MONITORING VISITOR USE IN AUSTRALIAN TERRESTRIAL AND MARINE PROTECTED AREAS
Practical applications of technologies

Jan Warnken and Michael Blumenstein
Technical Reports

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CONTENTS

ACKNOWLEDGEMENTS II

SUMMARY V

CHAPTER 1 BACKGROUND 1

INTRODUCTION 1
PRINCIPLE OBJECTIVE 2
DETAILED STUDY OBJECTIVES 2

CHAPTER 2 METHODOLOGY 3

GENERAL METHODOLOGY 3
KEY EVALUATION CRITERIA FOR VISITOR SURVEILLANCE AND MONITORING SYSTEMS (VSMS) 3
EVALUATION CRITERIA FOR ADVANCED VSMS 3
VISITOR MONITORING SCENARIOS 4

CHAPTER 3 VISITOR SURVEILLANCE AND MONITORING SYSTEMS (VSMS) 5

LOCATION-DEPENDENT/RESTRICTED SYSTEMS 5
PASSIVE SENSORS 5
Track counters 5
PINGING SENSORS 6
TRANSPONDER TECHNOLOGY (TAGGING) 6
LOCATION-INDEPENDENT (GPS-BASED) SYSTEMS 7

CHAPTER 4 DISCUSSION 9

CHAPTER 5 RECOMMENDATIONS 12

PROJECT A: GPS-BASED TRACKING SYSTEMS FOR PAMS IN AUSTRALIA 12
PROJECT B: A DECISION TOOL FOR SELECTING VISITOR MONITORING TECHNOLOGY 14
PROJECT C: DETAILED INVESTIGATION INTO THE ISSUES ASSOCIATED WITH THE INTEGRATION OF VSMA INTO OTHER PA (AND INDUSTRY) COMMUNICATION, FINANCIAL, BUSINESS AND MARKETING SYSTEMS (PARTICULARLY PARK FEE COLLECTION). 14

REFERENCES 18
ACRONYMS iv
AUTHORS 19

List of Tables

Table 1: Object Tracking or Counting Technologies 1
Table 2: Visitor Monitoring Scenarios in PAS 4
Table 3: Evaluation of VSMS Based on Key Requirements and Desirable Criteria 9

List of Figures

Figure 1: Conceptual Model of Time-Delayed GPS-Based Tracking System in Australia 10
Figure 2: Conceptual Model of Real-Time GPS-Based Vessel Tracking System used by DEC for Two Tourist Vessels in Shark Bay, WA 11
Figure 3: Conceptual Model of Future Work/Projects for Time-Delayed GPS-Based Tracking System in Australia 13
ACRONYMS

DEC      Department of Environment and Conservation (WA)
DPI&F    Department of Primary Industries and Fisheries (Qld)
GIS      Geographic Information System
GPS      Global Positioning System
IR       Infrared Light
PA       Protected Area
PAM      Protected Area Managers
PDA      Personal Digital Assistant
RFID     Radio Frequency Identification
VMS      Vessel Monitoring System
VMU      Vehicle Monitoring Unit
VSMS     Visitor Surveillance And Monitoring System
VTS      Vehicle Tracking System
SUMMARY

This report provides an analysis of potential practical applications of current and upcoming IT-based (digital) monitoring and surveillance systems and technology in other industry sectors for use in Australian terrestrial and marine protected areas. The knowledge generated will provide a basis for the potential future development of reliable and cost-effective methods for monitoring visitor movements and activities, and compliance with park regulations (including user pay systems).

Following outcomes of an initial industry reference group (IRG) meeting, emphasis was placed on vehicle tracking systems for commercial operators and movement detection or tracking technology independent of video or still image analyses. This removed one of the original objectives, review of legal issues pertaining to identification of individual persons by remotely operated optical surveillance equipment.

Objectives of Study

- Provide an overview of visitor surveillance and monitoring scenarios in terrestrial and marine protected areas that would benefit from more detailed information than currently available;
- Review surveillance technology and systems, their potential applicability and practicalities (including simple modifications) that could be employed for visitor surveillance scenarios identified above;
- Provide recommendations for further research and development of surveillance systems with the greatest user potential amongst protected area managers (PAMs) in Australia.

Methodology

Principle technical, operational and managerial information on visitor monitoring activities and technologies was compiled from previous work, interviews of protected area managers and technical consultants (surveillance and tracking industries), extensive Internet searches and attendance of a three day international conference on visitor monitoring and management. Geographic Information System (GIS) overlay analyses were used to highlight some of the particular spatial constraints pertaining to mobile phone technology in Australia. A systematic characterisation of principle monitoring scenarios was used to design a number of evaluation criteria for identifying the currently most advanced and most readily adaptable technologies for visitor monitoring in the Australian environment. Relevant technologies were evaluated were based on technological concepts, their physical limitations and their operational support requirements.

Key Findings

- Mobile phone (GPS)-based post-event vehicle tracking systems (VTSs with data logging capabilities) is the most adaptable visitor monitoring technology currently available;
- Various non-optical technologies for detecting/counting visitors on tracks outside vehicles are still being developed and currently not always reliable;
- Video and still-camera technologies are being developed and trialled, however, most require manual analysis and remain controversial in regard to privacy issues.
Future Action

- Initiate a follow-up study on VTS for use in Australian protected areas (Pas) with the objectives to:
  - investigate current views, interests and attitudes, and future plans of Australian tour operators and PAMs in regard to broad scale implementation of VTSs;
  - investigate in detail the requirements of PAMs, operators and other interested parties in regard to the tasks (types) of data filters for VTS data (in collaboration with transport and logistics);
  - investigate web-based strategies for delivering VTS data filter modules to end users of VTS data.

  and/or

- A second follow up study on developing ‘a decision tool for selecting visitor monitoring technology’ with the objectives to:
  - review of the practicalities of, and experiences with, current technologies in use
  - evaluate each technological approach in regard to range limitations, power requirements, sensibility to adverse weather conditions, opportunities for hiding equipment from sight, interference by wildlife, visitor densities to be monitored, data compatibility to other visitor monitoring exercises, requirements for staff training etc.; and
  - design a decision support model that would rank monitoring technologies based on answers entered by PAMs prompted by a set of simple, straightforward queries.
Chapter 1

BACKGROUND

Introduction

Recent work by Wardell and Moore (2004) on visitor monitoring systems for Australian national parks found that most Australian park agencies relied on traditional, unsophisticated yet robust sampling technology for capturing visitor data in the field. These technologies included mechanical (and occasionally digital) car counters, walking trail registration logbooks, localised surveys and visitor questionnaires, entrance fee records, and web-based surveys. Recently, some park agencies (e.g. DEC WA) started to introduce a limited number of GPS-based vehicle tracking systems for marine operators (Shark Bay Marine Park).

With the exception of VTSs and surveys, the majority of these approaches provided only spatially or temporally limited information about visitor movements within protected areas. Without more detailed and long-term data, management planning decisions are based on managers’ perceptions, which tend to be influenced by external (financial and political) pressures (Pitts & Smith 1993). Planning based on predominantly subjective observations can become problematic when trying to find the most efficient solution for striking a balance between conservation and visitor recreation. Even more advanced planning exercises using agent-based modelling approaches ultimately require validation of model outcomes against the real world phenomena (Cole 2005, Skov-Petersen 2005).

The advent of inexpensive, mass-produced IT-based tracking and communication devices has opened up a number of opportunities for automatically collecting ongoing data of visitor movements in remote locations in protected areas. Potential technologies range from optical surveillance devices (digital video or still cameras) to radiofrequency identification (RFID) tags and GPS and transponder-based based tracking systems. Table 1 lists a number of examples based on their principle mode of operation and the type of object they can detect (for more detailed description see Chapter 3).

<table>
<thead>
<tr>
<th>Technological principle</th>
<th>Basic requirements</th>
<th>Examples</th>
<th>Objects</th>
</tr>
</thead>
<tbody>
<tr>
<td>A) location restricted/dependent</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1) sensing of signals emitted by object (passive detection)</td>
<td>a ‘natural’ signal emitted by the object of interest strong enough to allow detection against background signal / ‘noise’ (and natural variations in background signal)</td>
<td>track counters (digital, ground vibration), wireless sensor networks (WSN) with motion detection motes, vis-video or camera surveillance (motion sensor activated), infrared image analyses</td>
<td>Visitors on foot</td>
</tr>
<tr>
<td>2) detecting reflection of signals emitted from a base station (pinging)</td>
<td>detection of a reflection of a unique (strong) signal (often coupled with information from transponder)</td>
<td>military or commercial radar (commercial aircraft and vessel traffic surveillance systems, speed radar), sonar (U-boat or mine detection, fish finder, etc.)</td>
<td>Vehicles</td>
</tr>
<tr>
<td>3) detection of specific transponder signal (tagging)</td>
<td>some type of unique ID tag (actively or passively transmitting object info) to be fixed to object of interest, and one or several local receivers (beacons or base stations) to detect presence / position of ID tag</td>
<td>RFID tags, swipe cards, toll bridge systems, mobile phone / PDA tracking, vehicle location systems, aircraft transponder</td>
<td>Visitors and vehicles supplied / fitted with tags</td>
</tr>
<tr>
<td>B) location unrestricted/independent</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GPS-based</td>
<td>access to GPS signal (satellites) and mechanisms for data storing and/or data transmission to central processing unit</td>
<td>fleet (vehicle, trailer, container) management systems, fishing vessel tracking (QFS BNE), truck toll system for German highways</td>
<td>Visitors and vehicles supplied / fitted with GPS receivers and data logging or data transmission devices</td>
</tr>
</tbody>
</table>
**Principle Objective**

The principle objective of this report was to identify the type of technology that would be most suitable for further developing visitor monitoring technologies in the Australian context.

**Detailed Study Objectives**

- Provide an overview of visitor surveillance and monitoring scenarios in terrestrial and marine protected areas that would benefit from more detailed information than currently available;
- Review surveillance technology and systems, their potential applicability and practicalities (including simple modifications) that could be employed for visitor surveillance scenarios identified above;
- Provide recommendations for further R&D of surveillance systems with the greatest user potential amongst PAMs in Australia.
Chapter 2

METHODOLOGY

General Methodology

The study encompassed three phases: (1) investigation of monitoring scenarios, (2) investigation of monitoring technologies, and (3) evaluation of technology against key requirements and other desirable criteria. For phase one, principle technical, operational and managerial information on visitor monitoring activities was compiled from one major previous study in Australia (Wardell & Moore, 2004) and interviews of protected area managers (PAMs). For phase two, the technological concepts, potentials and limitations of various visitor monitoring approaches were analysed through discussion with technical consultants (surveillance and tracking industries), extensive Internet searches and attendance of a three-day international conference on visitor monitoring and management. Spatial aspects pertaining to mobile phone technology in Australia were highlighted using Geographic Information System (GIS) overlay analyses and visual interpretation of thematic maps (where information was only available in image format). Finally, a contrasting, systematic characterisation of principle monitoring scenarios and technological concepts, their physical limitations and operational support requirements was used against a number of evaluation criteria (phase three) to identify the currently most advanced and most readily adaptable technologies for visitor monitoring in Australian protected areas (PAs). Evaluation criteria were developed to ensure identified systems would match intended uses and requirements of PAMs.

Key Evaluation Criteria for Visitor Surveillance and Monitoring Systems (VSMS)

Agencies managing protected areas are generally under considerable financial pressure to stretch their limited government funding to their growing number of estates and assets, and increasing visitor demands on service infrastructure. For the majority of PAs, this leaves only limited opportunities for investment in new technologies. Accordingly, one of the key assumptions for this project was that VSMS technologies had to be inexpensive in terms of costs per unit (hardware), costs for R&D, and effort and costs for maintenance. Low per unit costs are typically achieved by high production volume (number of systems built and in use), which reduces costs for hardware, economises maintenance, and lowers charges for R&D cost recovery. In other terms, the potential for widespread applicability was nominated as a key evaluation criterion for a more advanced VSMS.

Initial discussions with PAMs provided a second key assumption for new and advanced VSMS. Australian PAMs were not supportive of technologies that had the potential of generating scenarios which could be considered as an interference with privacy issues or viewed as the ‘big brother’ approach.

Other assumptions included that already existing duties of PAMs left little time for becoming acquainted with new and difficult to operate technology. In other terms, new VSMS had to be user friendly and reliable for both field staff as well as end users (managerial staff in regional and head offices).

These and other evaluation criteria resulted in a set of detailed key requirements and desirable selection criteria for advanced VSMS in Australia.

Evaluation Criteria for Advanced VSMS

Key requirements for future VSMS:

- provision of reliable (accurate) data (counts, movements) under highly variable and adverse weather and terrain conditions;
- wide applicability (i.e. for a number of monitoring scenarios, in remote marine as well as in terrestrial environments, for commercial operators as well as recreational visitors);
- high level compatibility and technology transfer with other industry sectors (to obtain maximum benefits from R&D funded outside the tourism sector);
- easy to use (all parties: visitors, operators, PAMs);
Practical Applications of Technologies

- low maintenance costs (e.g. low vulnerability to vandalism; long maintenance intervals (including supply of energy));
- low exposure to scenarios leading to interference with the protection of people’s privacy.

Desirable criteria for future VSMS:
- ability to collect directional information (visitor movements) (essential for some purposes);
- automatic relay of data from remote locations in readily usable formats for incorporation in visitor monitoring systems used by PAMs;
- relay of information back to visitors and operators, provision of benefits to all parties (PAMs, visitors and operators), including cost sharing potential;
- (where required) low-effort mechanisms to enforce/encourage the use of the equipment;
- capacity to incorporate the transfer of financial and invoicing data to PAM financial systems.

Visitor Monitoring Scenarios

For assessing the applicability of VSMS, two principle groups or classes (visitors in motorised vehicles, visitors outside motorised vehicles) and several subgroups or subclasses of visitor monitoring scenarios were used based on the mode of operation and travel and, for visitors outside engine powered-vehicles, whether the travel occurred on land or on water (Table 2).

Table 2: Visitor monitoring scenarios in PAs

<table>
<thead>
<tr>
<th>Type of visitor</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>People in motorised vehicles</td>
<td></td>
</tr>
<tr>
<td>commercial (licensed) operators</td>
<td>operators using buses, 4WDs, vessels, etc. in terrestrial and marine parks, bus charters (Oz Experience, Greyhound etc.)</td>
</tr>
<tr>
<td>individual travelers using a hire vehicle</td>
<td>national and international visitors using hire cars, including major car hire companies (AVIS, Hertz, Europcar, Thrifty, Maui, etc.), local self-drive 4WD tours, bare boat charters, etc.</td>
</tr>
<tr>
<td>individual travelers using their private vehicle</td>
<td>Semi-retired and retired long distance caravan travellers, day trippers, domestic visitors with own vehicle</td>
</tr>
<tr>
<td>People outside motorised vehicle</td>
<td></td>
</tr>
<tr>
<td>individuals or groups (incl. guided tours) outside a powered vehicle on dry land</td>
<td>day trippers, adventure tourists and hikers in parks, on beaches etc.</td>
</tr>
<tr>
<td>individuals or groups (incl. guided tours) outside a powered vehicle in or under water</td>
<td>swimmers, snorkellers, divers,</td>
</tr>
</tbody>
</table>

Note: the term engine-powered vehicle includes cars, 4WDs, minibuses, campervans, buses and trucks and also any type of vessel, including larger wind-powered craft with onboard engines (aircraft are not included as they are already closely monitored under air safety regulations).
Chapter 3

VISITOR SURVEILLANCE AND MONITORING SYSTEMS (VSMS)

VSMS can be separated into two types: those that use sensors which will be installed in one location to count or track any object of interest (location-restricted), or those that are installed with every unit to be monitored using GPS signals (location-independent, see Table 1).

Location-dependent/Restricted Systems

These types of VSMS can be separated into three subgroups, depending on their principle mode of object or motion detection (sensors): passive sensors, pinging sensors (emission of signal and retrieving of reflected signal) and tagging sensors (tri-angulations or detection of bearing and distance of a transponder emitting a unique signal).

Passive Sensors

Track Counters

The most common types of passive VSMS sensors are used for counting people on tracks, walkways, bicycle paths and other pathways. They all require a local power source (battery or solar) and a data logger, and have to be hidden from view by either concealing them under the path or in posts adjacent to the path. Track counters can use a range of detectors ranging from step (pressure) mats, acoustic slabs, pyro-electric (passive IR (near and middle range), active (beam) IR) sensors, hydro-acoustic tubes (for bicycles, wheelchairs, etc.), or Zelt-inductive loops. The resulting data are mostly counts with no directional information. Rain, ambient temperature and humidity, animal movements, changing track conditions (e.g. hardening during droughts) and high visitor densities can affect the accuracy of these detectors (Rupf-Haller et al. 2006). Some more advanced systems combine two or more detectors, which increases accuracy and allows detection of directional movements (Lue 2006). All systems are potentially vulnerable to vandalism and require regular calibration and inspection (Ross 2005), manual data transfer from data loggers (via cable or Bluetooth technology), and replacement of batteries (main power supply or back-up [solar]).

Although currently still expensive, military applications are pushing the development of wireless sensor networks (WSN) with motion detection motes. Depending on the sophistication of the network and its sensors, this technology is capable of detecting directional movements and relaying information back from remote sensors to a central unit.

Digital video or still camera counters (Vis or IR)

Original work with video or still camera was very limited due to the limited image storage capacity of wet films and magnetic tapes (see also Arnberger et al. 2005). Recent advances in digital data storage technology (memory cards) have provided the platform to use digital still cameras or time-lapsed video cameras for monitoring people in PAs. The camera-internal calculations for image capture, processing and storage still require considerably more energy than basic track counter sensors. Accordingly, camera systems should be kept in power-save mode unless an object is in range, which can be indicated by motion or IR sensors linked to the system. The current key problems with this technology are (a) the potential for violation of privacy laws (producing images that allow identification of people) and (b) the lack of automated image analysis software. Image resolution of such systems is usually kept at a minimum (to increase the number of images to be stored), and lenses are often covered with a dispersive film (e.g. grease) to blur the images collected from visitors in PAs thereby protecting visitor identities (Campbell 2006). Such blurred images are difficult to analyse by object recognition software, which leaves post-event evaluation of images a laborious, at times mind-numbing, manual and therefore expensive exercise.

Producing images of visitors can also lead to legal conflicts: a person willingly destroying or damaging a camera, who has been photographed at close range allowing her/his identity to be determined, is liable for civil damages and possibly committing a criminal act (depending on the legislation). Laying claims or charging such a
Practical Applications of Technologies

person, however, may amount to a violation of the protection of rights to privacy. Even discussing such events, including the possibility of accidentally creating a situation where individuals can be identified, during internal meetings to decide how to deal with such acts of vandalism can lead to serious problems with PA users if such information leaks to the general public (Hennig, pers. com. 2006). Another issue relating to any locally visible device relates to interference, rather than vandalism: some visitors will jump on track counters or pass a hand in front of infrared beams, or repeatedly move backwards and forwards at the point of monitoring to disturb or fool the system wherever a monitoring unit is visible.

Pinging Sensors

These types of sensors are mostly derived from military radar and sonar technology. They require a strong source of the probing (pinging) signal, suitable surface materials to reflect the probing signal, and a very sensitive and discriminative detection device. Current military and commercial naval and aircraft technology has become very sophisticated but is expensive and energy demanding. However, steep terrain is difficult to cover and visitors outside vehicles provide no suitable surfaces to reflect the probing signal. Radar technology is most effective for surveillance of air spaces and marine environments. Experiences with using radar for tracking mountain bikers in Switzerland have been unsatisfactory (Iten, pers. com. 2006).

Transponder Technology (Tagging)

The key concept of these devices is the emission of a unique code sequence that is recognised by one or several specific detectors, i.e. receiver stations or beacons. The unique code sequences can be emitted actively using a small internal or external power source, or they can be emitted passively, i.e. by backscattering a strong electromagnet input signal. The key differences between these two types are their costs and the distance over which they operate: passive radio frequency identification (RFID) tags are inexpensive (~ 10 cents) and emit signals at distances between 10 centimeters to ~ two meters, whereas active RFID tags (> ~ $ 2.-) or common transponders (> $ 10.-to up to > $ 100.-) can emit a signal between up to 100 meters or even several kilometres (depending on the power source and type of device). Active RFID tags and transponders can also hold more information, can be equipped with other sensors and, in some cases, can process and relay information about the current status of the object to be tracked.

In both cases, objects (in this case visitors to PAs or their vehicles) have to be equipped with tags; and detector stations or readers have to be supplied with external power, a data logger or data relay link, and ongoing inspections (maintenance) to ensure readers are functioning. Tracking the movements of objects carrying passive RFID tags requires a large number of detectors (only a pass can be detected) and a central processing unit to analyse the sequence of detected passes. This technology has been widely implemented for manufacturing and logistics processes where detectors can be installed so that objects have to pass in close proximity. Signals of active tags and transponders can be triangulated or tracked at greater distances by determining its bearing and distance to the detector. Readers for passive RFID tags (including swipe cards) require additional mechanisms to guide people to pass within one or two metres of the reader, e.g. a boom gate or a trail entrance gate.

The key limitation of these systems is the relationship between the monitoring distance and costs: the longer the distance between the tag and the reader, the more expensive the tag. The low costs of passive tags allow their use as a throw-away item (incorporated into entry passes or wrist bands), whereas active tags should be recovered from objects (visitors) after their use (possibly with a postage paid stamp on their back to be mailed back to PAMs in case the return of a smart card or other type of transponder has been overlooked). For monitoring visitors in controlled areas (e.g. camping grounds, visitor centres, entrance gates) PAMs need to carefully analyse the overall costs for installation and maintenance of boom gates and other entry control mechanisms, RFID tag readers, and their requirements for power and data relay before replacing existing systems. In popular areas, i.e. areas with many visitors and under regular surveillance of PA maintenance staff, electricity grid connected RFID tag systems could provide a more cost-effective alternative to salaries (including on-costs) for gate personnel and manual data entry. Vulnerability to vandalism and higher maintenance and power supply costs would, however, limit the use of RFID tags in remote areas receiving only a few visitors a year.

Cellular (Mobile) Phone Tracking

In principle, cellular phones resemble a transponder. Each mobile phone unit has a unique ID code, and the location of the unit is constantly monitored for providing the best access to the nearest available base station. With information from several base stations, the position of a mobile phone can be determined with 50 to 100
metre accuracy (depending on the density and number of base stations available). Because the user (visitor) carries her/his own transponder, and the ‘readers’ are existing cellular phone base stations, no hardware installation or maintenance is required. The key problems are that (a) most PAs in Australia are located outside urban areas where cellular phone coverage is limited or not available at all, and (b) tracking of cellular phones without consent of the unit’s owner can lead to violations of privacy rights (dependent on the information released by mobile phone tracking providers). In the current legal environment in Australia, mobile phone users have to give permission to mobile phone services providers to release information about the use and the location of a mobile phone unit. In theory, however, for monitoring visitors in large urban parks (> 10 hectares), this technology can provide useful information about visitor movements (the number, time of entry and subsequent exit, and to some extent the route taken, of mobile phone units in an area of interest).

### Location-Independent (GPS-based) Systems

Turning off the ‘selective availability’ of the global positioning system (GPS) on 1 May 2000 and thereby increasing the position accuracy from ~ 150m to between 5–15m has triggered a rapid development of non-military GPS-based tracking systems and products. The key components of a GPS-tracking system include a GPS receiver, a data logging or storing device, a data relay mechanism (often combined in one unit) and a (back end) central data processing facility. Objects, including visitors and their vehicles, that have been fitted with such units can be tracked anywhere in the world, provided their GPS units can receive the signals from at least three GPS satellites. Australia’s vast flat open landscapes and eucalypt forests with mostly dry open canopies usually provide the ideal terrain for GPS tracking. Most GPS systems provide unit holders with navigational information and, at the same time, collect information about the route and velocity of the object. Real-time and time delayed GPS-based vehicle/vessel tracking systems are now employed for monitoring shipping containers, trucks and semi-trailers, commercial fishing vessels (DPI&F VMS, Queensland), bus transport systems (Perth), stolen vehicles, people with GPS-enabled mobile phones or PDAs, and even automatic collection of highway toll charges from transport companies (TollCollect, Germany). The latter represents a multi-billion dollar operation, which uses specially developed on-board units (OBUs) and tracks several hundred thousand trucks over thousands of kilometres of roads and highways. After some initial glitches in the first two years of operation, the system is now almost flawless and has attracted considerable interest from other countries in Europe and outside. In terms of conservation management, VTSs have been primarily implemented for controlling fishing vessels and catch quota—commonly as real time systems via expensive satellite links (e.g. in Canada, US, Australia).

Real time GPS-based object tracking systems require a continuous data relay mechanism, usually via the SMS mobile phone network or satellites. Time-delayed systems require an on-board data logger to store the collected data until the object (person, vehicle) reaches a location where data can be reliably relayed back to the central data processing facility.

A number of recent developments have increased the potential for a more widespread application of this technology:

- the roll-out of the 3G cellular phone network which will reduce data transfer costs substantially;
- the increasing production of in-car satellite navigation systems (e.g. TomTom) and the development of better and more integrated multi-functional PDA units bringing down hardware costs;
- the emergence of small web-based VTS service providers; and
- the development of industry standards for VTS tracking providers under the National Transport Commission (NTS) (Model Legislation – Intelligent Access Program) Regulations 2005 (Cth).

Depending on additional data input (e.g. persons in a monitored vehicle) and data filters developed for the central data processing unit (usually a dedicated server) GPS-based VTS data can be employed to perform the following tasks related to:

- park management
  - electronic (automated) entrance (camping) and licence fee payment (pay as you enter / user pays [per site or area per person per day])
  - licence compliance monitoring of commercial operators (mostly marine parks and parks with off-road access)
  - general use monitoring (behaviour, densities and flows) of protected areas and general tourist areas;
- tour operations
  - monitoring of fleet vehicle use (major operators) and compliance with road/maritime safety standards (all operators)
  - navigation
Practical Applications of Technologies

- communication / advertisement of travel routes
- safety / security system for emergencies / breakdown.

The key advantages of a GPS-based tracking system for monitoring visitors in PAs are:
- visitors and operators can use these systems almost anywhere in Australia (in most terrestrial [excluding dense forests with moist canopies] and all marine environments);
- no installation of equipment in PAs is required and, therefore, GPS-systems are practically immune to vandalism;
- potential for providing useful navigation (and other, business relevant) information to the unit user (visitor, operator);
- all data can be processed centrally and automatically;
- most R&D for the tracking system is carried by other industry sectors; and
- equipment installation, maintenance and updates can be outsourced to VTS service providers.

The key constraints for a GPS-tracking system relate to
- cellular phone coverage for relaying data back to a central data processing unit (or, alternatively, the high costs for data transfer via satellites, e.g. Inmarsat C);
- the investment in a large number of GPS-tracking units; and
- policing of the correct use of this system where other than positional information is to be collected (e.g. numbers of passengers in a vehicle for automatically calculating park entry fees).

GIS overlay analyses of ABS tourist accommodation data, major transport nodes (air, road), PAs and the TELSTRA mobile network coverage (Appendices A to C, Queensland as an example) clearly indicate that real-time GPS-tracking would not be feasible using cellular phone systems. Most tourism hot spots (major and minor destinations), however, have good coverage, allowing data packages to be sent when tourists are picked up or returned after their day trip, or when they arrive after a few days travel at a major destination. Such time-delayed systems also carry the advantage that travellers are protected against any person or entity that may wish to use real time position information to the detriment of a person subject to GPS tracking. On the other hand, time-delayed systems would fail to send out an emergency signal in an area without cellular phone coverage.

PDA technology requires some more detailed consideration. The location of PDAs can be traced in two ways:
- if they are GPS-enabled, by simply collecting position information, provided the user/operator has authorised such data transfer;
- by monitoring information downloads from stations dispersed in the area of interest. In this case, a PDA operates similar to an RFID tag with the PDA unit and its IP address as the tag and the closest download station in the field the ‘beacon’.

The key problem with PDAs is their current value: if handed out to visitors, temptation of theft exists as some of these units are currently expensive. Where visitors use their own PDA, PAMs are advised to set up a system under which the PDA operator agrees in writing to having her/his position tracked in exchange for free information about the area to be visited.
Chapter 4

DISCUSSION

Currently there is no single visitor monitoring technology that would be applicable to all monitoring scenarios in Australian PAs. Some technologies are very location specific, while others provide more opportunities for adaptation to a range of scenarios and locations. Table 3 below summarises a basic evaluation of all principle VSMS technologies against requirements and criteria identified in Chapter 2.

Table 3: Evaluation of VSMS based on key requirements and desirable criteria

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Track counters</th>
<th>Video, still cameras</th>
<th>Pinging sensors</th>
<th>Passive RFID</th>
<th>Active RFID</th>
<th>Cellular phones</th>
<th>Real time GPS tracking</th>
<th>Time delayed GPS tracking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data accuracy (location or count)</td>
<td>IM</td>
<td>High</td>
<td>IM</td>
<td>High</td>
<td>IM</td>
<td>Low</td>
<td>high</td>
<td>High</td>
</tr>
<tr>
<td>Applicability</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Terrestrial PA, vehicles</td>
<td>Yes</td>
<td>Yes</td>
<td>(Yes)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>(Yes)</td>
<td>Yes</td>
</tr>
<tr>
<td>Terrestrial PA, persons</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>(Yes)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Marine PA, vessels</td>
<td>No</td>
<td>(Yes)</td>
<td>No</td>
<td>Part</td>
<td>Part</td>
<td>(Yes)</td>
<td>(Yes)</td>
<td>Yes</td>
</tr>
<tr>
<td>Marine PA, persons</td>
<td>No</td>
<td>(Yes)</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Tech transfer with other industries</td>
<td>Little</td>
<td>Some</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Easy to use, visitors and operators</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>IM</td>
<td>IM</td>
<td>IM</td>
</tr>
<tr>
<td>Easy to use, PAMs</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>IM</td>
<td>IM</td>
<td>Yes</td>
<td>(Yes)</td>
<td>(Yes)</td>
</tr>
<tr>
<td>Maintenance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy demand#</td>
<td>Low</td>
<td>IM</td>
<td>High</td>
<td>High</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Inspection and calibration</td>
<td>High</td>
<td>High</td>
<td>IM</td>
<td>High</td>
<td>IM</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Vandalism</td>
<td>High</td>
<td>High</td>
<td>IM</td>
<td>High</td>
<td>IM</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Protection of privacy</td>
<td>High</td>
<td>Low</td>
<td>High</td>
<td>IM</td>
<td>IM</td>
<td>Low</td>
<td>IM</td>
<td>IM</td>
</tr>
<tr>
<td>Directional data, movements</td>
<td>No</td>
<td>(Yes)</td>
<td>Yes</td>
<td>(Yes)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Automated relay of data</td>
<td>(Yes)</td>
<td>(Yes)</td>
<td>(Yes)</td>
<td>(Yes)</td>
<td>(Yes)</td>
<td>Yes</td>
<td>(Yes)</td>
<td>Yes</td>
</tr>
<tr>
<td>Benefits to visitors as well as PAMs</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>(Yes)</td>
</tr>
<tr>
<td>Policing of use required</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Some</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

NOTE:
High = high level of technical performance (accuracy or reliability, etc.), high demand (energy, etc.) or high likelihood (e.g. vandalism);
IM = intermediate performance, likelihood (as above);
Low = low performance, low likelihood, etc. (as above);
(Yes) = theoretically possible, but either practically difficult or expensive to implement or not yet developed;
Part = can be applied in some but not all situations;
# demand on energy to be provided by PAMs (commonly in remote locations with no access to the main electricity grid).

Results from this comparison indicate that tracking people (or any other object) immersed in water is inherently difficult: water limits transmission of electromagnetic waves considerably and, accordingly, visitor monitoring technologies are largely restricted to video and still camera technologies, or sound wave technologies with their sensitivity to environmental changes (temperature, salinity, etc.). Track counters are restricted to terrestrial environments and, apart from permanently installed Zelt-inductive loops (traffic control), have little overlap with other industry sectors. Most equipment items also require initial calibration and, subsequently, ongoing inspection and service. RFID tags could be very useful in monitoring visitors in controlled environments, i.e. situations where visitors have to pass close to structures such as entrance gates that could be fitted with readers. Pinging technologies (such as radar) and cellular phone tracking appear to be mostly unsuitable for monitoring visitor movements in Australia.
Time-delayed GPS-based tracking technologies are considered to be the most widely applicable system with strong links into other industry sectors, a great potential for providing fully automated data processing and outsourcing of all equipment maintenance, service and updates. The two greatest advantages of this technology lie in the ability to generate, or return, useful information to visitors or operators (e.g. navigational aids, location specific information), and to record movements to manage and plan for existing visitor use and potentially contribute to, agent-based simulation modeling of future use-scenarios. Another factor is the potential of this technology to utilise and combine existing hardware such as PDAs, in-car navigation systems and vehicle monitoring units (VMUs). Figure 1 below highlights some possible approaches for implementing GPS-based object tracking systems and their potential for feeding information to various end users. Ultimately, GPS-based tracking systems can even lead to new marketing products for tour operators, e.g. a password protected web-tool for informing friends and relatives where their clients have been travelling and, at the end of the trip, an automatically generated map of the tour and the sites visited.

**Figure 1: Conceptual model of time-delayed GPS-based tracking system in Australia**

GPS-based vehicle tracking systems also have the potential to establish a more detailed user pays system for operators and visitors, based on a per site (within a PA) and per visitor and seasonal basis. Each time a licensed operator with a GPS-based tracking system carries visitors to a particular site within a PA, a location-based query will determine which sites have been used and, depending on the charges associated with each site and the number of visitors entered by the operator (potentially as a Bluetooth-enabled download from the operator’s booking system), generate an account for each trip.

The key challenge for PAMAs is to manage (aggregate) the large amount of data that are produced by VTSs. Experiences with only two vessels monitored in real time by CALM in Shark Bay (see Figure 2 below) clearly demonstrate the need for either employing or assigning a staff member to visually check the operators movements on a remote screen display, or to design a system of queries that filters and displays only those data of interest, in the case of violation of licence conditions (speed, time at a specific place or in area where animals were observed).
Figure 2: Conceptual model of real-time GPS-based vessel tracking system used by DEC for two tourist vessels in Shark Bay, WA.
Chapter 5

RECOMMENDATIONS

All technologies discussed in this report have advanced, and are rapidly advancing, with the development of increasingly faster, smaller and more reliable hardware and battery technology. Currently there is no technology that would fit all applications. In order to decide which technological concept to pursue, PAMs need to analyse at first what their visitor monitoring needs are (e.g. entry gates only or movements within or between PAs, real-time or time-integrated, speed and other behaviour or not). Secondly, PAMs need to compare costs of manual data collection systems requiring staff time (observations, surveys, entry pass sales) with automated systems and their various economic set-ups (e.g. fully owned and maintained by PAMs vs. outsourcing of maintenance or lease systems). At a broader scale, further research is required to fine tune some of the technology concepts identified above, particularly VSMS as they represent the most broadly applicable technology. Based on the analysis and discussion of current VSMS, the following two studies have been suggested for further developing VSMS in the Australian context.

Project A: GPS-based Tracking Systems for PAMs in Australia

GPS-based object (vehicle or PDA)-based tracking systems are rapidly evolving in the transport and logistics sector. Several small Australian companies are currently emerging to supply GMS/Internet-based vehicle tracking solutions (VTS) under standards recently developed by the Transport Certification Authority (TCA). Tour operators and PAMs can adapt these systems to suit a range of needs including compliance management in sensitive areas, automated entrance fee collection, tourism use analyses and more. DEC WA has already implemented a first trial VTS system to monitor compliance of vessel based tour operators in the Shark Bay Marine Park which is part of the Shark Bay World Heritage Area.

Operators and managers can enter into lease agreements with VTS providers to install hardware for collection of GPS data (possibly with other attribute information), thereby outsourcing all system maintenance tasks. Once in place, VTSs will produce large amounts of data. The key need for widespread adoption of such GPS-tracking solutions is a system of filters (automated spatial queries) that (a) allow end-user defined condensation and extraction of data of interest (e.g. violations of licence conditions) and (b) provide user-defined reports on movements over defined time periods (e.g. daily use of fee-attracting sites within parks)—both to be displayed against background spatial information (user-defined maps). Other key issues are protection of privacy of operators and their clients, resentment against surveillance in general, and data ownership, particularly if aggregate data are to be provided to third parties (e.g. tourism management agencies).

Future research/work on VTS for PAMs needs to:

- investigate what type of common data filters are required by PAMs or other end-users and how to display user-defined query results in different environments (e.g. with or without end-user supported GIS) (and, at the same time, explore solutions for accelerating the uptake of this technology);
- develop solutions for providing managers with easy-to-use interfaces to design data filters (queries) and add additional (visitor-related) data to tracking information;
- analyse legal issues pertaining to data ownership and protection of privacy.

Research under (1.) would complement work already undertaken for DECIPHER (an Internet-based data mining and retrieval tool for tourism operators, www.decipher.biz) and related projects (data mining and provision of background information [maps]). Work for (3.) would in parts also rely on expertise gained through the DECIPHER project (legal issues of data acquisition and data distribution protocols).
By investing in this technology, STCRC in collaboration with its stakeholders could develop a product/company that processes most or all spatial information generated by major tour operators using terrestrial AND marine PAs in Australia. Based on a conservative estimate of 1/3 of all PA-based tour businesses being large enough to warrant such monitoring, the number of participating operators would easily extend beyond 5001.

Potential industry collaborators include PAMs, large tour operators, Qld DPIF (Vessel Monitoring System), BlackboxControl (GMS-VTS provider), spatial information providers (MapInfo Australia, SENSIS), and perhaps even hardware suppliers (HP, TomTom).

Figure 3 below provides a schematic diagram of VTS technology and the position of the work for this study.

**Figure 3: Conceptual model of future work/projects for time-delayed GPS-based tracking system in Australia**

NOTE: This project’s commercial potential extends into other industry sectors (e.g. vehicle operator compliance monitoring in the mining sector). Collaboration with other CRCs (Spatial data and GIS, mining?) is highly desirable.1

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1 e.g. 1/3 of 300 operators licensed by Parks Victoria, > 300 bare boat charter licences in the Whitsundays, all major reef and megafauna watching tours, tour and hire vehicle operators on Fraser Island.
Project B: A Decision Tool for Selecting Visitor Monitoring Technology

A second, much smaller project would entail development of a decision support system or manual to allow managers to select the most appropriate local solution for counting visitors (outside vehicles) in PAs (incorporating locality aspects, accuracy, equipment and maintenance costs, vulnerability to vandalism, data transfer etc.). This project would require a detailed review of the practicalities of, and experiences with, current technologies in use (IR (pyroelectric) counters (active, passive), acoustic slabs and tubes, zelt inductive loops, time lapse video, IR activated digital (still) cameras, radar, mobile phone tracking, swipe cards and RFID tags etc.) with focus on range limitations, power requirements, sensibility to adverse weather conditions, opportunities for hiding equipment from sight, interference by wildlife, visitor densities to be monitored, data compatibility to other visitor monitoring exercises, requirements for staff training etc. The resulting tool would provide references to major national and international suppliers and be made available (for an appropriate fee) to any PAM who wishes to install a visitor monitoring device or system. R&D of this tool would rely on a snowball effect starting with members of the MMV-3 network of researchers and practitioners.

NB: The potential end-users of the tool developed by this project would be limited to managers of protected areas (federal, state and local authorities, national and international) and occasionally local land owners. Collaboration with international PAM organisations, overseas research providers and national PAMs is highly desirable.

Project C: Detailed Investigation into the Issues Associated with the Integration of VSMA into other PA (and Industry) Communication, Financial, Business and Marketing systems (particularly park fee collection)

This would include investigating the feasibility (financial, technical and political) of developing the integration of these systems. Ultimately, this concept would lead to an automated exchange of relevant data between different park management systems. Practical examples would include to implement automatic on-line charging and payment systems for operators, query tools to extract relevant visitor use and revenue statistics at almost any desired scale (single locations in a park to a whole group of parks in an operator-defined region) and overlay tools to compare park characteristics, marketing initiatives and investment with visitor data.

The concept is illustrated below:

**Three Primary Goals**

**Primary**
- Increase revenue and financial efficiency
- Improve quality and quantity of data capture and increase/improve monitoring
- Decrease the cost of management and monitoring
- Improve visitor experience

**Secondary goals**
- Improve industry returns
- Provide market research data

**Essential elements**
- Research underpinning
- Integration
- Information technology and communication
- GPS technology
- Smart card technology
- Database management
- Internet capabilities
- Industry partnerships
- Interagency cooperation
APPENDIX A: ABS March quarter 2006 guest nights, and road and air transport nodes
APPENDIX B: Major tourist destinations and PAs under Qld State Government authority
APPENDIX C: Telstra mobile phone coverage and major tourist destinations
REFERENCES


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EC3, a wholly-owned commercialisation company, takes the outcomes from the relevant STCRC research; develops them for market; and delivers them to industry as products and services. EC3 delivers significant benefits to the STCRC through the provision of a wide range of business services both nationally and internationally.

- New products, services and technologies
- Uptake of research findings by business, government and academe
- Improved business productivity
- Industry-ready post-graduate students
- Public good benefits for tourism destinations

**Industries**
- Travel and tourism industry
- Academic researchers
- Government policy makers

**University Partners**
- Southern Cross University
- Griffith University
- James Cook University
- Bond University

**Commercialisation Partners**
- Curtin University
- Queensland University of Technology
- Bond University
- University of the Sunshine Coast

**Innovation**
- Collaboration
- Research and Development
- Commercialisation
- Education and Training
- Utilisation

**Key Products**
- Travel and tourism industry
- Academic researchers
- Government policy makers
The Sustainable Tourism Cooperative Research Centre (STCRC) is established under the Australian Government’s Cooperative Research Centres Program. STCRC is the world’s leading scientific institution delivering research to support the sustainability of travel and tourism – one of the world’s largest and fastest growing industries.

Introduction
The STCRC has grown to be the largest, dedicated tourism research organisation in the world, with $187 million invested in tourism research programs, commercialisation and education since 1997.

The STCRC was established in July 2003 under the Commonwealth Government’s CRC program and is an extension of the previous Tourism CRC, which operated from 1997 to 2003.

Role and responsibilities
The Commonwealth CRC program aims to turn research outcomes into successful new products, services and technologies. This enables Australian industries to be more efficient, productive and competitive.

The program emphasises collaboration between businesses and researchers to maximise the benefits of research through utilisation, commercialisation and technology transfer.
An education component focuses on producing graduates with skills relevant to industry needs.

STCRC’s objectives are to enhance:

• the contribution of long-term scientific and technological research and innovation to Australia’s sustainable economic and social development;
• the transfer of research outputs into outcomes of economic, environmental or social benefit to Australia;
• the value of graduate researchers to Australia;
• collaboration among researchers, between researchers and industry or other users; and efficiency in the use of intellectual and other research outcomes.