling Tourist Flow
The interaction model was optimised by varying the distance-decay exponent to achieve the best possible fit between predicted tourist activity and tourist activity calculated from scaled-up estimates of the West Coast survey data. The ARC/INFO interaction model provides a sum-of-errors statistic to describe "goodness of fit" relative to the attractiveness of the site. For calibration runs it is useful to look at predicted visitor numbers against the scaled-up recorded visitor numbers from the West Coast survey with the model using the production-constrained option (i.e., total visits equals the "production" of trips from accommodation centres).

For our network of tourist assets we found that the "goodness of fit" statistic was generally negative, implying an overall underestimate of tourist numbers. Values for this statistic range from –220 to –170. If the distance-decay value is set to a higher value (e.g., 2.0) the very attractive sites tend to be overestimated and the smaller nearby sites underestimated (e.g., tourists tend to bypass minor attractions in favour of travelling greater distances to major attractions). By comparison, if the distance-decay value is set to a low or even negative value, the tendency is for the many smaller attractions to gain visitors at the expense of the few larger attractions (e.g., tourists are more strongly discouraged by distance to travel to attractions). There are a small number of outliers in these results (i.e., sites with very large overestimates or underestimates for visitor numbers) that appear to cause the overall negative fits. Some of these outliers appear unable to attract any visitors past intervening stops, despite being attractive sites (i.e., high recorded visitor numbers).

Modelling Visitor Impact

Although identifying a key indicator of environmental change/impact and relating the observed level of impact at the site to the number of visitors is conceptually a simple approach, it has proved difficult to implement. There are few good quality data on visitor numbers available, and even fewer describing visitor impacts. Impacts are almost always complex interactions of multiple effects over time. Not all impacts are equal; the environment may be more sensitive at different times of the year (e.g., breeding periods), and management practices can have a large influence on the relationship between visitors and impacts. Some impacts may be cumulative, while others are discrete events in time. Given the short time frame of this project relative to the period over which impacts occur, it was not possible to collect data for a longitudinal study for a given asset at different visitation rates. Data from similar assets but with different levels of use/impact could be used to derive a visitation-response for a given asset type. However, such an approach must take into account the degree of dissimilarity between the sites. We have identified the collection of tourist impact data as an area in urgent need of further research (in fact our current FRST-funded programme focuses on this).

The shapes of the experts' visitor impact curves (Fig. 3) suggest that impacts for the majority of asset types will follow a cubic polynomial function, which typically anticipates higher impacts per visit at low visitor numbers, relatively little additional impact for moderate visitor levels, but as numbers increase to very high levels the per visit impact again becomes high This seems counter-intuitive, since at the highest visitation levels we are using the best-practice management system, so per visitor impacts should be lower. However, the shape of the curve appears to be a result of reducing the complex interaction between visitors, impact, and management to a single curve. In some cases, such as the Fox and Franz Josef glaciers, the degree of biophysical impact per visitor on the asset is not considered to be high because the asset is not very sensitive to tourist activity. In fact, we anticipate that at such sites, off-site factors (e.g., waste disposal at accommodation centres) or on-site social factors (e.g., perception of overcrowding) may limit the utilisation of these assets long before any on-site biophysical effect becomes significant. At other more sensitive sites (e.g., the white heron colony and fragile cave sites) the carrying capacity of the asset is much lower and

on-site biophysical impacts would rapidly limit sustainable use. Many of these assets are already nearing their biophysical capacity (e.g., the white heron colony), although it is interesting to note that in at least one case (the Westland black petrel colony south of Punakaiki) the manager of the site records a positive impact of tourism on bird numbers. Because the operation has been carefully managed and financial resources have been used to improve the bird-nesting habitat, there are now more petrels in the colony than when tourists first began to visit the site. However, at highly sensitive bird colonies such as the sooty shearwater colony at Mt Oneone, even low numbers of visitors are likely to cause serious disturbance, so that as few as 500 visitors per year in an unmanaged environment might represent the sustainable limit. The latter case differs from all others in that the visitor impact curve is a hyperbolic function, indicating very high impact per visit from very low numbers of tourists and little ability to manage the site to mitigate these impacts.

DISCUSSION

While the network modelling approach shows some promise, there are some problems that need to be solved. Although the interaction model appears to work tolerably well, we did not find the statistic available to be particularly sensitive to error in the model for the range of results we achieved. This may in part be due to the persistent outliers that did not respond to the optimisation procedure. An alternative explanation may lie in determining the most appropriate level at which to generalise tourist behaviour, and hence the complexity of the transport networks. On a continuum of network complexity, should we use the iconic sites only as attractions and leave all others out of consideration, or should we (as we did in this study) include all sites that may be visited so that the "virtual tourists" have a more realistic set of choices (e.g., Shanty Town vs Franz Josef Glacier)? More critical may be the fact that the basis of traditional interaction models is a linear treatment of decay due to travel time, based on a 'return-to-base' scenario of individual movements. As alluded to, the situation of most visits is that they occur as collateral activities associated with a transfer to a new base each night, and in many non-iconic cases the likelihood of visitation is not a linear decay but reflects cyclic regularities in stopping behaviour (e.g., lunch breaks). Means of modelling this are under investigation (Forer, Simmons and Chen 2002).

The flow data used in this prototype can also be substantially enhanced. The network analysis currently uses crudely weighted projections from the West Coast flow data, but in the next version will use estimates of movement and flows that integrate the West Coast survey with portal-weighted flows derived from the IVS and DTS, and also cross-validate with the Accommodation Survey (Forer 2002). The West Coast Survey data were collected to derive an understanding of detailed tourist movements on a short time scale and with high spatial resolution and to inform us on visitor stopping patterns. This can in future be enhanced through further cross-referencing to existing national sources to give better-aggregated monthly or seasonal data. It could be further augmented by referencing across to detailed site estimates for visits to Department of Conservation sites on its VAMs database (Forer and Simmons 2002).

We have also identified difficulties in modelling impacts that need to be addressed. What does sustainable use imply in the context of a natural asset being impacted by tourists? How do we encapsulate the complexity of specific on-site impacts into a modelling structure that can give useful answers to questions of carry capacity and thresholds of acceptable change for selected natural assets? Our current models are simplistic and rely upon expert, though subjective, knowledge. While experts are often able to provide a useful indication of the real situation, their impressions are often open to debate and may not be supported by any hard scientific evidence. If models such as the ones presented in this paper are to be used to support policymaking and management of tourism, we should be able to back up expert opinion with more rigorous and defensible biophysical research and analysis. At present our visitor impact curves offer a useful means for conceptualising the relationship between visitors and impacts, but they should be based on rigorous and defensible (i.e., testable) relationships. The modelling structure we have developed can easily accommodate improved impact analyses; the challenge then is to design and carry out suitable impact assessment methodologies that will yield the necessary results. This is already the subject of the next phase of our research programme.

IMPLICATIONS/APPLICATION

The DMS presented here represents a prototype environment that enables us to determine environmental impacts of tourism on a range of iconic natural attractions, and to explore the implications of increasing tourist numbers and changes in the composition of tourist flows on such impacts. The DMS is designed so it can easily incorporate refinements to both tourist flow and environmental impact modelling. As more targeted data on tourist behaviour and improved data and models for estimating environmental impact on natural assets become available, the predictions of the DMS will become increasingly more accurate.

The DMS should be important to tourism and other planners where there are limits on the supply side of asset availability. Where this is the case, for example there is only one white heron colony that can be visited and it is nearing visitation capacity, then planners will need to think about how to manage and/or accommodate increasing numbers of tourists who may want, but cannot gain access to, this sort of experience.

CONCLUSION

The prototype DMS we have developed linking other lines of research shows potential as a management tool for understanding the likely impacts of tourism on natural assets. However, considerably more work is required before such a system could be implemented in an operational setting.

This calibrated model can be used as a tool in resource planning since it allows us to use existing demand within the network to forecast the flow of tourist activity under increased tourism scenarios.

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