Monitoring visitor numbers in New Zealand national parks and protected areas

A literature review and development summary

Gordon Cessford and Rob Burns

DOC RESEARCH & DEVELOPMENT SERIES 293

Published by
Science & Technical Publishing
Department of Conservation
PO Box 10420, The Terrace
Wellington 6143, New Zealand

DOC Research & Development Series is a published record of scientific research carried out, or advice given, by Department of Conservation staff or external contractors funded by DOC. It comprises reports and short communications that are peer-reviewed.
Individual contributions to the series are first released on the departmental website in pdf form. Hardcopy is printed, bound, and distributed at regular intervals. Titles are also listed in our catalogue on the website, refer www.doc.govt.nz under *Publications*, then *Science & technical*.

ISSN 1176-8886 (hardcopy)
ISSN 1177-9306 (web PDF)
ISBN 978-0-478-14414-7 (hardcopy)
ISBN 978-0-478-14415-4 (web PDF)

This report was prepared for publication by Science & Technical Publishing; editing and layout by Amanda Todd. Publication was approved by the Chief Scientist (Research, Development & Improvement Division), Department of Conservation, Wellington, New Zealand.

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ABSTRACT

This report outlines the main difficulties encountered when monitoring visitors, the range of visitor monitoring options available to park managers, and the features that park managers would like in their visitor counting tools. Following this is an outline of progress in the development of visitor counting tools and systems by the New Zealand Department of Conservation up to 2008, which includes an outline of the key lessons learned from this research. The identification of visitor behaviours is an essential component of visitor management in protected areas. The fundamental baseline information required in any visitor monitoring programme is the number of visitors, and how these are distributed in time and space. However, in the past, obtaining visitor counts in a reliable and cost-effective manner has proven to be more difficult than expected. This report does not contain any technical specifications for the counters developed, but provides a key reference resource for anyone involved in the general development and use of visitor counting systems.

Keywords: visitors, monitoring, national parks, counters, recreation, tourism

Cessford, G.; Burns, R. 2008: Monitoring visitor numbers in New Zealand national parks and protected areas: a literature review and development summary. *DOC Research & Development Series 293*. Department of Conservation, Wellington. 46 p.

1. Introduction

Worldwide, most conservation management agencies for protected natural areas (e.g. national parks) have a common responsibility for the protection of natural, historic and cultural heritage values, while simultaneously allowing the use of these areas for recreation and tourism (Cessford & Thompson 2002). Monitoring is an essential management tool for addressing these responsibilities, and is carried out to fulfil three main purposes (Legg & Nagy 2006):

- To inform the manager when the system is departing from the desired state
- To measure the success of management actions
- To detect the effects of disturbances or trends

For visitor management purposes, the types of monitoring generally required include monitoring of:

- Performance measures and budgets for operational auditing
- The condition of specific natural, historic and cultural heritage assets of conservation priority, and the changes in their related sustainability indicators
- Visitor numbers and their patterns and characteristics of use
- Physical impacts—visitor effects on specific natural, historic and cultural heritage assets and processes
- Social impacts—visitor conflicts and satisfaction with the quality of recreation experiences

Monitoring for operational auditing is normal business management practice, for which numerous methodologies have been developed. Similarly, monitoring for natural, historic and cultural heritage values in parks has a long tradition, and is well supported by specialist methodologies. For example, in national parks, the scientific interest in creating inventories and in observing the development of species and ecosystems has often been a driving force for the establishment of monitoring schemes, so that in many countries, systematic long-term ecological monitoring programmes are seen as a fundamental duty of a national park service. This interest has increased rapidly in recent years, with one study referring to a recent bibliography on vegetation monitoring alone that cited 1406 references (Legg & Nagy 2006).

In contrast, visitor monitoring is not a well-established research tradition and has often been relatively neglected compared with biophysical management needs (AALC 1994; Cope et al. 2000; Loomis 2000), even though knowledge about visitor numbers is a basic requirement for the management of visitor services, experiences and impacts[1].

The most fundamental visitor information that is required by park management agencies is the number of visitors to the area. Without good visitor use data, the consideration of any more complex visitor impact and management issues

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[1] Essentially the 'Type 1: Visitor Numbers' data referred to by Booth (1988).

is highly constrained. Accurate and reliable information about visitor numbers is essential for a variety of strategic and operational planning tasks in park management, and it can support many management outcomes (DOC 1992; AALC 1994, 2000; Hornback & Eagles 1998; Watson et al. 2000), including:

- Defining design standards for some visitor facilities and services
- Performance reporting on visitor service provision
- Relating use-levels to social and physical impacts
- Minimising conflicts between visitor groups
- Identifying potential problem ‘hotspots’ within parks
- Identifying demand trends and generating forecasts
- Strategic provisioning of visitor facilities, services and staff
- Scheduling maintenance tasks, staff allocations and resource provision
- Allocating infrastructure and services within a park
- Monitoring visitor compliance with some use regulations
- Identifying key sites as indicators of wider visitor flow and impact patterns
- Identifying the social, economic and political significance of recreational use of natural areas

It is important not to underestimate the value of monitoring visitor numbers. The development of visitor monitoring techniques is concerned with more than just exploring the technology of visitor counting methods—it is about providing fundamental baseline and strategic data for visitor and conservation management. The more reliable the data, the better the outcomes when applied to processes such as visitor flow modelling, visitor impact assessment, and the wider scale development of natural resource and tourism management policies. No matter how good the management application or model being developed, if the data are not reliable the old saying always applies: ‘garbage in, garbage out’. Therefore, it is very important that high standards are applied to the collection, processing and storage of visitor count data, and that a consistent effort is sustained over time. However, despite the clear need for such quality baseline data, monitoring of visitor numbers has rarely been carried out with rigour.

To address this need, an innovation programme was established to improve the application of visitor monitoring in the Department of Conservation (DOC). This report summarises the programme’s findings and progress up to 2008, when the focus shifted from research and development of new visitor monitoring tools and systems, to a focus on their consolidation, distribution and application. The development of specific visitor monitoring tools by DOC was influenced by the range of methods available and their respective advantages and disadvantages. Therefore, this report begins with a literature review that outlines the different methods for obtaining visitor count data and factors that should be considered when choosing counter options.

2. Methods for obtaining visitor count data

The collection of visitor count data is not an easy task in parks, which often include sites that are remote; may have few nearby roads, towns or entry and exit points; may lack an electricity supply; and may have few staff present on-site. Furthermore, visitor counting practices across park management agencies have generally been accompanied by uncertain specification of monitoring objectives, a wide variety of counting and sampling methodologies, and few examples of structured visitor monitoring frameworks to integrate count data and apply the information to management. In this context, visitor monitoring can often be characterised as an opportunistic exercise that involves a mix of different counting methods and techniques, which are based on a strategic sampling of visitor sites that optimises data needs and site conditions with resourcing capacities.

Cope & Hill (1997) and Cope et al. (2000) summarised the wide variety of monitoring approaches taken by land management agencies in the UK countryside. Although they found that a high proportion of managers were undertaking some sort of visitor monitoring, they noted that the methods used were widely varied between areas. The approaches used were not coordinated or systematic, and many relied on on-site questionnaire surveys or car counts. With reference to more remote settings, a survey of over 400 US wilderness managers from multiple agencies showed that 63% relied on ‘best guess’ estimates of visitor use and 21% used ‘frequent field observation’ (McClaran & Cole 1993). Only 16% had any systematic procedure for deriving their use-level estimates (e.g. from permits). In a survey of 308 managers from across the four main park management agencies in the USA, Washburne (1981) found that the techniques for measuring use-levels fell into four classes: ‘best guesses’ based on informal observations, trail registers, trail registers calibrated by visitor counters, and agency-administered permits. Across all agencies, almost 40% of managers were using the ‘best guess’ informal observations; this approached 80% for the US Fish and Wildlife Service, reflecting their more highly dispersed sites and low visitor-use profile. Permits were used by about 40% of managers overall; this approached 70% in the National Park Service, reflecting their more defined visitor sites and extensive use of permit systems.

In more recent times, technological developments have provided a wider range of monitoring options. For example, the US National Parks Service now uses vehicle counters located on key access roads to obtain the majority of their use estimates (B. Street, Manager, Visitor Counting, US National Park Service, pers. comm. 2000). In the UK, the higher population levels present in and around natural areas have allowed greater use of manual counting and visitor survey techniques (Cope & Hill 1997; Cope et al. 2000). In Australia, many different counting techniques are used across different park systems (AALC 1994), with the most common being car counts, automatic counters, ranger observation and fee collection (McIntyre 1999). Most Australian agencies have developed their own blend of these different techniques, which can result in some interesting new possibilities. For example, while vehicle counts are the most common technique used across the State Parks of Victoria, in some places it was found that the estimates obtained were highly related to particular weather conditions; therefore, an inferential weather-based model and associated use-estimation formulae were applied, making the expensive car counters available for use elsewhere (D. Zanon, Visitor Research Leader, Parks Victoria, Australia, pers. comm. 2001).

It is clear that while visitor count monitoring is widespread and diverse, its application is characterised by its inconsistency. The Australian experience possibly sums up this situation best: when reviewing the status of visitor monitoring in the several parks comprising the Australian Alps National Parks, the Australian Alps Liaison Committee stated that 'with the exception of Namadgi National Park, existing visitor monitoring systems are more "opportunistic" than "systematic"' (AALC 1994). This is also the case in most European countries, where visitor monitoring, if carried out at all, is usually organised on an ad hoc basis without systematic planning. In many cases, results from improvised 1-day counts that have been conducted outside any systematic sampling strategies have been extrapolated and used for management decisions, without appropriate calibration or consideration of the limitations of the results. As noted by Legg & Nagy (2006), the results of inadequate monitoring for ecological purposes can be both misleading and dangerous, not only because of the inability to detect significant changes, but also because it creates the illusion that something useful has been done. Such work may need to be repeated later to a higher standard and with added costs.

It is clear that any development of visitor counting systems must be seen as part of a wider strategic information need, and be supported by a wider information management system. Before this can be done, it is important to recognise the methods by which visitor count data can be obtained accurately and consistently.

Management agencies have a wide variety of counting techniques available to them, which generally fall within four broad categories:

- Direct observation—using staff observers or camera recordings at sites
- On-site counters—recording and storing visitor counts at sites
- Visit registrations—counting permits issued or records in registers
- Inferred counts—other data counts used to provide on-site estimates

The following sections provide basic descriptions of these counting techniques, and summarise their respective advantages and disadvantages with reference to criteria that include precision, accuracy, cost, error potential, coverage, data handling, maintenance requirements, detectability and practicality. The information has been obtained from several key references: Raine & Maxey (1996); Hornback & Eagles (1998); Cope et al. (2000); Watson et al. (2000); Arnberger et al. (2002b); Cessford et al. (2002); Muhar et al. (2002); and Cessford & Muhar (2003).

2.1 DIRECT OBSERVATION

Direct observation involves the use of staff observers to directly record what they see either while they are on-site or in recordings from on-site cameras.

2.1.1 Field observers

Field observers are on-site and manually record visitor data on recording forms or with hand-held counting tools. They are usually based at some fixed observation location, although on occasion observers roam the observation area.

Advantages

- Accurate, flexible and mobile
- Can include descriptive data (e.g. visitor characteristics, behaviour and equipment)
- Can be permanent in some staffed sites
- Is a preferred method for calibrating other counts

Disadvantages

- Costly in staff time, and competes with other staff tasks and priorities
- Often used in unsystematic and opportunistic ways
- Subjective unless highly structured
- Less feasible away from permanent sites or key access points and routes

2.1.2 Camera recordings

Video or photographic recordings of visitors on-site can be manually viewed later at base to collect required visitor data. Recordings are usually manually collected from the field, although some transmitted images may be recorded at base. Most recordings would be continuous video, possibly with reduced frame speeds to save space on tapes. On some occasions, time-lapse photography or remote sensing techniques may be used.

Advantages

- Accurate, flexible and mobile
- Can allow visual interpretation of visitor characteristics
- Commercial units are available from security/surveillance market
- Motion-triggered recording or time-lapse video with adjustable recording intervals allow for longer observation periods without tape change
- Is the main alternative to direct observations for calibration of other counts
- In the future, use of digital cameras with image transmission via high-speed mobile phones will allow real-time monitoring

Disadvantages

- Equipment is costly to use and maintain and is vulnerable to damage
- Staff time is needed to interpret films
- Needs a long calibration phase

- Difficult to distinguish passenger numbers when using vehicle counts
- Power requirements mean it is not a long-term option at unattended sites
- Less feasible away from permanent sites or key access ways
- Can raise ethical privacy issues

2.1.3 Remote sensing

Aerial photography or other imagery from plane or satellite can show visitor presence and distribution at specific times.

Advantages

- Can cover large areas and be repeated regularly
- Offers additional spatial perspective, giving numbers and distribution
- Can be used simultaneously for other types of conservation monitoring

Disadvantages

- Only useful in open spaces
- Subject to weather conditions
- Only offers a snapshot in time
- Very costly to improve on the limited scale precision
- Very expensive for long-term use

2.1.4 Applications for direct observation

Table 1 summarises the types of information applications for which these direct observation methods can best be used. These applications relate to the basic data that are collected by the respective methods. Of these methods, fixed observers and video recordings provide the most useful information, as they allow collection of visitor count data, are time-referenced, and provide useful additional data on group and visitor type, and visitor activities and behaviours. However, both can be demanding on staff time and they can rarely be employed for extended continuous periods in the field. The limitations of the other observation-based methods can be compensated for by undertaking extensive data calibrations as required; however, this is also very demanding on resources. All of these methods can only be applied to a limited number of sites at any one time, and none would generally be suitable for long-term continuous monitoring, especially when a large number of sites need attention.

TABLE 1. APPLICATIONS FOR DIRECT OBSERVATION.

A tick '✓' means '*Yes, directly*'; a question mark '?' means '*Maybe indirectly, if data collection is calibrated or structured more specifically to do so*'; and a cross '×' means '*No*'.

COUNT METHOD	VISITOR NUMBERS	DATE & TIME	TRAVEL DIRECTION	ROUTE TAKEN	SPATIAL DISTRIBUTION	GROUP SIZE	VISITOR FEATURES	VISITOR BEHAVIOUR
Fixed field observers	✓	✓	✓	?	?	✓	✓	✓
Roaming field observers	?	✓	✓	?	?	✓	✓	✓
Video recordings	✓	✓	✓	?	?	✓	✓	✓
Time-lapse photo/video	✓	?	?	×	×	?	?	?
Aerial/satellite imagery	?	✓	×	×	?	?	×	×

2.2 ON-SITE COUNTERS

On-site counters are devices that are placed on-site to record the passage of visitors. They have a trigger that is activated by a visitor passing over it, which results in a count being recorded. If the trigger is simply mechanical, only limited information can be obtained. If the trigger generates some electronic signal, however, more extensive information options are possible.

2.2.1 Mechanical counters

Mechanical counters rely on physical displacement and movement of structures as a result of visitor weight or action (e.g. hinged boardwalks, turnstiles, gates, doors or stiles). This movement can trigger a mechanical count device attached to the structure, typically by pushing on its count button (e.g. a manual tally counter). In some cases, the mechanical displacement process can involve the separating of paired magnets, which can be used to generate a count signal.

Advantages

- Simple and cheap to build
- Can be built into existing structures
- Have a long history of staff use and experience
- Can be linked to electronic loggers

Disadvantages

- Moving parts are susceptible to damage from wear, water, heat/cold deformation and blockage by soil and plant matter, resulting in high maintenance
- No date/time references
- Specific on-site structures required
- Often detectable by visitors, making them subject to vandalism or generation of excessive counts
- Wildlife may trigger counts

2.2.2 Pressure counters

Pressure counters rely on visitors stepping on them; the resulting deformation pressure then triggers a sensor (e.g. pneumatic tubes, sensor cables, pressure pads or strain gauges). A count signal is transmitted from the sensor to a data recording device where the count can be logged. In some cases, only the gross count is recorded; however, in recent years it has become more common for time and date information to be attached to each count record. This information is usually downloaded in the field and then uploaded later in the office to main information databases, although recently it has become more common for counts to be remotely transmitted directly to the main database.

Advantages

- Provides a wide variety of technological methods for counting people and vehicles
- Can be connected to a variety of devices (electronic loggers, camera or video)

- Small size and weight, making them easy to conceal and easier to protect from weathering damage
- Low power use
- Sensitivity and interval can be adjusted to exclude some false counts
- Can also obtain time and date information

Disadvantages

- Need careful sensitivity calibration when constructed
- May be sensitive to temperature
- Limited battery life
- Subject to the quality of electronics and programming
- Usually need to be built into a structure
- Accuracy depends on correct installation, operation and maintenance
- Require ongoing calibration
- Wildlife may trigger counts

2.2.3 Active optical counters

Active optical counters utilise light beams that are interrupted by a visitor passing (e.g. active infra-red or visible light beam). This interruption triggers the transmission of a count to a data recording device. This information is usually downloaded in the field and then uploaded later in the office to main information databases, although in some cases the count can be remotely transmitted directly to the main database.

Advantages

- Small size and weight
- Inexpensive
- Accurate if used appropriately
- Not sensitive to temperature
- Long range across wider tracks
- Sensitivity, interval and placement can be adjusted to exclude some false counts
- Can be used to obtain time and date information

Disadvantages

- Need careful alignment of transmitter and receiver (or reflector if not a through-beam system)
- Alignment is highly sensitive to disturbance
- Hard to conceal (particularly light-beam counters), making them susceptible to vandalism
- Lenses/reflectors may be obscured or soiled
- Higher power consumption than passive sensors
- Wildlife or swaying branches may trigger counts

2.2.4 Passive optical counters

Passive optical counters rely on change in a background infra-red signature (e.g. passive infra-red) to trigger a count. These are sometimes referred to as heat sensors, although it is the change in infra-red signature rather than temperature that is the trigger.

Advantages

- Small size and weight
- Inexpensive
- Accurate
- Sensitivity and interval can be adjusted to exclude some false counts
- Can obtain time and date information
- Low power consumption

Disadvantages

- Variable detection range depending on an object's infra-red characteristics relative to the background
- May undercount groups if distance between sensor and groups are large
- Sudden lighting changes may trigger false counts
- Lenses may be obscured or soiled
- Wet jackets can mask a visitor's infra-red signature
- Limited number of appropriate sites
- Require careful placement to minimise environmental variations

2.2.5 Magnetic sensing counters

Counters that use magnetic sensors rely on changes in magnetic fields caused by passing metallic objects (vehicles, sports and camping gear, etc.) to trigger counting devices (e.g. induction loops, magnetic pads or countcards). Counts are then transmitted to a data recording device.

Advantages

- Small size and weight
- Inexpensive
- Loop/pad sensors are buried, so not easily detected by visitors, and other sensor (e.g. boxes/cards) can sometimes be buried
- Can obtain time and date information
- Can distinguish between vehicles and bikes, and can be configured to indicate vehicle type
- Sensitivity and interval can be adjusted to exclude some false counts

Disadvantages

- Primarily only used for vehicle detection (including bicycles)
- Require sensitivity adjustment and calibration for different vehicle types and loadings

- Possibly require specialised interpretative software
- Relatively expensive for sensor and download interface units
- Not widely used resulting in limited pool of expertise

2.2.6 Microwave sensing counters

Microwave counters detect changes in reflected radio waves from moving objects. These changes trigger a count, which is then transmitted to a data recording device.

Advantages

- Small
- Can be set to detect vehicles or people
- Can be set to detect direction
- Can obtain time and date information
- Sensitivity and interval can be adjusted to exclude some false counts

Disadvantages

- Primarily only used for vehicles
- Require a clear line of sight
- Need to be set high, making them hard to conceal
- Tend to undercount groups
- Cannot distinguish between types of vehicles
- High power consumption
- Relatively expensive

2.2.7 Applications for on-site counters

Table 2 summarises the types of information applications for which these on-site sensor methods can best be used. All of these methods operate on the same principle, simply using different sensors to generate a signal when a visitor passes. This signal is sent to a data logger, where additional time and date information can be added. Although these counters can only be used to record visitor numbers, time and date, they can function well in remote areas for extended continuous periods. Thus, they serve as valuable baseline counters for widespread counting needs.

TABLE 2. APPLICATIONS FOR ON-SITE COUNTERS.

A tick '✓' means '*Yes, directly*'; a question mark '?' means '*Maybe indirectly, if data collection is calibrated or structured more specifically to do so*'; and a cross '×' means '*No*'.

COUNT METHOD	VISITOR NUMBERS	DATE & TIME	TRAVEL DIRECTION	ROUTE TAKEN	SPATIAL DISTRIBUTION	GROUP SIZE	VISITOR FEATURES	VISITOR BEHAVIOUR
Mechanical	✓	✓	?	×	?	?	×	×
Pressure/vibration	✓	✓	?	×	?	?	×	×
Active optical beam	✓	✓	?	×	?	?	×	×
Passive infra-red sensor	✓	✓	?	×	?	?	×	×
Magnetic field	✓	✓	?	×	?	?	×	×
Microwave beam	✓	✓	?	×	?	?	×	×

The limitations of each counter depend on its sensory approach and the rigour required in installation and operation to minimise count error. Other indirect limitations will be based on the power, electronic and software components the counters include for downloading, storing and processing the counter data. As well as the sensors themselves, all of these components should be tested together under operational conditions to ensure the complete system functions correctly.

2.3 VISIT REGISTRATION

2.3.1 Visitor registers/hut books

Voluntary or compulsory self-registration of visits can be used to monitor visitor numbers and characteristics (e.g. track registers, hut books, other site visitor books or sign-in/sign-out forms). Where voluntary, the reliability of these methods can be highly variable. Where they are a compulsory requirement for use, they can be very effective; unfortunately, however, this is a rare situation.

Advantages

- Flexible, low cost and simple
- Can gather additional basic data (e.g. visitor profile, trip intentions)
- Can be linked to safety check in/out processes
- Good indicators if well calibrated
- Hut books have a long history in many regions, making them useful for documenting long-term changes

Disadvantages

- Limited if used on a voluntary basis
- Require ongoing calibration
- Some sites may be vulnerable to vandalism
- Response rates may vary with site location, presentation, maintenance, advocacy and cultural tradition of register use
- Regular maintenance and checking is required
- Data must be compiled, interpreted and handled manually

2.3.2 Permit, booking and fee

Official administrative records from site or trip permits, facility or trip bookings, fee payments to the park, and client data from private providers of facilities or trips can be used to monitor visitors to an area. Where such information is already being collected, only a minor change to its management and content may be needed to provide useful information about visitor numbers, visitor characteristics and trip patterns.

Advantages

- Flexible, low cost and simple
- Accurate
- Can gather considerable additional data
- Can be linked to safety management processes
- Can be extrapolated from related enterprises (e.g. cable cars, buses, shops)

Disadvantages

- Can only be used for situations and activities where bookings, permits or fees are required
- Subject to visitor compliance (booking and paying)
- Subject to cooperation of private enterprises

2.3.3 Applications for visit registrations

Table 3 summarises the types of information applications that visit registrations can best be used for. Compulsory registers or permit/booking and fee records that are compulsory for use of a site are the most comprehensive way of obtaining visitor use information. However, in New Zealand there are few situations where such methods can be used as, unlike other countries, there is little regulated access or fee-stations on access roads. Voluntary registers in the form of hut and intention books are common, however, and although there is often inconsistency in their use by visitors, these do provide a valuable resource. Extensive calibration processes and advocacy could facilitate better application of voluntary registers as monitoring tools. In the main, registration methods are only applicable to selected segments of the population of visitors to a site (predominantly those using concessions services, or in specific situations such as the booking systems on the Great Walks). Commercial providers of recreation facilities and services in parks sometimes have impact monitoring provisions included in their operating agreements with park management agencies (Cessford & Thompson 2002). Where beneficial, these could be expanded to address wider visitor monitoring needs, particularly if the licensed operation is long term and has staff in fixed locations.

TABLE 3. APPLICATIONS FOR VISIT REGISTRATIONS.

A tick '✓' means '*Yes, directly*'; a question mark '?' means '*Maybe indirectly, if data collection is calibrated or structured more specifically to do so*'; and a cross '×' means '*No*'.

COUNT METHOD	VISITOR NUMBERS	DATE & TIME	TRAVEL DIRECTION	ROUTE TAKEN	SPATIAL DISTRIBUTION	GROUP SIZE	VISITOR FEATURES	VISITOR BEHAVIOUR
Voluntary registers	?	?	?	?	?	?	?	×
Compulsory registers	✓	✓	✓	✓	✓	✓	✓	×
Permits/bookings/fees	✓	?	?	?	?	?	?	×

2.4 INFERRED COUNTS

2.4.1 Indicator counts

Indicator counts use surrogate indicators that are linked to visitor use (e.g. carpark counts, weather conditions, transport service use, trail deterioration, or amount of damaged vegetation) to infer visitor numbers. These are heavily reliant on extensive calibration exercises, and some are more practicable than others.

Advantages

- Can substitute for more resource-demanding monitoring options
- Can use other existing information
- Can take advantage of more easily accessible measures
- Can offer good local calibration options if reliable indicators are found

Disadvantages

- Often depend on local circumstances and opportunities, making their usefulness highly variable between sites
- Although there are often links between the intensity of recreational use and 'traces' left by visitors, any predictive relationships for use-levels are very difficult to identify
- Precision is low in the absence of extensive calibration efforts

2.4.2 Interview/survey counts

User surveys can derive visitor number estimates by asking specific questions and using representative sampling designs. In addition, they can provide considerable value by enhancing information for count calibration processes.

Advantages

- Can ask any question desired, which can then be linked to other monitoring needs (e.g. visitor profiles, intentions, satisfactions and impacts)
- Especially useful as calibration enhancement tools

Disadvantages

- Like field observations, these are expensive and time-consuming
- Do not make direct counts
- Can only be applied to a limited sample of visitors for a limited time
- Require rigorous sampling and question design

2.4.3 Applications for inferred counts

Table 4 summarises the types of information applications for which inferred counts can be best used. Where good surrogate indicators can be found, these methods have high potential, especially if the indicator also fulfils another complementary monitoring need. Although such cases will be rare, they will be valuable when identified. Survey sampling methods and their additional roles in enhancing the calibration processes for other counters provide the most systematic and important application of inferred methods.

TABLE 4. APPLICATIONS FOR INFERRED COUNTS.

A tick '✓' means '*Yes, directly*'; a question mark '?' means '*Maybe indirectly, if data collection is calibrated or structured more specifically to do so*'; and a cross '×' means '*No*'.

COUNT METHOD	VISITOR NUMBERS	DATE & TIME	TRAVEL DIRECTION	ROUTE TAKEN	SPATIAL DISTRIBUTION	GROUP SIZE	VISITOR FEATURES	VISITOR BEHAVIOUR
Indicator counts	?	?	?	?	?	?	?	?
Interview/survey counts	?	✓	✓	✓	?	✓	✓	✓

3. How to choose a counting method

Each of the methods described in section 2 has its own set of advantages and disadvantages, so that the final selection of a visitor counting approach and technique will always be based on a compromise between the need for accuracy and practicality. To ensure that the best technique is chosen, management objectives for the monitoring should be clearly specified. As mentioned earlier, visitor monitoring can contribute to a wide variety of management goals; therefore, the goal of each monitoring scheme should be clearly defined. In some cases, a goal may require a mixture of monitoring methods, reflecting the different requirements and coverage capacities of the various methods.

Assuming that the management objectives for a visitor monitoring system have been determined, and the advantages and disadvantages of the various techniques have been taken into account, there are four main factors to consider when selecting a technique:

- Visitor use patterns in time and space
- Physical locations and settings of sites
- Calibration requirements
- Availability and organisation of resources

3.1 VISITOR USE PATTERNS

Visitor use patterns vary through time and between sites. Even within specific sites, the temporal and spatial patterns of activity are variable (e.g. time of day, season, entry/exit points and presence of attractions). This commonly includes variation in the number of visitors, the activities they are engaged in, group sizes, and the areas and facilities they use. These variations have different implications for counting strategies, depending on the scale of the monitoring system required. There are many examples of monitoring systems that have been specifically developed for application in individual parks as stand-alone units (e.g. Cope et al. 2000).

The development of a monitoring system may be a relatively simple exercise of identifying strategic points where visitors can be counted, e.g. key access roads, road ends, carparks or gateway trails. Sometimes particular facilities, such as visitor centres or accommodation sites, represent key nodes that can provide strategic counts that are useful indicators of visitor movements over the wider area, especially if linked to external counts of visitor flows. However, once visitors are within the park itself and are entering the more remote locations, their activities tend to be more widespread and diverse, limiting the number of counting options. At this point, periodic observations combined with a series of visitor counter devices become more applicable. Since counter devices cannot generally distinguish between different visitor types and activity groups (e.g. bikers v. walkers), specific observation programmes may be required to complement and calibrate the raw visitor counts.

In many cases, monitoring strategies may be required over large areas within a park, or across a system of linked parks and other protected areas. If there is a requirement for more than simple site-specific counts, strategic bottlenecks or nodes should be identified as key locations for counts that are representative of the whole park system. For the Australian Alps National Parks, Wyld (1995) recommended that a modest number of priority sites should be selected across any park system based on:

- Places of specific management concern
- Places where specific management actions are under consideration
- Places that are considered representative of broader management issues

This suggests that a fixed network of key indicative visitor count sites is required, whilst also allowing some flexibility to undertake other shorter term site-specific and issue-specific counting as required. To maintain the internal integrity of a visitor counting system over time and allow calibration and indexing functions, some count sites should be permanent, some periodically rotated according to identified needs, and others used on a case-by-case basis to meet particular short-term needs. To meet this requirement, a variety of count techniques should be available to managers.

The timing of counting operations is also important. Unless counts are established as a continuous and long-term process at a site, they are best applied in a strategic sampling context, based on the priority questions being asked. In other words, those limited sampling periods when counts take place should be as representative of the full range of relevant site conditions as possible. Depending on the priority questions concerned, this sampling would need to take account of different times of the day, week or year, seasonal variations, weather variation and special-use occasions, such as holidays or other community events. Sampling can be a good option—not every visitor needs to be recorded. For example, a series of time-lapse video-monitoring projects found that in a heavily used recreational area in Austria, a sampling time of 15 minutes per hour was sufficient to gain a representative sample (Brandenburg 2001).

3.2 PHYSICAL SETTINGS

The physical settings of sites used by visitors and their behaviours within them will also affect what counting options are available to managers. Roads and tracks are obvious places for undertaking visitor counts, particularly at key bottlenecks such as park access points. Some counting devices also require locations where visitors are confined to single file. The physical layout of a visitor-use system may need to be modelled to identify where different types of counts can be used, and where key representative nodes or bottlenecks occur.

When counter devices are being used as the preferred counting option, it is also important to consider the climate and physical location. Water penetration has proven to be a particular problem for most kinds of counter devices, corroding metallic components and destroying electronics. If combined with sub-zero temperatures, the freeze-thaw cycles can seriously damage the structural integrity of counters. Low temperatures can also reduce battery life, while high temperatures may cause warping and deformation of the structures holding counters. Sometimes mechanical parts may be jammed through soil or ice intrusion, or count sensitivity may be reduced by snow or dislodged soil cover, resulting in serious under-counting. Where counters cannot easily be concealed, there are often problems with vandalism and tampering. Therefore, in outdoor environments counters need to be water-resistant, discreet, robust and include few if any moving parts.

3.3 CALIBRATION REQUIREMENTS

Calibrating what was recorded by the primary visitor count method with what actually happened is a critical component of any effective visitor monitoring approach. The disadvantages of the various counting methods (summarised in section 2) indicate some of the ways in which false counts may be generated. While direct observations are usually highly reliable and preclude the need for calibrations, they have limited application for long-term continuous counting. In contrast, visitor counting devices have been used extensively, but bring with them a range of potential miscounting issues. For example, miscounts from a beam counter can be triggered not only by visitors, but also by wildlife or waving plant foliage on windy days; miscounts from a passive infra-red counter can be triggered by visitors walking past in tight groups, or even by visitors with very dark or light clothing relative to their background (Gasvoda 1999); pressure counters may be buried too deeply to count all visitors crossing them, or not deeply enough, sensing the passing of small animals; people may interfere with any counters they notice, sometimes taking much entertainment from making repeated passes; and in some instances not all people passing a counter are specific site visitors, e.g. some may be park employees or local residents simply passing by.

Where there is the potential for false counts or counts are not representative enough to fulfil the management need, correction factors may need to be applied to calibrate the basic visitor counts. Even with correct methodological application, some error in counts is inevitable. These errors are acceptable as long as they are checked using field calibrations of observed and logged counts, the error levels are relatively constant, and the appropriate corrections are applied to the counts. In a calibration exercise undertaken for this study, video and visual observations of a counter located in a wooden staircase on a New Zealand forest trail established that it was stepped on by 80% of visitors walking uphill and 95% of those walking downhill (see section 4.2.1). In this case, the overall visitor 'hit-rate' of around 90% of people stepping on the counter was acceptable because it was consistent and allowed managers to apply a 10% correction when required. Similarly, even a count method as variable as recording from trail registers can provide an accurate guide to use-levels, provided that there is a consistent ratio between the total number of visitors and the number of persons actually registering (Leatherberry & Lime 1981).

Such calibration exercises require the application of secondary monitoring methods (or reference to complementary survey monitoring methods), highlighting the need for incorporating such methods into the overall monitoring strategy. The visitor monitoring interview is a particularly useful complementary method, which, although not primarily directed at visitor counts, usually involves approaching a sample of visitors to directly query their profile characteristics, activities, routes and visit behaviours, both past and intended. The extrapolation of additional data collected from visit registers can also be a useful complementary method, particularly where such registration is compulsory or well calibrated with observed visit patterns (Muhar 2001). This information allows managers to add value to visitor count data, enabling the extrapolation of additional information to the whole of the count dataset, and the overall use-levels these data represent. In some intensively managed settings, stratified count-period sampling using direct observational surveys combined with probability calculations and associated extrapolations may even substitute for monitoring by on-site counting devices (e.g. Gregorie & Buyhoff 1999; English et al. 2001).

Cross-checking calibration by secondary methods can also help to determine the accuracy of different counting approaches. For example, a mixture of complementary methods was used in the Danube Floodplains National Park to monitor dog walkers and their compliance with a leash regulation (Brandenburg 2001). In this park, it is compulsory to keep dogs on a leash. People were interviewed at an information booth about their willingness to accept this rule (52%); at the same time, the actual number of respondents with dogs on a leash was noted by the interviewer (53%). However, data from a hidden video camera a short distance up the track showed a much lower compliance on survey days (32%), suggesting that many owners let their dogs loose once away from known observation. The overall annual compliance was even lower (25%), indicating that compliance decreased further when the information booth was not staffed.

Clearly, secondary and complementary monitoring methods offer much potential for adding value to basic visitor count data, not only providing an essential calibration step, but also allowing the extrapolation of useful secondary information as required (e.g. visitor profiles from surveys). Simple observation methods may be misleading in some cases, especially when some contentious behaviour may be at issue. Therefore, it is important to recognise that basic counts should not be taken at face value. For further discussion of such complementary methods, refer to Ross (2005).

3.4 AVAILABILITY AND ORGANISATION OF RESOURCES

The main limitation to developing a visitor counting system (or any other type of monitoring approach) will be the availability of staff and funding resources to operate and support the system. In the past, many agencies have not identified the systematic collection of visitor data as being as high a priority as the collection of other biophysical data (AALC 1994; Cope et al. 2000; Loomis 2000). This situation is now changing as the importance of visitor data is becoming more widely recognised, so that its collection is more often systematically planned. For example, a very specific implementation programme has been developed and applied incrementally in the Australian Alps National Parks over the last 10–15 years (AALC 1994; Wyld 1995).

Whatever the funding levels available, the high number and diversity of places used by visitors across park management systems means that some compromise, in the form of a sampling solution, will almost always be required in the implementation of visitor monitoring systems. Improved efficiency with respect to counting accuracy, operational costs, strategic sampling strategies and data management processes will maximise the utility of a visitor monitoring system. It is important that the visitor counting task is seen as only one component of a complete visitor data management system driven by a series of specific management objectives (AALC 1994; Wyld 1995; Hornback & Eagles 1998; McIntyre 1999; Watson et al. 2000). Such a system has been established over the last decade in South Australian parks based on vehicle counts. This system features a central reporting system, a standardised set of vehicle counters, customised software interfaces, staff training procedures, and the capacity to integrate data from other monitoring modules once these are developed (NPW 1999). In New Zealand, DOC combined new counter designs with specific data management software linked to its Visitor Asset Management System (VAMS) database, to provide the template for a nationally integrated visitor counting and reporting information system[2].

It is important to emphasise that integrating counter systems with database and management frameworks is not a simple, routine task. It will only be successful when there are high levels of commitment and coordination between the different management and technical disciplines in an organisation, and rigorous testing of each electronic component and software processing stage. As any software developers will know, despite extensive rigour, some 'bugs' will still occur, so that any system will need ready access to technical support to problem-solve as new issues arise. Such an organised and technically supported framework is preferable for ensuring effective application of limited resources to successful visitor monitoring processes, regardless of the scale of the monitoring activity.

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[2] VAMS is discussed further in section 4.3.

4. Development of DOC visitor monitoring tools

Over many years, park rangers and managers in DOC expressed a range of needs (consistent with the types of reasons summarised generally in section 1) for more reliable visitor counting tools. While many different approaches had been tried by individual managers both in New Zealand and internationally, there had been no attempt to develop nationally systematic and standardised visitor monitoring tools. However, a key development took place in the late 1990s, when DOC developed the Visitor Asset Management System (VAMS) to improve the management of its extensive inventory of visitor facilities (e.g. huts, tracks, bridges, boardwalks, signs) across the country (see section 4.2). This development of a national data management system was recognised by DOC as an opportunity to address its visitor monitoring needs more systematically. Consequently, more attention was devoted to identifying its visitor counting needs, and identifying effective tools and systems to do the job.

4.1 PREFERRED COUNTER CHARACTERISTICS

In New Zealand's mostly remote conservation areas, visitor use is dispersed, permit and fee systems are rare, staff and resources are widely spread, on-line electricity supply is usually absent, vehicle access is limited, and environmental conditions are often harsh and variable. Consequently, there was an emphasis on basing any visitor monitoring system on visitor counter devices in the field (see section 2.2). DOC park rangers and managers have experience in the operation of such counters. When asked what features they considered most important in visitor counter hardware, their responses were largely consistent across New Zealand (Raine & Maxey 1996), as well as with similar managers overseas (Gasvoda 1999; Watson et al. 2000). The desired features commonly included:

- High portability
- Lightweight construction
- Accurate counts
- Low maintenance
- Low cost
- Robust
- Easily concealed
- Low power consumption
- Water resistant
- Tolerant of temperature variations
- Minimal moving parts or electronics

Simplicity was a consistent theme, and in some cases there were reservations about the value of having more sophisticated systems to collect more detailed data, due to the greater potential vulnerability of the hardware involved:

> 'The responses also suggested that complex systems with cameras and date-stamps are not in demand.' (Gasvoda 1999: 3)
>
> 'The most surprising result of the survey was that enthusiasm for more sophisticated data collection came quite low on the series of priorities for counter performance. DOC staff cared much less for direction-of-travel and time-based data logging than they did for accurate, reliable performance.' (Raine & Maxey 1996: 9)

This preference for simplicity and reliability reflects the historical experience of managers with counter development internationally. Accounts by managers showed that there was a highly variable success rate between different types of counters, with many examples of hardware and software failure (Raine & Maxey 1996). Therefore, it is understandable that managers prefer simple systems. Furthermore, the scepticism about the promise of better results from new technology was often warranted as, according to managers, new technology was often promised by providers without adequate provision for the testing regimes and operational support required to make it work. This can result in considerable difficulties for management agencies when trying to apply these technologies.

The purpose of counts has also not always been clearly specified, and in the past there was no integrated data management system available to collate count data and provide reporting options back to park managers or other potential users of the data. Failure to ensure data delivery back to managers in a practically useful way can add to scepticism about the value of visitor counting, counting devices and count modelling systems, and may contribute to reduced commitment to their applications.

Based on the information from literature reviews (summarised in sections 1–3), personal experience and feedback from park managers, many of whom had used commercially available counters or developed their own localised counting methods in the past, DOC decided to develop its own on-site counters in-house as the basis for a visitor counting system (see section 2.2). Four distinct types of counters were identified as being necessary for covering the general range of DOC visitor counting needs (Table 5). It was also decided that these would be supplemented by observations by staff or recordings from video cameras, where counter calibration checks and/or count projections using visitor flow models were required. Monitoring for wider visitor characteristics was considered to be a separate information exercise, which could be incorporated into counter calibration tasks (e.g. Ross 2005) or through other information needs, e.g. satisfaction monitoring.

As well as counters for a national monitoring system, DOC also identified the requirement for case-specific counter options to meet more specialised management information needs, such as determining use levels of a particular facility (e.g. toilets) or visitor activity types (e.g. mountain bikes). However, these were considered to be a secondary priority in the wider counter-system development process, to be addressed on a case-by-case basis as required.

TABLE 5. RECOMMENDED COUNTER TYPES FOR PROTECTED AREAS IN NEW ZEALAND.

COUNTER METHOD	SETTING AND OPTIONS
Step counters	Pressure sensor built into the vertical front-board of a back-filled earth step or multi-step structure. Sited on a wide range of frontcountry and remote backcountry tracks.
Boardwalk counters	Pressure/strain-sensors built into a boardwalk or bridge structure. Sited on a range of tracks—mainly in high-use frontcountry and more developed backcountry areas.
Path counters	Pressure sensor under a hard path surface or infra-red detection across a path. Sited on high-use tracks with priority on those with full-access capability (e.g. wheelchairs, prams, elderly).
Vehicle counters	Pressure, vibration or induction loop sensor buried under road surface, or built into road structures such as bridges or culverts on strategic roads.
Observations	Fixed-location observations as required for counter calibrations, with later expansion for obtaining complementary monitoring data on specific visitor characteristics.
Specific counters	Special-purpose counters as required to obtain specific information, e.g. facility use, visitor activity or a particular management issue.

The key principle for the development programme was to separate the development tasks for count sensing from those for the management of count data. Thus, the process was effectively carried out by developing two essential and complementary components:

- Count sensors—a variety of hardware sensor-systems required to generate a visitor count signal
- Data exchange and management systems—generic software, hardware and database systems required to convert a count signal into useable and reliable monitoring information for managers through VAMS (see section 4.2)

It was decided that the step counter would be developed as the first operational count sensor and a data management system would be designed to convert its outputs into useable management information, which would fulfil the purpose of the whole visitor monitoring programme. Once both these components were established, a wider variety of count sensors would then be constructed, to provide coverage for a wider variety of sites.

4.2 DEVELOPING THE SENSORS

A main component of the development process was to find effective and reliable sensors. A previous assessment had shown that most commercially available counter tools were either too expensive, difficult to use or unreliable in the field. Therefore, the focus was on developing new tools. The first tool to be developed was the step counter, which became a very cost-effective operational unit and served as a basis for the development of the entire visitor monitoring system. The fundamental count processing and download software, databases and reporting systems were all developed in parallel with the step counter, and data from new counter types were then also managed using these systems.

4.2.1 The step counter

A feasibility study for a step-based counter was undertaken in late 1998, following a literature review on human walking and step-use behaviour (see Appendix 1). Specific observations of step-use behaviour were made using a time-lapse video system installed in a DOC office to determine the way in which people used the internal stairwell steps. This was aimed at testing whether step use could provide a high enough visitor hit-rate to make a step counter feasible, and whether this would work best if the top or bottom step in any sequence was targeted. It was found that 86% of all individuals going down stood on the top step compared with only 27% of those going up (Table 6). This supported review findings and previous observations in the field that people were more cautious stepping down than up, but this also indicated a problem, as the overall counting efficiency was only 63%. However, literature review and previous observations suggested that the step may have needed to be higher than the 175 mm used in the trial. Therefore, a prototype step counter that was 200 mm high was developed. This riser height was compatible with the range of step standards used by DOC (Standards New Zealand 2004).

A demonstration of the prototype counter was given to the Senior Technical Officers and to participants at a DOC Recreational Planners Meeting (Wellington, November 1998). The prototype counter was then installed at Otari-Wilton's Bush, Wellington, to test it under operational conditions. A video trial for this counter was set up over Easter 1999, a busy period in this reserve, to test its 'hit-rate' efficiency and to provide some examples of the types of data outputs generated. The hit rate was found to be very high, with an overall counting efficiency of 93% (Table 7); thus, the higher 200-mm step had considerably reduced the amount of error. It was also found that the data obtained could be summarised as the number of steps per day, per hour over several days, and per minute of a selected day, highlighting the variety of analysis options and potential utilities to managers.

TABLE 6. STEP-USE VIDEO OBSERVATIONS IN A DOC OFFICE USING 175-mm-HIGH STEPS.

DIRECTION TRAVELLED	PASSES (VIDEO)	LOGGED COUNTS	COUNTING EFFICIENCY
Up	107	30	28%
Down	160	137	86%
Total	267	167	62%

TABLE 7. STEP-USE VIDEO OBSERVATIONS IN OTARI-WILTON'S BUSH USING 200-mm-HIGH STEPS.

DIRECTION TRAVELLED	PASSES (VIDEO)	LOGGED COUNTS	COUNTING EFFICIENCY
Up	54	50	93%
Down	20	25	125%
Totals	74	75	97%

Some additional insights were also gained from the video observations. Under-counting was mainly caused by more than one person standing on the step at once, because the track was 1.2 m wide and quite steep below the counter. However the overall hit rate was very high, with only four people missing the counter completely (all going uphill). Over-counts were caused by some people travelling downhill taking longer to leave the step (with some actually stopping). Using the knowledge gained from these video observations, the design could be modified to increase the accuracy of the counts. To reduce the number of under-counts, it was proposed that counters should be installed on a narrow pathway to restrict people to single file and thus optimise counting accuracy. To reduce the number of over-counts, the 1-second time delay that had initially been built into the count logging circuit was reduced to well below 1 second.

At this point in the project, progress was interrupted by staff changes and other high-priority projects. There was also a new requirement to make the step counters compatible with the developing VAMS system (see section 4.3), which meant the software components needed to be redesigned. However, installation, operation and reporting guidelines were prepared in late 2001, and ten step counters were sent into the field for trial by DOC staff during 2002. As part of this trial, monitoring continued of the original Otari-Wilton's Bush step counter and another counter was installed at Castle Hill (Kura Tawhiti), as part of a specific visitor research project. These various trials were used to further refine the basic counter design and to test the new software applications. Many information issues and technical bugs were identified through trial and error, including the requirement for many revisions of the inter-dependent software applications due to ongoing upgrades of wider DOC data management systems. There were also some other, more fundamental changes made. For example, in response to manager observations and requests, the basic counter design was changed to include a wider sensor surface that increased hit-rate efficiency across a wider range of installation conditions. The electronic hardware was also simplified, and made more robust and resistant to water damage. Following these changes, the step counters proved to be very robust and reliable in the field—one was even found to have been fully operational despite being submerged in a flooded mountain stream for several days with boulders continuously washing over it (these were also counted!).

The results generated by these counters indicated that an effective and practical management tool was being created. Detailed count calibrations were carried out on the step counter at Castle Hill (Kura Tawhiti) during the wider visitor survey programme. The numbers and times of visitors crossing the counter were recorded by visual observation; the counter data were then downloaded and direct comparisons were drawn between observations and recordings. The results from a number of these trials showed that the step counter had high accuracy (c. 90–95%). This counter operated successfully for a year (Dec 2002 – Feb 2004), during which time it recorded over 34 000 visits. The data collected could be interpreted in various ways (e.g. Appendix 2). After February 2004, a software programming fault developed that caused a gap in the data flow. Finding such 'bugs' and developing 'fixes' was part of the purpose of the field testing in the context of the longer term development programme.

This longer term development programme continued to require ongoing input from staff involved in fieldwork, research, electronics, management, VAMS software design, and data logger software design. The counters needed to be trialled in field conditions over significant periods of time, to allow for the effects of changes in temperature, rainfall, and general wear and tear on the counter structure, electronics and power consumption. Even if all necessary staff members had been able to prioritise this task as required, as would have been ideal in the absence of other time demands, it would have required a lot of time. Although the deployment of operational units to the field was the priority, the development team would not allow a national deployment until they had confidence in the robustness, simplicity and reliability of the step counters and their supporting information management systems. However, this resulted in some debate by managers who had a strong need for this tool.

Prompted by the opportunity to engage an international counter calibration researcher in the project, a stocktake was taken at the end of 2003. This highlighted some priority tasks for 2004:

- Development of a strategic national counter deployment plan
- Commitment to deployment and logistical support (e.g. staff/resources for counter roll-out, installation, maintenance, advice and data management)
- Development of a counter calibration system (see Ross 2005)
- Ongoing improvements and upgrades of the hardware, software, programming and data systems for counter sensors, and for the interactive components of the data management system (counter electronics, data loggers, data and upgrade transfer software, VAMS data management and reporting)

During 2004, the step counter was completed and made operational, and the provisional data management system was also completed and made provisionally operational. Five step counters were installed in the Orongorongo valley tracks of Rimutaka Forest Park, both to test the hardware, software, communication, and data management and reporting systems, and to assist with the development of calibration systems (see Ross 2005). This trial identified some production faults in the counter electronics that were remedied by new specifications and design. Counters then functioned successfully for the 6-month duration of the trial period. By the end of 2004, operational units were being rolled out according to an initial national deployment plan; at the same time, data management and reporting options were available through VAMS (see section 4.3). This was largely facilitated by the appointment of a dedicated coordinator for the counter system deployment and development. By June 2005, there were 40 operational step counters established in the field[3], each of which was linked to the VAMS database and generated data that were used to develop new reporting tools (see section 4.3). At this stage, counter development shifted toward a more action research approach, where the rigours of full field operation led to new refinements and upgrades.

During 2005, counter deployment and improvement, and the development of new sensors depended on the available resources. Ongoing maintenance, support and advice for the monitoring system and its varied components was necessary, along with the development of new counter sensors, and the development of new data applications and reporting options as required. The longer term establishment of counters in the field identified problems with occasional water-tightness faults in counter connection cables, which resulted in design improvements for sealing the electronic components and connecting data loggers to them. Variations on the base design were also being developed to cater for a wider range of track widths, to reduce some of the operational limitations identified and to reduce unit costs. These included developing step counters that were narrower than the previous standard; new pad counters; wireless communication between counters and the hand-held data loggers; radio technology to transmit count data direct from counters to the databases at base; and video options for standard calibration work.

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[3] The site selection for deploying these counters was determined using a stratified statistical sampling design for visitor survey and monitoring, in an attempt to achieve a representative sample of DOC visitor sites and visitor group categories (Gray 2004). This approach was later reviewed and shelved due to implementation difficulties.

4.2.2 Development of other sensors

In addition to the step counter, other new counter designs were trialled and evaluated. Some of these innovations, such as boardwalk-based counters, were initially rejected due to major problems with structural vibration that caused over-counting errors. However, recent advances in sensor materials suggest options could be developed at some future time. A highly cost-effective passive infra-red sensor was developed and trialled, but proved to have the same practical limitations in use as the more expensive 'off-the-shelf' options available (see section 2.2.4). Although active infra-red beams were being used at some DOC sites and can work effectively in particular settings and situations, they are relatively impractical and costly compared with step counters as a stock tool for wider applications.

A more successful development was a new pad counter design employing more advanced sensor materials that overcame many of the disadvantages usually found with such sensors (see section 2.2.2). These pad counters were tested extensively in the lab and in the field, and field observations in basic trials indicated that they exceeded the performance reliability of other similar commercial sensors.

All these counters were developed to provide designs that were cheaper, more reliable and simpler to use than the commercial alternatives. Although problems emerged with these new counters during testing and trials, they were progressively solved with design and component improvements, and were still highly cost-effective relative to commercially available products, which themselves have been of variable reliability in the past. However, by the end of 2007, no better alternatives had been found for vehicle counters to the standard commercial types of buried induction loops, and this development ceased as the overall programme shifted to implementation of current tools in 2008.

4.3 DEVELOPING THE DATA MANAGEMENT SYSTEM

The other key component in the development process was the design of appropriate generic software, database systems and communication connections, to enable count data obtained in the field to be made available to managers in the office. Regardless of the type of sensor being used, the different components of the wider visitor monitoring system all needed to be able to 'talk' to each other, to convert the data signal derived from the sensor into useable management information. This required specific software and programs to be written, not only to enable data download, transfer, processing and reporting, but also to enable software updates to be transferred back to the sensors in the field. This was a long and complex development task, which involved much 'trial and error', and depended extensively on integration with the VAMS system.

The Visitor Asset Management System (VAMS) is the national management database of the 3700 specific visitor sites in parks managed by DOC (Cessford & Thompson 2002). Each specific site may be referenced individually from the database, and there is extensive site-specific information attached to each site on its physical condition, any facilities provided there, the recreational setting and social values associated with it, and any management prescriptions or task scheduling required. The system was designed to allow new information fields to be added as required, including visitor count information. This information is held in a central database, but is updated during regular field inspections through the use of hand-held data loggers into which information can be typed or, in the case of the visitor counters, is uploaded directly from the counter devices.

VAMS provides a practical and systematic process and template for uploading, transferring, storing, accessing and reporting on visitor count data from counters. Integration of the counter system into this broader data management system added significant value to the practical operation of counter tools and to the practical applications that could be made from the resulting count data. Some extended data exploration options outside VAMS were trialled using external providers (primarily the HARMONI package from Information Tools Ltd, Wellington), which provided some useful insights. However, despite considerable effort, these promising tools were found to be too demanding of current DOC resources and capabilities to be practical options for day-to-day management practice at the national, multi-site scale DOC was operating at. Therefore, attention focussed on developing further tools in VAMS to query, manipulate and display the data from any or all of the counters. This has now been developed to an operational state in VAMS, and allows count data to be queried and displayed in a variety of ways, including counts by location according to time of day, week, month and year. Figure 1 provides a sample counter report page from a standard VAMS query, while Appendix 3 provides some examples of the types of outputs that can be generated from the count data using basic query and charting tools.

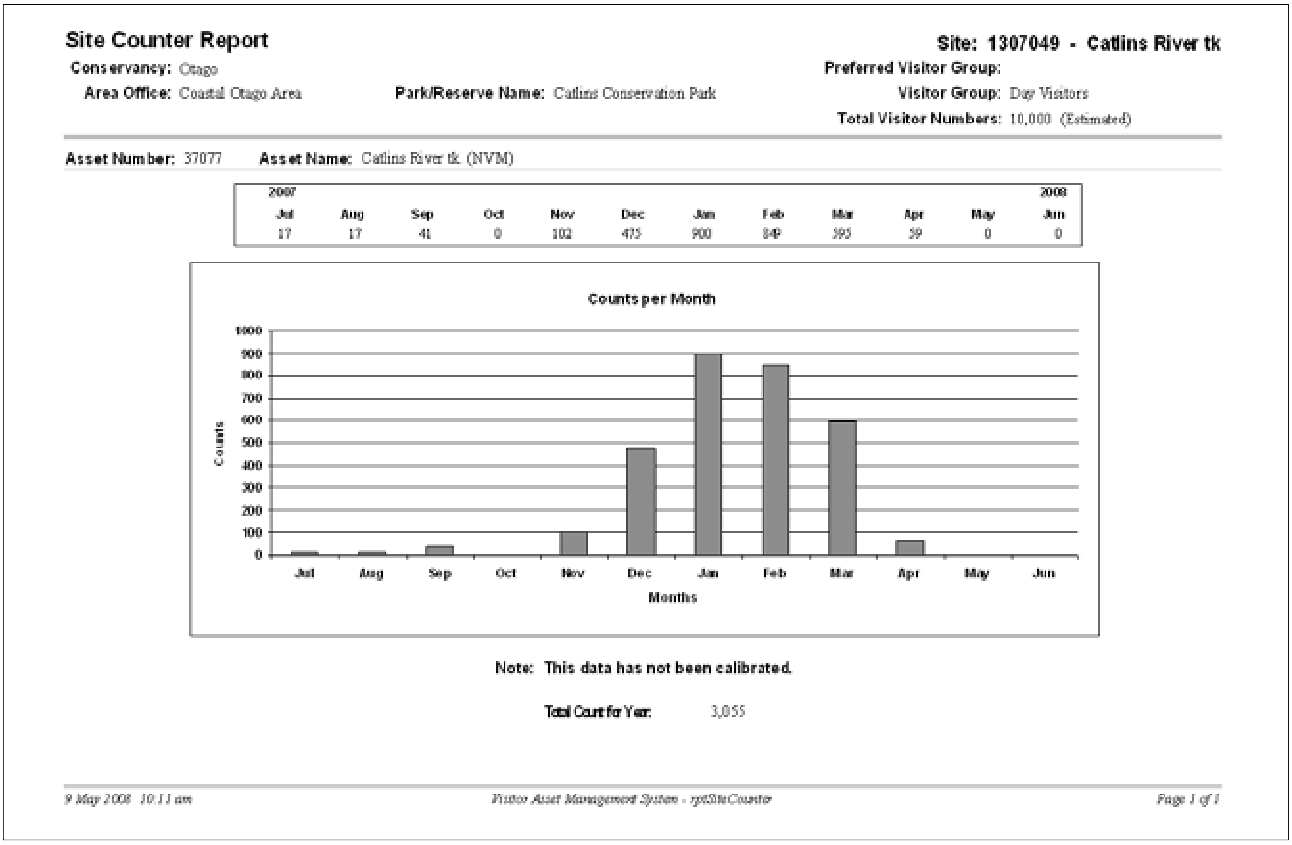

Figure 1. Sample page showing standard Visitor Asset Management System (VAMS) counter report.

4.4 DEVELOPMENT STATUS (TO MAY 2008)

The scale of this project expanded far beyond the original 'good idea' innovation of a step-based counter. By the time the counter system was considered fully operational in early 2008, there were many more components of the system that had required development and consideration (Fig. 2). Some were essential core components of a base system, while others were expansions of that system into new counting opportunities and needs. This was much more than was initially anticipated when the programme was first conceived.

Towards the end of this visitor number monitoring development programme, progress was summarised in a series of seminars, starting with the national DOC Recreation Planners Workshop in June 2005, and concluding with a presentation to the Australasian 'Tracks and Trails' conference in March 2008. Throughout the duration of this programme, such demonstrations of the full potential utility of the system, from counter installation to final reporting options, were critical for gaining support from field staff and managers, which was necessary to bring it to the stage of operational implementation.

The success of the DOC counter is now best judged by the current demand from field staff. After initial doubts following false starts with 'new counters', field staff are increasingly appreciating the simplicity of the system, savings in time, centralised data management, and the in-field installation and helpdesk support provided by the project. Demand for the counters is currently stretching capacity to deliver and support. In May 2008, there were 165 counters operational in the field, and another 80 on order from DOC field units. Over 80% of DOC's area offices now have counters in the lands they manage. The data generated are now providing useful daily and seasonal trends, as well as hourly patterns, which together are enriching managers' understanding of visitor use patterns. By building a robust counter, and providing ongoing support and centralised data management, DOC has been able to improve its visitor monitoring in an increasingly diverse range of settings.

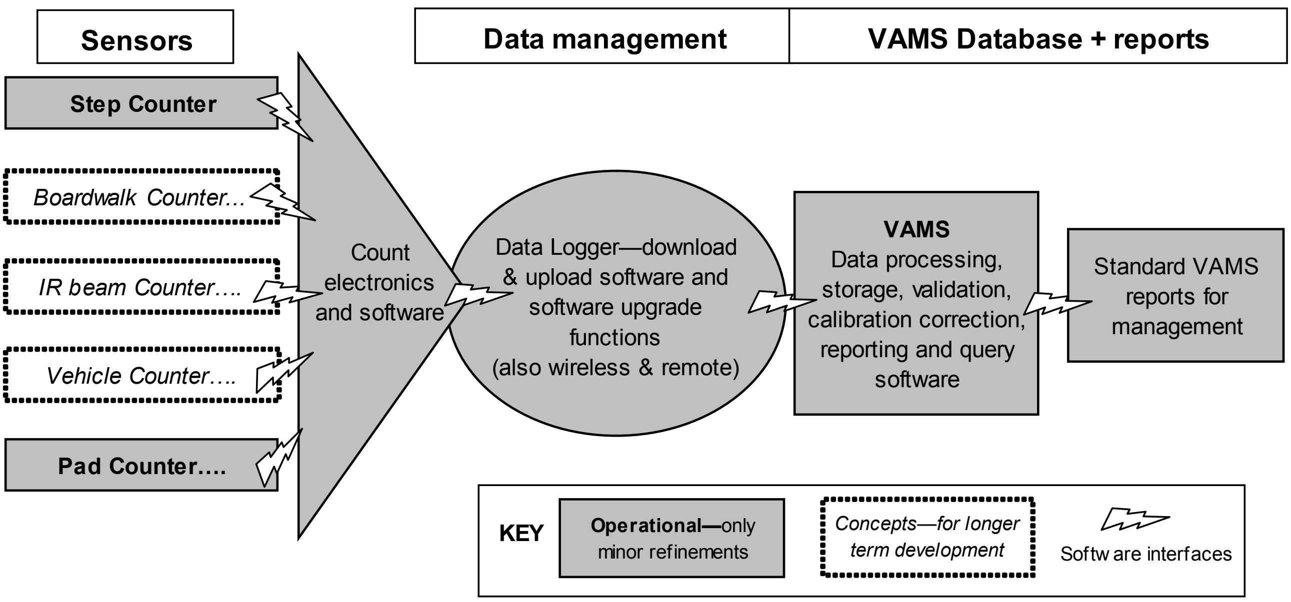

Figure 2. Development programme for DOC visitor monitoring tools—summary to January 2008.

5. Summary and conclusions

There are many important reasons why park managers and other similar decision-makers should increase their awareness and use of visitor monitoring approaches, as summarised in section 1. The most fundamental baseline need is to achieve reliable and accurate estimates of visitor numbers, but monitoring techniques can also be used to determine visitor distributions and use patterns, and the descriptive characteristics of individuals, groups and activities.

Park managers wishing to develop monitoring systems to estimate visitor numbers have many different techniques available to them that are able to cover a wide variety of sites and situations. Each technique has its own particular set of advantages and disadvantages that must be taken into consideration when evaluating the most appropriate options to apply. It is also important to remember that any visitor counting technique must be undertaken according to well-defined and specific management objectives. In most situations, these objectives will not be defined in isolation on a case-by-case basis; instead, the counting approach will need to be developed as part of a wider visitor monitoring programme. It is important to recognise that such wider programmes may need to be based on a rigorous site sampling strategy to ensure that the sample is representative of the wider system.

In many cases, it will also be important to undertake complementary monitoring methodologies. There are two main reasons for this. The first purpose is for counter calibration, which involves applying specific methodologies to check the accuracy of the primary counting techniques, and calculating correction factors that can be applied to the data collected to make visitor number estimates more accurate. This should be required in all cases. The second purpose is to provide additional information about the nature of the visits and the visitors, which may be extrapolated on the basis of the core visitor counts. This is a more optional, value-adding function. Should time and resources allow, the most positive outcome will be achieved if both the calibration and value-adding roles can be undertaken together as an integrated process.

While there are many examples of the development of new count sensors, this has rarely been carried out in combination with the development of an appropriate data management system. In the case of DOC, the development of the VAMS system provided an electronic framework for the development of a systematic approach to the monitoring of visitor numbers. New sensors were then developed in parallel with a data management system linked to VAMS. This ensured that the most reliable and valid data were received, processed and delivered to managers as useable information. Following these developments, the main requirements were ongoing commitment to properly support and maintain the system, to carry out required data calibration and validation processes, and to continue an ongoing process of system refinement, improvement and customisation to meet new needs as required. New developments in counter technology, monitoring systems and park management practice will continually raise new challenges and opportunities. Integrated systems, such as that established by DOC, allow new innovations to be readily incorporated as required.

This does not come without considerable effort, however. The successful development of a visitor counter system in DOC took far more time and work than was originally anticipated. Through this process many lessons were learned, insights gained, and innovations conceived and developed. The following points summarise some of the main lessons learned and outline recommendations for developing a visitor monitoring programme:

- Visitor count data provide fundamental baseline information for visitor management and have a multitude of potential applications. Since not all of the useful applications will necessarily be identified when a programme commences, the establishment of a baseline data resource with allowance for ongoing accumulation over time will be invaluable. Many additional applications may become more apparent and valuable once long-term datasets have been collected. However, for this to be successful there must be some commitment to consistency in methodology and data content over time.
- Visitor count data should ideally be collected as part of a wider long-term monitoring programme, which is based on clearly specified objectives but allows sufficient flexibility to fulfil unanticipated needs for new information. A specific process to identify information needs over time should be carried out, which should consider short-, medium- and long-term needs.
- Any monitoring system must be backed up by institutional support and commitment that includes funding to enable some staff to be dedicated to both ongoing development and operational application. Some components require ongoing support from specialists, while the whole system requires an ongoing maintenance support role.
- Although development of count sensors is a different process from development of a data management system, neither can work without the other. Therefore, the two should be designed in parallel. Once a system is in place, continual improvement practices can be applied progressively over time as opportunities arise.
- The data management system should be developed as a generic stand-alone system, into which a variety of different sensors may feed data. Data management has too often been a neglected component of monitoring system development in the past, with the focus tending to be placed on the sensor component.
- There are some basic criteria for evaluating counter options that can guide sensor choice and/or design to fit different purposes and site situations (summarised in section 2). The development of a new counter should be recognised as a process of concept definition, testing, piloting, reviewing and refining, and monitoring. Time and resources must be allocated to this.
- No matter how good the visitor monitoring system is considered to be, the monitoring programme must include an in-built counter calibration and data validation component to maximise data accuracy. This is part of the ongoing operational maintenance requirement for any system (see Ross 2005).
- Many different components need to be completed and coordinated for successful counter development and application. These include electronics, software, programming, hardware, field testing, reporting, calibration, training and reviewing. This will require the skills of many sectors of an organisation, which could result in significant increases in development time when not all are able to complete desired contributions when required. Consequently,

in the absence of a strongly defined management mandate for such work to take priority, such an innovation and development project requires a long-term sustained effort, and a degree of flexibility in the scheduling of output milestones.

- The development of visitor monitoring systems is an ongoing process of continual improvement, rather than a specific endpoint fulfilled by a specific tool. Therefore, once a system has been established, the most positive directions for future work will involve improving the:
  - —Hardware and software associated with the current and potential new visitor counting techniques.
  - —Integration of complementary calibration monitoring techniques with the core visitor counting approaches.
  - —Methods used to identify the specific management reasons and objectives for undertaking visitor monitoring in different situations.
  - —Methods used to identify the optimum strategic sampling sites for counts that best represent the wider park systems of interest.
  - —Integration of visitor count techniques into wider monitoring systems that include specification of management objectives, systematic data collection and storage capacities, and user-friendly reporting options from the core databases created.
- Individual organisations will not necessarily have the full spectrum of specialist capability. For example, specialists in visitor monitoring are few in number and widely dispersed. Therefore, specialist collaborations across different management organisations and different countries should be encouraged, to allow the sharing of individual best practices among the wider international management and research community (e.g. the international methodological review carried out by Hornback & Eagles (1998), and the international specialist conference proceedings documented by Arnberger et al. (2002a) and Sievänen et al. (2004)). Opportunities to collate and synthesise the various examples of best practice into generic guidelines for park managers should also be promoted. However, it is important to acknowledge that no matter how sophisticated we become, the management solution will always be a necessary compromise between the need for visitor information accuracy, and the practical capacities of an organisation to carry out the monitoring and measurement.

6. Acknowledgements

Many DOC staff contributed to the development of the visitor counting system, from the early beginnings with Peter Carey and Murray Douglas, through to the major hardware and software refinements managed by Stu Cockburn and supported by Geoff Thomas, to the final trial, development and implementation work of Rob Burns. Mike Edginton facilitated the critical resource support at the final trial and implementation stage. This research was funded by the Department of Conservation (Science Investigation No. 3474).

7. References

AALC 1994: Visitor Monitoring Strategy. Prepared for the Australian Alps Liaison Committee by Environment Science and Services Ltd. Australasian Alps Co-operative Management Program. 161 p.

AALC 2000: Visitor monitoring in National Parks: notes from a best practice workshop. Australian Alps Liaison Committee, Australasian Alps Co-operative Management Program. 83 p.

Arnberger, A.; Brandenburg, C.; Muhar, A. 2002a: An integrative concept for visitor monitoring in a heavily used conservation area in the vicinity of a large city: the Danube floodplains National Park, Vienna. Pp. 195–201 in: Proc. North-Eastern Recreation Research Symposium 2001, Bolton Landing, NY, USDA Forest Service, General Technical Report NE-289, USDA.

Arnberger, A.; Brandenburg, C.; Muhar, A. (Eds) 2002b: Monitoring and management of visitor flows in recreational and protected areas. Proceedings of the MMV1 conference held at the Institute for Landscape Architecture and Landscape Management, Bodenkultur University Vienna, Austria, January 30 – February 02, 2002. 485 p.

Booth, K.L. 1988: Recreation and tourism research for conservation. *Science & Research Internal Report 10*. Department of Conservation, Wellington. 16 p.

Brandenburg, C. 2001: Erfassung und Modellierung von Besuchsfrequenzen in Erholungs- und Schutzgebieten. [Registration and modelling of visitor loads in recreational and protected areas.] Unpublished PhD thesis, Institut für Freiraumgestaltung und Landschaftspflege, Universität für Bodenkultur, Vienna.

Cessford, G.R.; Cockburn, S.; Douglas, M. 2002: Developing new visitor counters and their applications for management. Pp. 14–20 in Arnberger, A.; Brandenburg, C.; Muhar, A. (Eds): Monitoring and management of visitor flows in recreational and protected areas. Proceedings of the MMV1 conference held at the Institute for Landscape Architecture and Landscape Management, Bodenkultur University Vienna, Austria, January 30 – February 02, 2002. 485 p.

Cessford, G.; Muhar, A. 2003: Monitoring options for visitor numbers in national parks and natural areas. *Journal for Nature Conservation 11(4)*: 240–250.

Cessford, G.; Thompson, A. 2002: Managing tourism in the New Zealand Protected Area System. *Parks 12(1)*: *26–36*. Protected Area Programme, World Commission on Protected Areas (WCPA), World Conservation Union (IUCN).

Cope, A.; Doxford, D.; Probert, P. 2000: Monitoring visitors to UK countryside resources: the approaches of land and recreation resource management organisations to visitor monitoring. *Land Use Policy 17(1)*: 59–66.

Cope, A.; Hill, A. 1997: Monitoring the monitors. *Countryside Recreation News 5(2)*: 10–11.

DOC (Department of Conservation) 1992: Visitor monitoring manual: methods to count, record and analyse information about visitor numbers. Unpublished internal report for the Resource Use and Recreation Division, Department of Conservation, Wellington. 84 p.

English, D.B.K.; Kocis, S.M.; Zamoch, S.J.; Arnold, J.R. 2001: Forest Service national visitor use monitoring process: research method documentation. www.fs.fed.us/recreation/programs/nvum/methods/methods052001.rtf (viewed 9 May 2008).

Gasvoda, D. 1999: Trail traffic counters: update. Report 9923-2835-MTDC. USDA Forest Service, Missoula Technology and Development Centre, Missoula, Montana. www.sctrails.net/TRAILS/LIBRARY/FSPubs/trafficcounter/index/htm (viewed 9 May 2008).

Gray, A. 2004: Sample design for ROS descriptor and satisfaction surveys. Unpublished report prepared by Statistics Research Associates Ltd for the Southern Regional Office, Department of Conservation, Christchurch. Held by the Heritage Appreciation Unit, Research, Development & Improvement Division, Department of Conservation, Wellington.

Gregorie, T.G.; Buyhoff, G.J. 1999: Sampling and estimating recreational use. USDA Forest Service, General Technical Report PNW-TGR-456. Pacific Northwest Research Station, Portland, Oregon. 48 p.

Hornback, K.E.; Eagles, P.F.J. 1998: Guidelines for public use measurement and reporting at parks and protected areas. World Commission on Protected Areas, World Conservation Union (IUCN), Gland, Switzerland. 59 p.

Leatherberry, E.C.; Lime, D. 1981: Unstaffed trail registration compliance in a backcountry area. USDA Forest Service Research Paper NC-214, North Central Forest Experiment Station, St. Paul, Minnesota. 11 p.

Legg, C.L.; Nagy, L. 2006: Why most conservation monitoring is, but need not be, a waste of time. *Journal of Environmental Management 78 (2)*: 194–199.

Loomis, J.B. 2000: Counting on recreation use data: a call for long-term monitoring. *Journal of Leisure Research 32(1)*: 93–96.

McClaran, M.; Cole, N. 1993: Packstock in wilderness: use, impacts, monitoring and management. USDA Forest Service, General Technical Report INT-301. Intermountain Research Station, Ogden, Utah. 33 p.

McIntyre, N. 1999: Towards best practise in visitor use monitoring processes: a case study of Australian protected areas. *Parks and Leisure, Sept. 1999*: 24–29.

Muhar, A. 2001: Erholungsnutzung und Besucherlenkung. Pp. 285–313 in: LIFE-Projekt Wildnisgebiet Dürrenstein, Forschungsbericht Begleitforschung 1997–2001. [Recreational use and visitor management in the Dürrenstein Wilderness Area.] Amt der NÖ. Landesregierung, St. Pölten.

Muhar, A.; Arnberger, A.; Brandenburg, C. 2002: Methods for visitor monitoring in recreational and protected areas: an overview. Pp. 1–6 in Arnberger, A.; Brandenburg, C.; Muhar, A. (Eds): Monitoring and management of visitor flows in recreational and protected areas. Proceedings of the MMV1 conference held at the Institute for Landscape Architecture and Landscape Management, Bodenkultur University Vienna, Austria, January 30 – February 02, 2002.

NPW 1999: Visitor data system: project overview. National Parks and Wildlife Service, South Australia. 33 p.

Raine, J.K.; Maxey, N.G. 1996: Refinement of track counter design. *Department of Mechanical Engineering, Technical Report No. 53*. University of Canterbury, Christchurch. Report to Science and Research Unit, Department of Conservation, Wellington. 84 p.

Ross, J. 2005: Visitor counters in parks: management practice for counter calibration. *Department of Conservation Technical Series 33*. Department of Conservation, Wellington. 34 p.

Sievänen, T.; Erkkonen, J.; Jokimäki, J.; Saarinen, J.; Tuulentie, S.; Virtanen, E. (Eds) 2004: Policies, methods and tools for visitor management: proceedings of the Second International Conference on Monitoring and Management of Visitor Flows in Recreational and Protected Areas, June 16–20, 2004, Rovaniemi, Finland. Metlan työraportteja / Working Papers of the Finnish Forest Research Institute 2. www.metla.fi/julkaisut/workingpapers/2004/mwp002-en.htm (viewed 9 May 2008).

Standards New Zealand 2004: New Zealand Handbook: Tracks and Outdoors Visitor Structures, SNZ HB 8630:2004. 81p.

Washburne, R.F. 1981: Carrying capacity assessment and recreational use in the National Wilderness Preservation System. *Journal of Soil and Water Conservation 36(3)*: 162–166.

Watson, A.E.; Cole, D.N.; Turner, D.L.; Reynolds, P.S. 2000: Wilderness recreation use estimation: a handbook of methods and systems. USDA Forest Service, General Technical Report RMRS-GTR-56. Rocky Mountain Research Station, Ogden, Utah. 198 p.

Wyld, L. 1995: Review of visitor monitoring in the Australian Alps. Prepared for Australian Alps Liaison Committee. 18 p.

Appendix 1

REVIEW OF WALKING BEHAVIOUR AND STAIRS

A literature review of human gait research was carried out[4] to identify whether any generalisations about visitor walking patterns could be used to inform the design of new counters, particularly with regard to the optimum physical dimensions and locations required for any counter devices. Since the specific intention was to develop boardwalk, step and buried pad counters, this review focussed on walking behaviour on flat surfaces and on steps. The main topics of interest were:

- 'Stride length' (for flat surfaces): What is the optimum counter dimension to capture at least one step for all walkers whilst minimising capturing two?
- 'Step on' (for steps): What is the general behaviour of people going up and down steps, with respect to optimum step height, tread and entry/exit slopes? What step dimensions will maximise the 'hit rate' of people 'stepping on' the step edge?

A1.1 Stride length

It was important to determine the length of people's strides so that any boardwalk sensor would minimise the number of missed counts caused by long-striding people stepping over the sensor section, whilst simultaneously minimising the potential for over-counting caused by short-striding people stepping on it twice. An extensive review of literature and park practices was carried out. Since no relevant data were found in the park management and monitoring literature or disciplines, this information was sourced from the fields of gait analysis and bio-mechanics.

It was found that although stride length was a commonly measured variable, it was often reported as a stride index (a ratio of stride distance to leg length). However, a number of studies and reviews did report stride length and the effect of various factors on it (Table A1.1). The mean stride length was calculated to be c. 0.73 m, and most stride lengths were between c. 0.67 m and 0.79 m (95% confidence levels). However, a number of variables influenced stride length. Age, gender and load being carried were the main sources of variation in stride length in most cases. Additional variations were related to the relatively low height in a Japanese sample (Sekiya & Nagasaki 1998), and the high degree of fitness among a sample of army trainees carrying loads (Martin & Nelson 1986). Overall, the main generalisations that could be drawn from these studies and from similar studies that used stride indices rather than simple distance were that:

- Mean stride length for walkers across a variety of settings and test subjects is around 0.73 m ± 0.06 m (SD)
- Stride lengths are lower for females, older walkers, and less physically active walkers

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[4] Carried out by Gordon Cessford as part of the overall project.

- Decreased stride length for older walkers often does not occur until after around age 60
- Stride length decreases with increasing carried load, especially among women
- Stride length decreases with increasing slope
- Stride length increased when walkers are moving faster, unless they are carrying a load, in which case greater step speed tended to occur

TABLE A1.1. STRIDE-LENGTH REVIEW SUMMARY.

This information is based on studies that reported simple stride length rather than a stride index.

MEAN STRIDE LENGTH (m)	SUMMARY NOTES (INCLUDING SOME DATA TRANSLATION)	REFERENCE
0.775	Observational street sample for gender and load. Gender: males = 0.825 m; females = 0.745 m. Load: no load = 0.801 m; notable load = 0.730 m. Load was subjectively defined based on descriptive criteria.	Eke-Okoro & Sandlund (1984)
0.873	Experimental student sample for gender and load. Gender: males = 0.885 m; females = 0.861 m. Load: no load = 0.873 m; load of 36 kg = 0.849 m. A fit group of army trainees, so the longer stride lengths and load capabilities expected.	Martin & Nelson (1986)
0.668	Experimental multi-age sample for gender and age. Gender: males = 0.726 m; females = 0.610 m. Age: 19–39 = 0.705 m; 40–62 = 0.700 m; 63+ = 0.600 m. The high proportion of older walkers lowered the mean step lengths.	Himann et al. (1988)
0.765	Experimental analysis of step force, so no other data.	Martin & Marsh (1992)
0.739	Extensive review of earlier studies, including several on step length and gender. Mean values reported for gender were: males = 0.782 m; females = 0.695 m. Extensive bio-mechanical information on walking. Also some effects of increased load on cadence and stride length at higher speeds.	Zatsiorky et al. (1994)
0.732	Experimental analysis of gait for different age groups. Age: 20–40 = 0.760 m; 60–80 = 0.705 m. Detailed analysis of numerous gait variables.	Ostrosky et al. (1994)
0.737	Experimental analysis of gait parameters, so no other data. Stride length increased when required to walk faster than normal preferred walking pace.	Sekiya et al. (1996)
0.727	Experimental analysis of step length variability with speed and gender. Stride length increased when required to walk faster than normal preferred walking pace. Gender: males = 0.760 m; females = 0.695 m.	Sekiya et al. (1997)
0.670	Experimental analysis of gait characteristics on treadmills (which reduced gait length overall). At least 10% increase in stride length when required to walk faster than normal preferred walking pace.	Growney et al. (1997)
0.710	Extensive review, with general population averaging 0.710 m (males = 0.730 m; females = 0.64 m). Both decreased with age.	Hageman (1995)
0.679	Experimental analysis of gait characteristics on walkway by gender. Gender: males = 0.695 m; females = 0.664 m. Subjects were relatively short (mean height = 1.65 m), so mean stride length lower than in other samples.	Sekiya & Nagasaki (1998)
0.750	Experimental analysis of stairclimbing mechanics, including level walking gait measures. Mean stride length of 1.5 m, which was consistent for short, medium and tall subjects.	Livingston et al. (1991)
Total		
0.734 ± 0.060	Overall mean step length and standard deviation from several different studies operating in different experimental conditions and with different test subjects.	

Given these findings, it was clear that there would need to be some compromise when deciding on the optimum length of any sensor section in a boardwalk, which would require some subjective decision-making. Therefore, as part of the development process of buried pad counters for flat surfaces, it was noted that field observations may be required to identify the stride behaviour of walkers in an outdoor setting, and the effects of load, setting type and visitor type. However, in the meantime, based on these review results, it was recommended that the optimum length for a pad counter was 0.7 m.

A1.2 Stair use behaviour

It was also important to determine people's behaviour on stairways, as the viability of the step counter depended on ensuring a high 'hit rate' on the step sensor by people going both up and down. Although an extensive search of literature and park practices was carried out, very little relevant material was found, the main research being into stair safety and accidents. This supported the comment by Ehara et al. (1995) that few reports on stair climbing have been published. A few studies have investigated the human mechanics of stairclimbing, but none of these considered the effect of stair dimensions (Livingston et al. 1991). However, from the limited literature that was available and some field observations, some generalisations could be made:

- Almost all walkers stand on the leading edge of the last step in a down-stair sequence, and almost none extend their stride to stretch over the leading edge from further back on the stair tread.
- Most walkers use the first step in an up-stair sequence and a high proportion stand on the leading edge; both these behaviours increase with increased stair height.
- Walkers scan ahead and hesitate to adjust their stride before the first step in an up-stair sequence.
- Preferred stair dimensions for a variety of different people and situations are commonly around a riser height of 180 mm (7 inches) and a tread length of 280 mm (11 inches).

Two main aspects of this stair behaviour appeared to be critical for maximising walker 'hits' on a visitor counting device that would be built into the leading edge of a step. The first is the stair descent pattern, where people almost always step down from the leading edge, to avoid any extending of their leg over and down to the next step. This was noted in Crosbie (1996), and was consistently seen in observations carried out as part of this investigation. In a stair sequence, this pattern appeared to be most prevalent on the last step down. The second is the stair ascent pattern, where riser height influences where visitors place their feet on the step up. In simple terms, the greater the riser height, the higher the proportion of feet being placed on the leading edge of the step up. The overall conclusion drawn from these findings was that, wherever possible, the step counter should be located in the first up-step (last down-step) of a stair sequence, and that this step should be as high as possible.

The height of steps is an important issue. The major structural components of stairways, especially when considered in relation to safety issues, are the riser and run dimensions, and the stair-to-stair variability of these dimensions

(Startzell et al. 2000). As noted above, the optimum height for stair risers was considered to be around 180 mm. Irvine et al. (1990) found that at around this level, stair acceptability was very sensitive to changes in riser dimensions, depending on relative age, gender, height and fitness. Safety issues also become more apparent with substantially higher or lower step heights: substantially higher steps (usually over 220 mm) made stair descent more difficult and unstable, while substantially lower steps (usually under 130 mm) made stairs less defined and thus harder to distinguish (Pauls 1985; Irvine et al. 1990; Templar 1992; Chown 1993). Few people prefer steps outside these riser dimensions (Irvine et al. 1990), although Startzell et al. (2000) did caution that most of these studies used relatively fit and able subjects aged under 70, and that lower step heights, among other features related to stair safety such as handrails, may well be preferred by older and/or significantly less able people. This would be a particular concern for outdoor recreation facility managers in areas where relatively large numbers of such users are anticipated.

This type of research is generally undertaken in controlled laboratory experiments that simulate conditions usually encountered indoors or in other built environments. Therefore, other issues may apply in field conditions, where use is more diverse, and behaviours and expectations are different. For example, a commonly observed behaviour on approaching an up-stair sequence was that people visually scanned ahead to the first step, and slowed their approach to set themselves up for stepping up (Templer 1992; Crosbie 1996). In a park track setting, such scanning ahead is common on the uneven surfaces often encountered, and walkers are aware of the obstacles they must pass. In this respect, and taking the fitness aspect into account, the challenge of a substantial step up or down is not as significant as may be the case in a building or built environment. However, it is also apparent that in a park setting where the steps are substantially high, people sometimes form informal paths around steps. This indicates that stair height should not be increased much beyond 220 mm, especially if located in a frontcountry setting, where less physically capable people would be expected in greater numbers.

The DOC standards for stair height reflect this awareness of visitor capabilities, having a preferred height of 180 mm, a minimum of 150 mm, and a range of maximum heights (DOC 2000; Standards New Zealand 2004), depending on the site setting and the type of visitor group anticipated (DOC 1996). These correspond to the range of stair height specifications in the New Zealand Building Code (Table A1.2).

TABLE A1.2. MAXIMUM DOC STAIR HEIGHT SPECIFICATIONS (DOC 2000; STANDARDS NEW ZEALAND 2004).

VISITOR GROUP	SETTING TYPE	MAXIMUM HEIGHT	EQUIVALENT STAIR TYPE (NZ BUILDING CODE)
Short-stop travellers; day visitors (accessible)	Frontcountry easy-access sites; widest possible visitor range	190 mm	Common and Main Private
Day visitors; backcountry comfort seekers	Easy backcountry settings; wide visitor range	200 mm	Secondary Private
Backcountry adventurers; remoteness seekers	Difficult settings for small range of fit and experienced visitors	220 mm	Service or Minor Private

Results from observational trials suggested that the current standard step height of 200 mm was appropriate for the step counter; thus this would be the recommended minimum for any step counter. Height only affected the effectiveness of the counter when it was installed incorrectly, making the step height too low. This was observed during early field trials, where some counters installed by field staff that were reported as having low 'hit rates' were found on inspection to have been installed incorrectly. Once correctly installed, the hit rates became consistent with correctly installed counters elsewhere.

A1.3 Recommendations

For a flat surface counter that requires a person to step on it to be counted, e.g. a buried pad counter on a path or a boardwalk counter, a minimum length of 700 mm is optimum. This will be most likely to capture at least one step from most walkers. If it is found that some people step on it twice due to shorter strides, software for a suitable time-delay can be written to ensure that only the first step is counted.

Buried pad counters may be smaller if they can be located in places where normal striding pattern is interrupted and step-on is guaranteed, such as stepping on or off a section of boardwalk, or through some control barrier on the track.

For a step counter, a minimum height of 200 mm is required to optimise hit rate. This will be enhanced if the step is the first/last in a stair sequence, where people interrupt their normal striding pattern to negotiate the obstacle. A similar outcome can be achieved by locating step counters on sloping sections of track. Since step heights greater than 200 mm exceed the recommended standards for steps by DOC, 200 mm is the optimal height.

A1.4 References

Chown, G.A. 1993: Stair design and stair safety. Committee Paper, prepared for the standing Committee on Housing and Small Buildings. Canadian Commission on Building and Fire Codes, National Research Council of Canada.

Crosbie, J. 1996: Step adjustment during negotiation of kerbs: a covert study. *Gait and Posture 4(2)*: 192–193.

DOC (Department of Conservation) 1996: Visitor Strategy. Department of Conservation, Wellington.

DOC (Department of Conservation) 2000: Outdoor visitor structures: design data for access structure stairs. Draft report, prepared for the Department of Conservation.

Ehara, Y.; Beppu, M.; Nomura, S.; Kunimi, Y. 1995: Biomechanics of stairway walking. *Gait and Posture 3(4)*: 267–277.

Eke-Okoro, S.T.; Sandlund, B. 1984: The effects of load, shoes, sex and direction on the gait characteristics of street pedestrians. *Journal of Human Movement Studies 10*: 107–114.

Growney, E.; Melgan, D.; Johnson, M.; An, K. 1997: Repeated measures of adult normal walking using a video tracking system. *Gait and Posture 6*: 147–162.

Hageman, P.A. 1995: Gait characteristics of healthy elderly: a literature review. *Issues on Aging 18(2)*: 2–14.

Himann, J.A.; Cunningham, D.A.; Rechnitzer, P.A.; Paterson, D.H. 1988: Age-related changes in speed of walking. *Medicine and Science in Sports and Exercise 20(2)*: 161–166.

Irvine, C.H.; Snook, S.H.; Sparshatt, J.H. 1990: Stairways risers and reads: acceptable and preferred dimensions. *Applied Ergonomics 21(3)*: 215–225.

Livingston, L.A.; Stevenson, J.M.; Olney, S.J. 1991: Stairclimbing kinematics on stairs of differing dimensions. *Archives of Physical Medicine and Rehabilitation 72*: 398–402.

Martin, P.E.; Marsh, A.P. 1992: Step length and frequency effects on ground reaction forces during walking. *Journal of Biomechanics 25(10)*: 1237–1239.

Martin, P.E.; Nelson, R.C. 1986: The effect of carried loads on the walking patterns of men and women. *Ergonomics 29(2)*: 1191–1202.

Ostrosky, K.M.; Van Swearingen, J.M.; Burdett, R.G.; Gee, Z. 1994: A comparison of gait characteristics in young and old subjects. *Physical Therapy 74(7)*: 34–43.

Pauls, J.L. 1985: Review of stair-safety research with an emphasis on Canadian studies. *Ergonomics 28*(7): 999–1010.

Sekiya, N.; Nagasaki, H. 1998: Reproducibility of the walking patterns of normal young adults: test-retest reliability of the walk ration (step-length/step-rate). *Gait and Posture 7(1)*: 225–227.

Sekiya, N.; Nagasaki, H.; Ito, H.; Furuna, T. 1996: The invariant relationship between step length and step rate during free walking. *Journal of Human Movement Studies 30*: 241–257.

Sekiya, N.; Nagasaki, H.; Ito, H.; Furuna, T. 1997: Optimal walking in terms of variability in step length. *Journal of Orthopaedic and Sports Physical Therapy 26(5)*: 266–272.

Standards New Zealand 2004: New Zealand Handbook: Tracks and Outdoors Visitor Structures, SNZ HB 8630:2004. 81 p.

Startzell, J.K.; Owens, D.A.; Mulfinger, L.M.; Cavanagh, P.R. 2000: Stair negotiation in older people: a review. *Journal of the American Geriatrics Society 48(5)*: 597–580.

Templer, J.A. 1992: The staircase: studies of hazards, falls and safer designs. The MIT Press, Massachusetts Institute of Technology, Cambridge, Massachusetts.

Zatsiorky, V.M.; Werner, S.L.; Kaimin, M.A. 1994: Basic kinematics of walking. *The Journal of Sports Medicine and Physical Fitness 34(2)*: 109–134.

Appendix 2

VISITOR NUMBERS TO CASTLE HILL

Example information from an early extended trial of the step counter at Castle Hill, 20 Dec 2002 – 18 Feb 2004 ($n = 32\,811$).

Figure A2.1. Monthly visitor numbers.

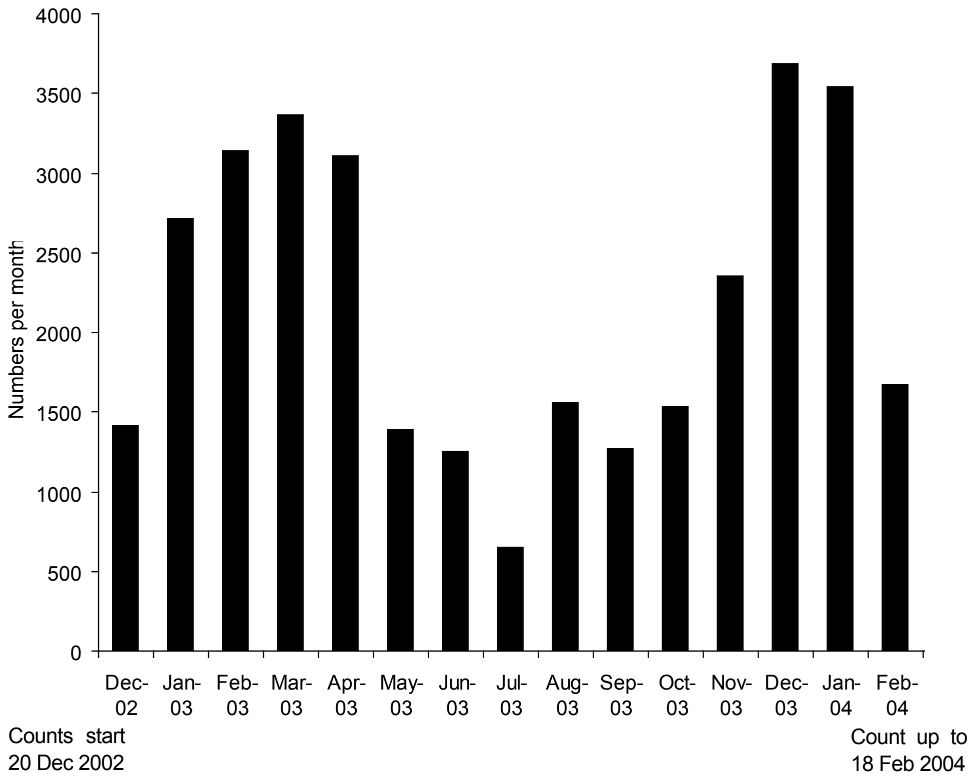
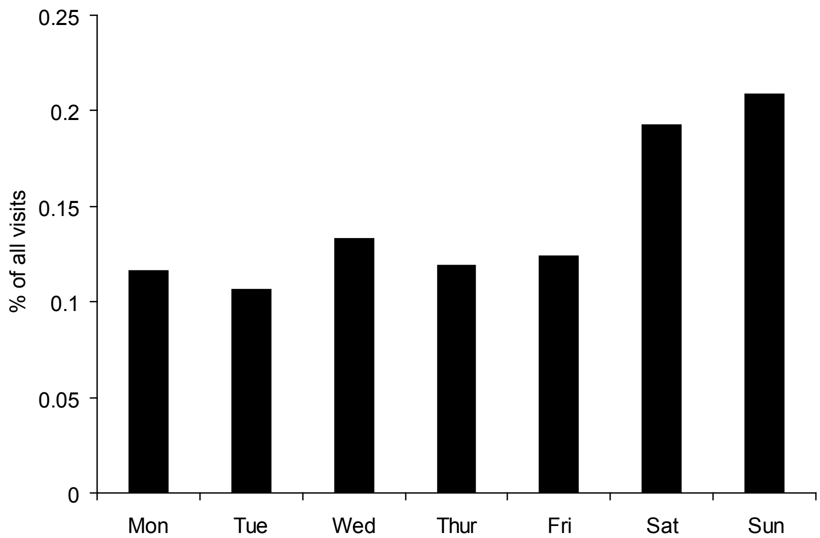


Figure A2.2. Percentage of visits by day of week.



Appendix 3

EXAMPLE OUTPUTS OF COUNT DATA FROM VAMS

The following figures provide examples of what managers may receive when developing queries in the Visitor Asset Management System (VAMS). They demonstrate how this information can be used to highlight annual, seasonal and daily use patterns on walking tracks. These charts have been taken directly from VAMS pivot-table data; consequently, they are not formatted to publication standard.

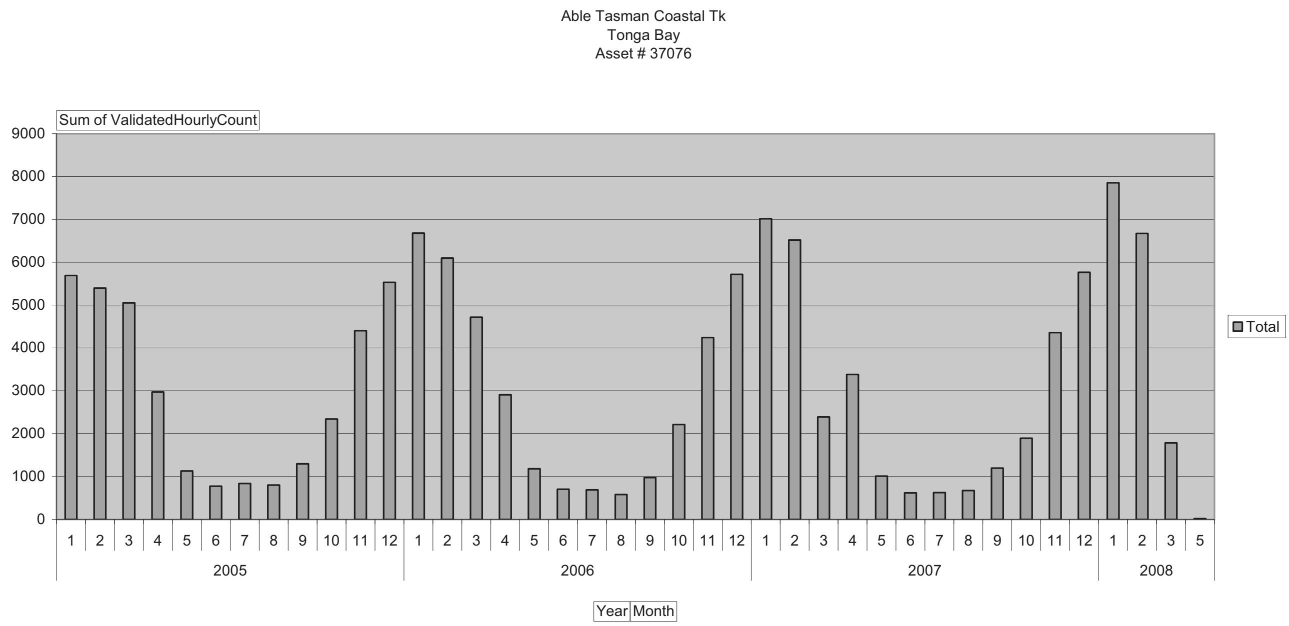


Figure A3.1. Abel Tasman Coastal Track counter, Tonga Bay (Asset #34330). This shows monthly counts for the period of January 2005 – April 2008. Annual patterns of use are highlighted, as well as an underlying trend of increasing use.

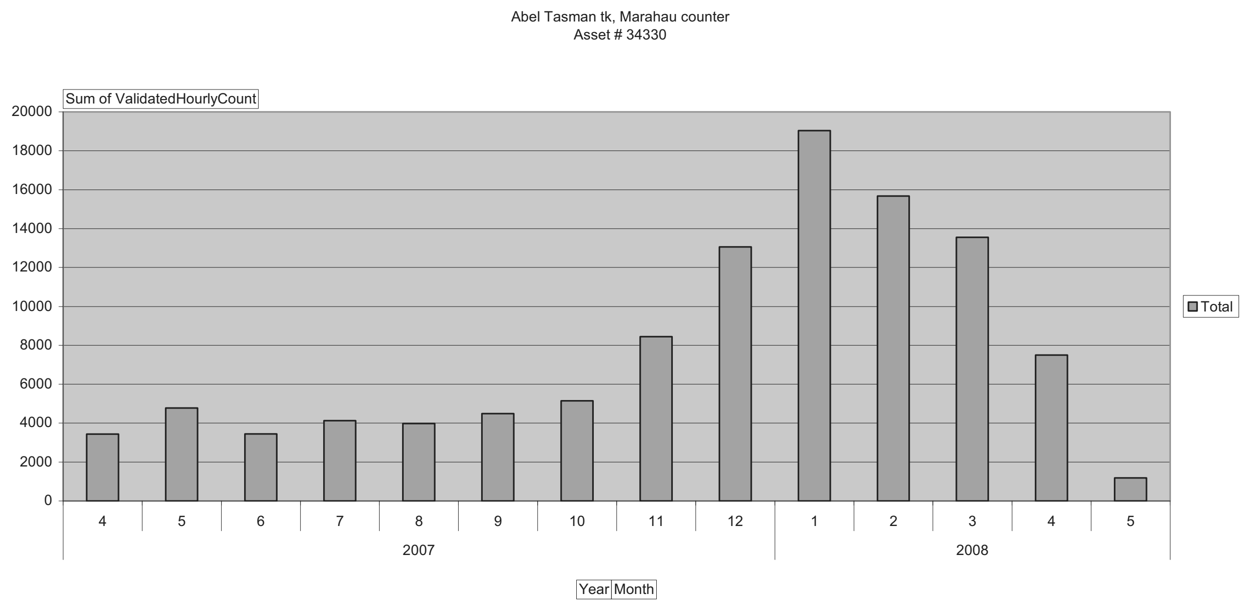


Figure A3.2. Abel Tasman Coastal Track counter, Marahau (Asset #34330). This shows monthly counts for the 1-year period of April 2007 – April 2008. The annual seasonal pattern of use is highlighted.

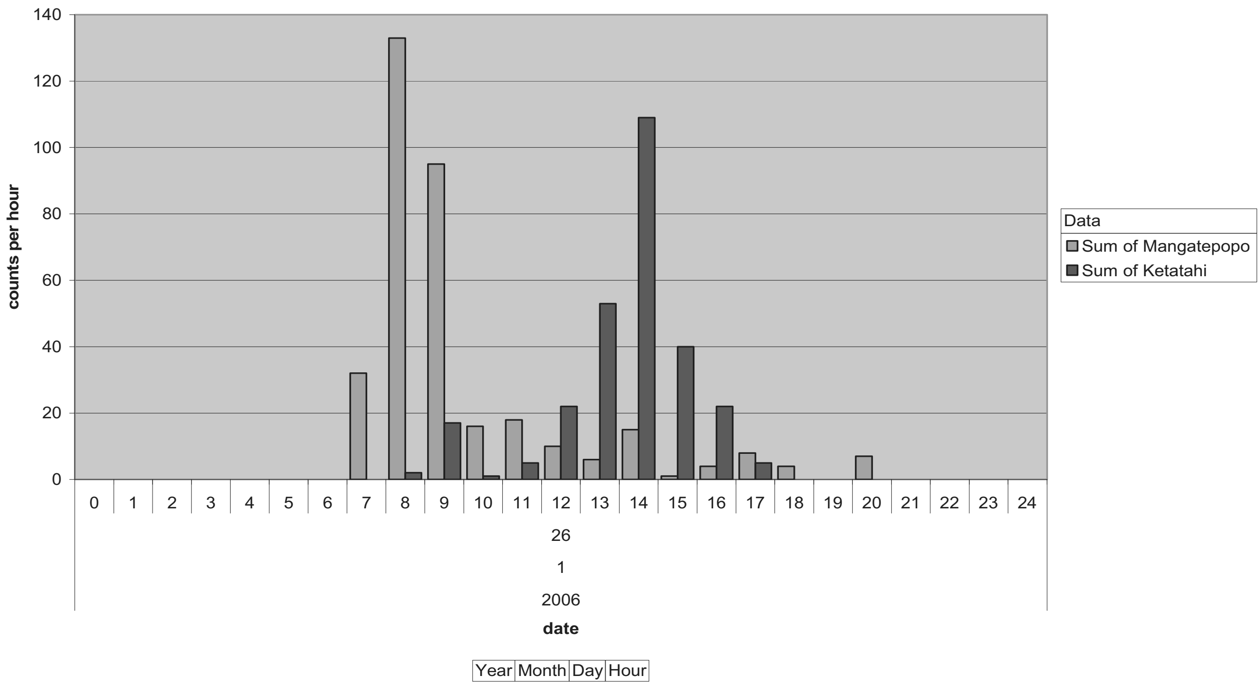


Figure A3.3. Tongariro Alpine Crossing: Mangatepopo counter (Asset #37053) and Ketetahi counter (Asset #37049). This shows a single day's counts from this track on 26 January 2006. The counts came from two counters located at either end of a very highly used Great Walk. This shows that most visitors using this track leave from Mangatepopo carpark and most pass the counter at around 8.00 am. Most then reach the second Ketetahi counter between 1.00 and 3.00 pm. This highlights the largely one-way nature of this track, and the highly concentrated peak of visitor use. This pattern has been shown to be typical for this track.

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