GUIDELINES FOR DESIGN AND IMPLEMENTATION OF MONITORING PROGRAMS TO ASSESS VISITOR IMPACTS IN AND AROUND AQUATIC ECOSYSTEMS WITHIN PROTECTED AREAS

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ABSTRACT

Understanding and managing visitor's perceptions, goals and activities as they interact with the natural world is fundamentally important in sustainably managing high-use sites within protected areas. In this study, we examined the appeal, use and consequent impacts of visitation in and around focal swimming holes adjacent to camping areas in protected areas, with particular emphasis on field trials of aquatic indicators. The study sites, a series of focal swimming holes, were chosen because they represent extremely important components of the regional tourism landscape. Furthermore, it has been widely accepted that although a lot is known of the impacts of visitors in terrestrial systems, the patterns of use and impacts of visitors on aquatic ecosystems are poorly understood and understudied.

To understand visitors' perceptions/attitudes/activities and their impacts, we undertook a study that incorporated visitor surveys with environmental monitoring field trials. Critically, our fieldwork spanned a period of significant changes in use by overlapping periods of school holidays, weekends and a period following school holidays.

We found that appropriately selected indicators responded significantly and quickly to visitor impacts, but that the impacts tended to be highly localised and short-lived. The long-term ecological consequences of these impacts are unknown and this topic undoubtedly requires more research effort. In the meantime, this study provides protected area managers with information that is critical to understanding, monitoring and managing visitors in and around high-use aquatic sites. Furthermore, this report outlines an easy-to-follow and transparent approach that protected-area managers can follow to develop and implement tailored monitoring programs to assess visitor impacts in and around the high use aquatic sites under their management.

We propose that ongoing collaborative relationships between aquatic ecologists and protected area staff will generate data and understanding of system response to visitors that will be of great interest to both groups. We present a conceptual model that highlights how these collaborations can work to ensure both engagement from researchers and sustainable management outcomes for high use aquatic sites in protected areas.

Acknowledgements

The Sustainable Tourism Cooperative Research Centre (STCRC), an Australian Government initiative, funded this research. The report builds on earlier work which examined the spatial and temporal scales of visitor activities, and therefore, impacts, in and around aquatic ecosystems within protected areas. Significantly, this report should be read in conjunction with the report by Hadwen, Arthington and Boon (2008), as it draws from and builds on that material to develop an easy and transparent approach to developing and implementing monitoring programs to assess visitor impacts in and around aquatic sites within protected areas. Whilst the emphasis is on protected areas, the approach and underpinning knowledge developed in this project is certainly more broadly applicable to studies of aquatic (and other) systems outside of protected areas.

This work is dedicated to the memory of Christine S. Fellows, a talented scientist, a wonderful wife (of Wade L. Hadwen) and an adoring mother (of Eli F. Hadwen). This work benefited greatly from her intellectual and field contributions. She will be greatly missed.

GUIDELINES FOR DESIGN AND IMPLEMENTATION OF MONITORING PROGRAMS TO ASSESS VISITOR IMPACTS IN AND AROUND AQUATIC ECOSYSTEMS WITHIN PROTECTED AREAS

SUMMARY

This report is divided into four chapters. The first chapter introduces the field sites used in the field trials and documents the visitor survey instrument developed to assess visitor perceptions and activities at these sites. In addition, the data generated from the visitor surveys are presented and discussed. The second chapter introduces the critical components of the design of the field trials, including indicator selection and the importance of selecting relevant upstream and downstream control sites in this type of monitoring. The third chapter presents the outcome of field trials and includes critical elements of hypothesis testing and the need to relate indicator responses to spatially and temporally relevant aspects of visitation. The final chapter integrates the outcomes of the first three chapters and outlines the approach that protected area managers need to follow in order to develop and implement their own defendable and tailored monitoring programs in and around high use aquatic sites within their jurisdictions.

Objectives of Study

The principal objective of this study was to develop, test and recommend a defensible and easy-to-implement approach to detecting the impacts of visitors at focal swimming holes in protected area settings. To achieve this objective, we addressed four critical questions, as follows:

- How important are focal aquatic sites to visitors and how do they use these systems?
- What spatial and temporal scales of examination are required to assess visitor impacts?
- Which indicators respond to visitor activities?
- How can indicators and their application be presented to protected-area managers, to facilitate uptake of these monitoring approaches?

Methodology

Details on the general approach and specific methods are presented in each of the chapters. Briefly, this report documents the design, implementation, analysis and interpretation of field trials of indicators that were selected to assess visitor impacts in and around focal swimming holes. The fieldwork was conducted in the Sunshine Coast Hinterland, in state forests and national park areas near Kenilworth, in Southeast Queensland (more information is provided in Chapter 1).

The approach followed five steps, as follows:

1. To determine the perceived importance of aquatic ecosystems as focal sites that attract visitors to particular destinations, we developed a survey instrument that was approved for use by the Griffith University Human Ethics Committee.

2. To examine visitor impacts, we first selected indicators for field trials on the basis of their spatial and temporal resolution, as per the desktop evaluation of indicators undertaken in our earlier report (see Hadwen, Arthington & Boon, 2008a).

3. After choosing appropriate indicators, we then designed the monitoring program to maximize spatial and temporal resolution of the analysis. Specifically, we selected upstream, focal and downstream pools in which we sought to compare the indicator performance. This approach enabled us to examine the spatial and temporal extent of impacts and whether any upstream, or more plausibly, downstream consequences could be ascertained.

4. Analytically, we sought to compare indicator scores among upstream, focal and downstream sites and through time (associated with changes in visitation across the study period).

5. Finally, we discuss how both the selection of indicators and the interpretation of indicator performance require knowledge of both the ecological system and the visitors and their behaviour. To this end, we advocate that it is the approach outlined in this report (and not necessarily the selected indicators themselves) that should form the basis of future monitoring efforts, both in the current field sites and in others outside the fieldwork component of the project.

Key Findings

A large list of indicators were assessed in the study, to test the recommendations of Hadwen, Arthington and Boon (2008a) and to examine their performance and ease of implementation in real-world conditions and to generate datasets of significant size and depth to provide the protected-area staff at these field sites with valuable information that will feed into their sustainable management of these high use aquatic sites.

Indicator performance was generally consistent with the expectations of Hadwen, Arthington and Boon (2008a). Three indicators responded strongly to visitors, both spatially and temporally:

- turbidity—a measure of the clarity of the water column
- filtered reactive phosphorus—a measure of the availability of a critical plant nutrient in the water column
- *E. coli* counts —a measure of faecal contamination from warm-blooded animals

These three indicators cut across physical (turbidity), chemical (filtered reactive phosphorus) and biological (*E. coli* counts) indicator groups and as such represent substantial depth in monitoring effort when applied concurrently.

Although no other indicators responded significantly to both the temporal and spatial elements of visitation, oxides of nitrogen, benthic chlorophyll *a* concentrations, and the presence of exotic fish species all responded significantly, either temporally (benthic algal chlorophyll *a* concentrations) or spatially (oxides of nitrogen and presence of exotic species), to visitation during the study period.

Visitors and their activities tended to elicit temporally short-lived and spatially restricted responses. These findings concur with our expectations for both the nature of visitor use and the physical, chemical and ecological characteristics of the streams in which these field trials took place.

On the basis of the success of the indicator trials and the well-documented need for resources, staff and expertise to design and implement visitor impact monitoring programs, we advocate for continued collaborative effort between researchers and protected area staff. To this end, the final component of the report identifies the key elements of monitoring that can be conducted by researchers and protected area staff and highlights areas where collaborative effort can enhance the success of monitoring programs and increase the likelihood of detecting and understanding visitor impacts in high use aquatic sites.

Future Action

The measured performance of a range of different indicators at the sites examined in this study provides useful pointers for the future indicator development and a wider application across a broader range of aquatic sites. We recommend, however, that it is the approach, rather than the indicators per se, that should be taken from this study and applied elsewhere in future monitoring efforts. That conclusion is not only due to the fact that not all aquatic ecosystems are the same, in terms of their response and sensitivity to visitor impacts, and not all visitors are the same, in terms of the activities they participate in, but that the capacity of protected area staff to implement visitor impact monitoring programs in and around high use aquatic sites is likely to vary greatly from park to park, region to region and State to State. Ultimately, we recognise that protected-area staff capacity and resources will likely dictate the scale and intensity of monitoring efforts, but it is important to follow the process outlined in this report to ensure that protected area managers get high quality data and a good return for whatever level of investment they can dedicate to monitoring the condition of high use aquatic sites.

Chapter 1

HOW IMPORTANT ARE FOCAL AQUATIC SITES TO VISITORS, AND HOW DO THEY USE THEM?

On the Need to Understand Visitors

Critical to any monitoring and assessment program is the need for a thorough examination of threatening processes and pressures on the system (Green 1979, Underwood 1996a, Underwood 1996b). In the case of examining visitor impacts in relatively pristine environments, an understanding of the demand, perceptions and activities of visitors is required prior to the design and implementation of a monitoring program. Although this is a logical and intuitive requirement, it is surprising how often quality visitor data is absent within protected areas (Hadwen et al. 2007, Hadwen, Hill & Pickering 2008b). This lack of quality visitor data not only reduces the capacity of park managers to design and implement monitoring programs, but it also has significant implications for staff and resource allocation and day-to-day management of visitors at focal sites.

In this field-based study, we sought to collect information on visitor perceptions and activities from visitors at three different, but nearby sites: Charlie Moreland Park (CMP), Booloumba Creek 1 (BC1) and Booloumba Creek 3 (BC3) campsites (Figure 1).

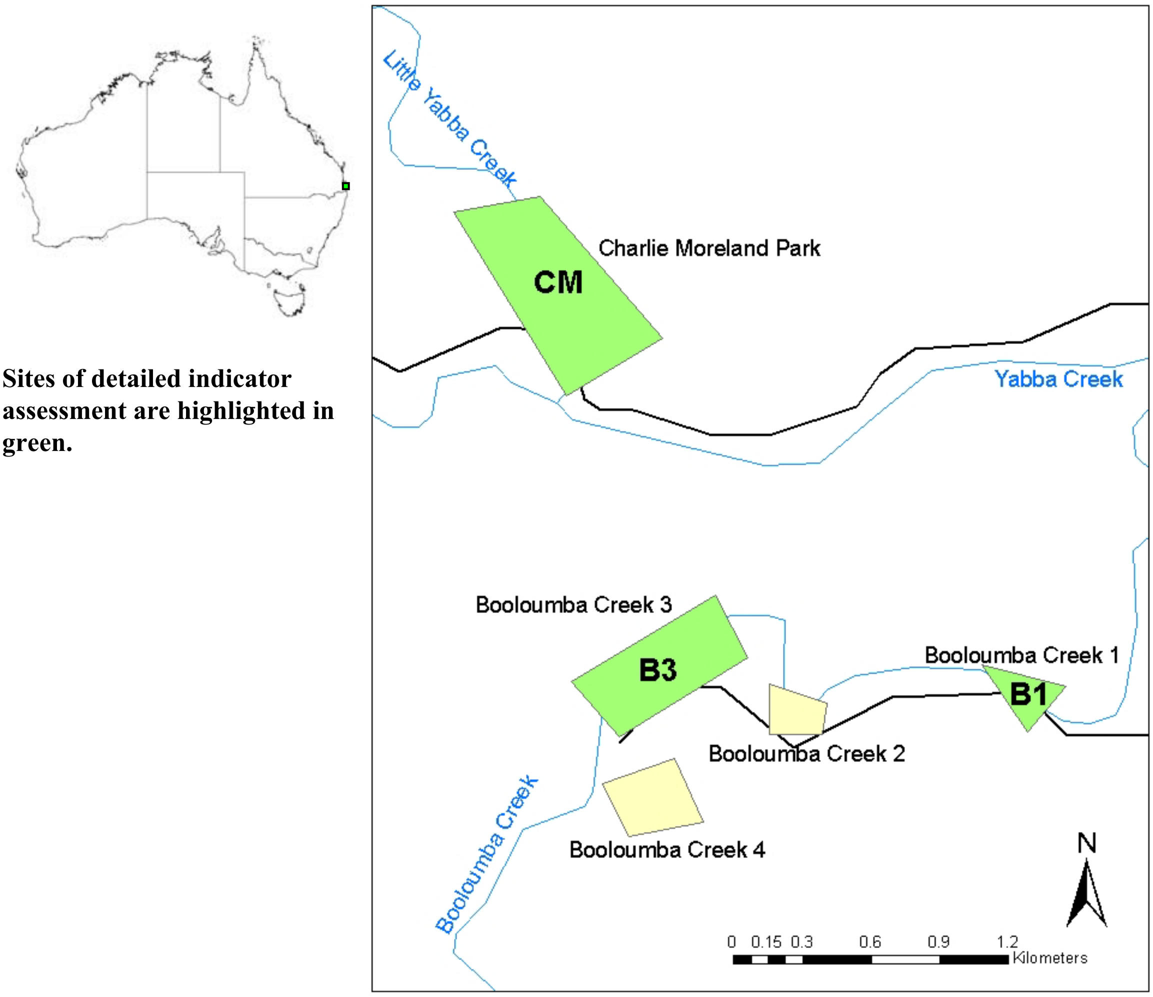

Figure 1: Location of field study sites in Southeast Queensland, Australia

All three sites are campsites that are next to streams that represent focal sites of visitor activities in the region. At CMP, which is a largely cleared, grass-dominated campground and a small day use area, access to Little Yabba Creek is mostly at the focal swimming hole (see Figure 2). BC1 is a forested campsite setting and, like CMP, campsites do not adjoin the stream directly and access is predominantly at the nearby swimming hole (see Figure 3). In contrast, at the nodal BC3 campsite (Figure 4), direct access is available to Booloumba Creek at a number of points, with the most prized campsites having immediate and private access to the stream. Although a focal swimming hole is also present at BC3, visitor activities occur along a much longer stretch of stream than as is the case at CMP.

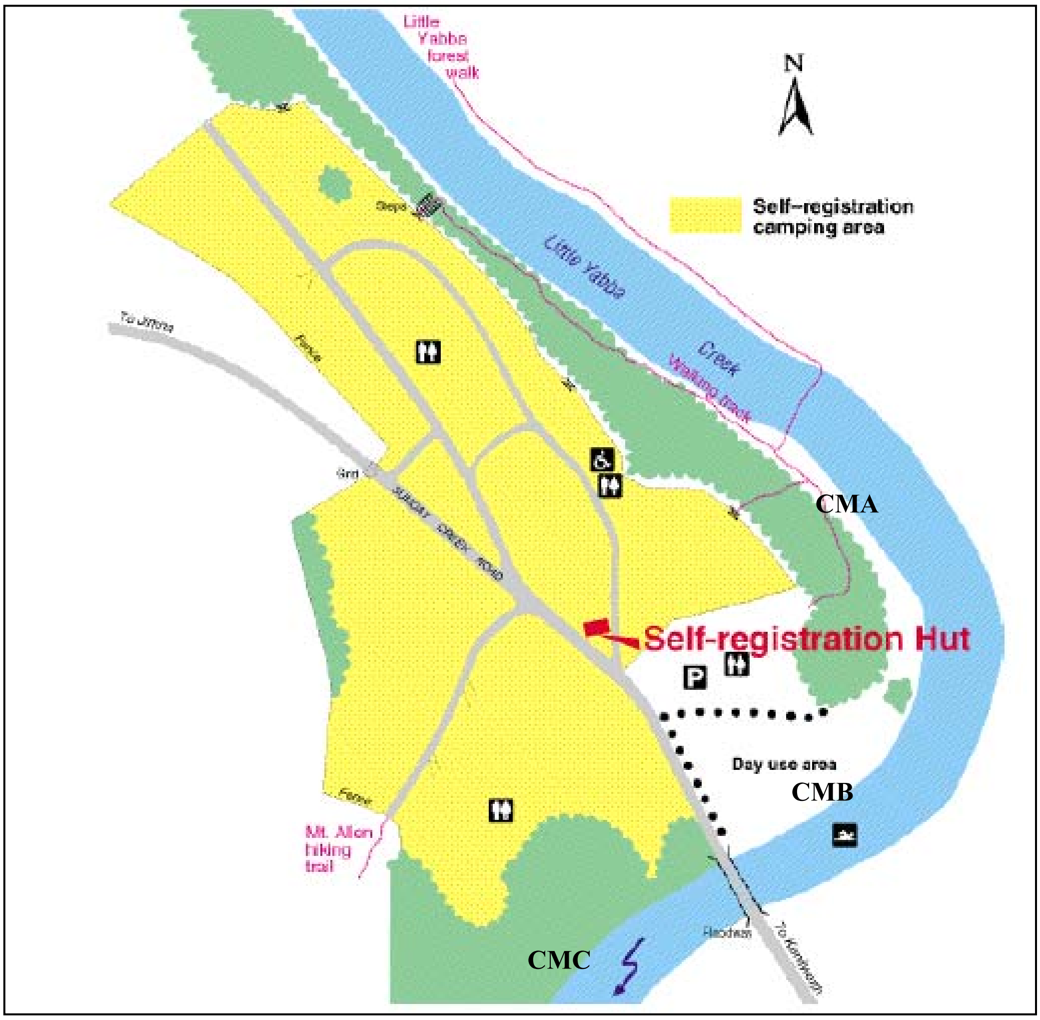

Figure 2: Charlie Moreland Park campsite configuration, day use area and stream access, with field sites labeled as CMA (upstream control), CMB (focal site) and CMC (downstream control)

Approach to Understanding Visitor Demand for Aquatic Sites

At CMP and BC3, we undertook visitor surveys to obtain detailed comments from each group of users, whether they be couples, families or tour groups. To this end, a detailed survey instrument was developed (see Appendix A), which sought to ask visitors a range of demographic, perception- and activity-related questions that specifically related to the presence of focal aquatic sites near the campground. Given the detail and length of the survey, the emphasis was on fewer detailed surveys rather than a large number of simple surveys. This approach enables resource managers to collect the necessary depth of information against which monitoring and management strategies and activities can be based.

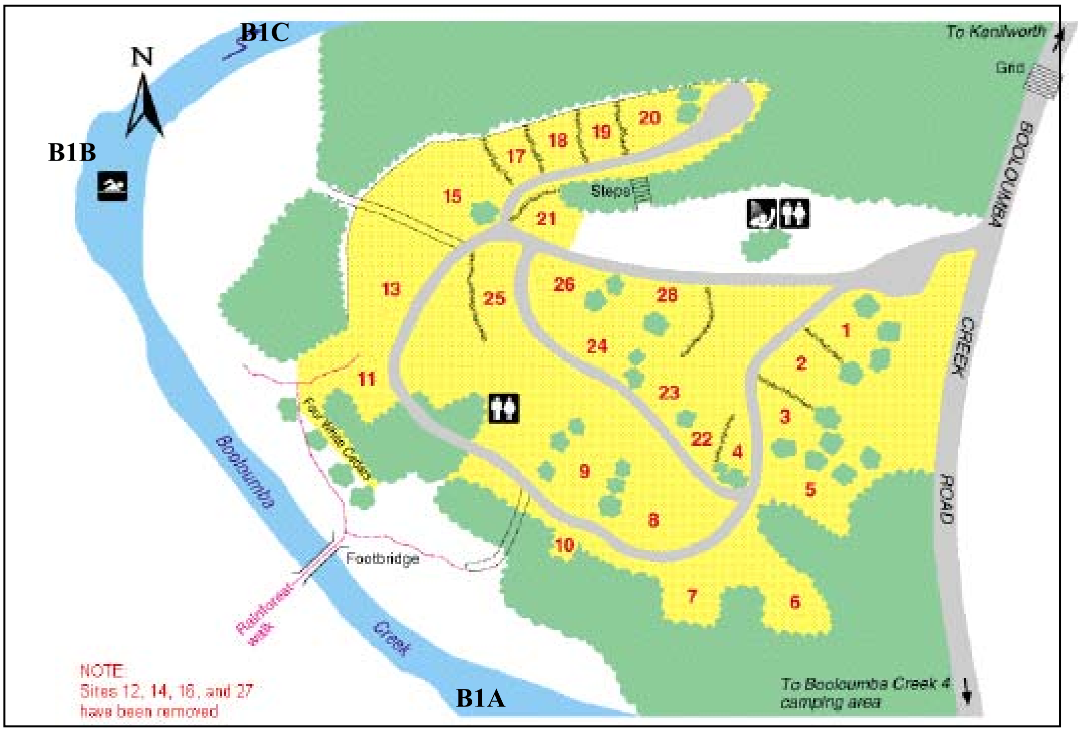

Figure 3: Booloumba Creek 1 campsite configuration and access to stream, with field sites labeled as B1A (upstream control), B1B (focal site) and B1C (downstream control)

Results and Discussion

A total of 19 surveys were undertaken across CMP and BC3 campsites. No respondents who were invited to partake in the surveys refused to participate and many commented on how important work of this type was in ensuring the sustainable management of unique sites like those at CMP and BC3.

For both sites, a very high percentage of respondents had been to these campsites before, indicating a high level of return visitation (Table 1). This finding is in stark contrast to sites with greater profiles (both domestically and internationally), which typically have a high proportion of first time visitors on any given occasion. Despite the similarities across sites in repeat visitation, there were different trends in the number of visits to each site per year. For CMP, half of the visitors surveyed identified themselves as nearby residents and many visited this site on numerous occasions per year. For respondents from BC3, more than half indicated that they visited this site more than five times each year, despite the fact that no respondents were nearby residents.

The demographic mix from respondents at CMP and BC3 sites indicated that they visited these sites in groups of friends and family members, although a quarter of respondents at BC3 were part of community group camps at the time of the survey. Interestingly, the gender mix was quite different between sites, with males dominating respondents at CMP and almost three quarters of respondents at BC3 being female. This result is largely driven by the fact that surveys for each campsite were completed by a single individual, so there may not be such a split in genders across sites.

The majority of visitors at CMP nominated stays of 1–2 days in duration. In contrast, all respondents from BC3 planned to stay at the site for between 3–5 days, indicating that length of stay differed between these two campsites.

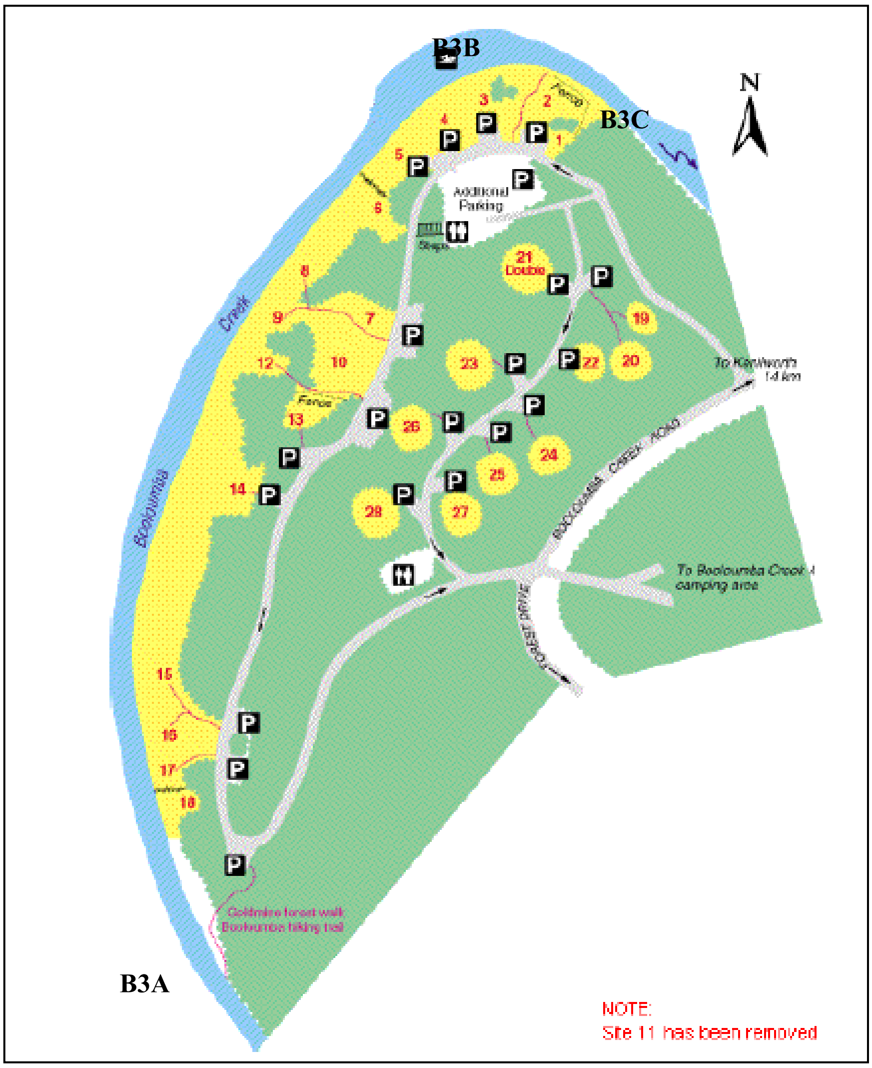

Figure 4: Booloumba Creek 3 campsite configuration and access to stream, with field sites labeled as B3A (upstream control), B3B (focal site) and B3C (downstream control)

Table 1: Visitor demographics from surveys conducted in October 2008 in Charlie Moreland Park (CMP) and Booloumba Creek 3 (BC3) campsites. Data also presented as combined scores pooled across both campsites

Site	CMP	BC3	Combined
Number of respondents	8	11	19
Have you been here before?			
No, this is my first time visiting this location	0	27	16
Yes	100	73	84
If yes:			
I am a nearby resident	50	0	26
I visit this location < 5 times a year	50	18	37
I visit this location > 5 times a year	0	55	32
What means of transport did you use to get here?			
2wd vehicle	13	55	37
Hired bus or minivan	0	27	16
4WD vehicle	88	18	53
What sort of group are you here with today?			
Couple or family	25	64	47
Friends	75	36	53
Community group	0	27	16
What is your gender?			
Male	63	27	42
Female	38	73	58
To what age group do you belong?			
Under 18	0	0	0
19–24	0	18	11
25–34	13	9	11
35–44	0	55	32
45–54	50	18	32
> 55	38	0	16
How long do you intend to stay at this site?			
< 1 day	0	0	0
1–2 days	63	0	26
3–5 days	38	100	74
> 5 days	0	0	0
What sort of accommodation are you staying in whilst here?			
Camping in undeveloped sites	50	45	47
Camping in sites with facilities (caravan parks)	63	55	58

Data relating to visitors perceptions and motivations is presented in Table 2. At both sites, respondents indicated that they felt that the number of visitors present during the study period was 'About right'. Respondents also indicated that their decision to visit the two sites was strongly influenced by the setting and the natural environment, including the presence of the streams adjacent to the campsites. This finding provides further support for the suggestion that focal aquatic sites are highly appealing to visitors in protected areas (Hadwen, Arthington, Boom Lepesteur & McComb, 2005a). Whilst campsite facilities were also obviously important, nearby attractions and accommodation bore very little influence on decision-making processes for visitors at either site.

In terms of the activities undertaken by visitors to these sites, respondents from CMP nominated a wider range of activities than did respondents from BC3. Specifically, water and land sports were nominated by CMP respondents, which reflect the open grassing setting and the sandy bottom of the focal swimming hole. In contrast, sports were not nominated as likely activities by BC3 respondents, presumably due to the closed-rainforest setting and cobble-based substrate in that catchment. For water-based activities water quality, water clarity, accessibility from campsites and local plants and animals were all very important in influencing visitor satisfaction.

Water-quality perceptions differed between CMP and BC3 respondents, which reflect natural differences in turbidity and sediment stability at two sites. CMP is a slightly turbid sandy-bottomed swimming hole. In contrast, BC3 has a very clear cobble-bottomed site. Almost 90 per cent of the respondents from BC3 indicated that the water quality at the site contributed greatly to their experience. In contrast, only 50 per cent of the CMP respondents felt the same way. This disparity is also reflected by the results for what aspects of water quality were reported as being disappointing, with CMP respondents indicating that water quality/visibility and visible algal growth on surfaces had contributed to their reduced satisfaction. In contrast, no respondent from BC3 indicated that there were any aspects of water quality that displeased them.

Table 2: Summary of visitor survey data relating to site characteristics and appeal from visitor surveys in October 2008 in Charlie Moreland Park (CM) and Booloumba Creek 3 (BC3) campsites. Data also presented as combined scores pooled across both campsites

Site	CMP	BC3	Combined
How do you feel about the number of visitors at this site today?			
Far too many	0	0	0
Too many	0	0	0
About right	88	100	95
Too few	13	0	5
Far too few	0	0	0
How important were the following in influencing your decision to come here?			
Resident animals	3.4	3.4	3.4
Resident plants	3.8	3.3	3.5
Streams/rivers/lakes	3.8	3.9	3.9
Forests	3.8	3.7	3.8
Scenery	4.0	3.7	3.8
Toilet and day use facilities	3.7	3.5	3.4
Camping facilities	3.5	3.6	3.6
Bushwalking trails	3.5	3.6	3.6
Nearby accommodation	1.4	1.7	1.6
Nearby towns	1.5	2.5	2.1

What activities do you intend to partake in at this site?			
Swimming	63	100	84
Bird watching	63	27	42
Water sports	13	0	5
Land-based sports	25	0	11
Hiking and bushwalking	75	100	90
Photography	50	45	47
Relaxing/picnicking	100	91	95
Sunbathing	25	18	21
Camping	100	100	100
Other	0	9	5
How do these factors influence your experience of water-based activities			
Water quality (absence of odours)	3.9	3.9	3.9
Water clarity	3.8	3.8	3.8
Water temperature	3.3	2.7	2.9
Lack of weeds in water	2.8	3.3	3.1
Lack of tree stumps in water	3.2	2.9	3.0
Land-based facilities	3.5	2.7	3.0
Presence of jetties/boardwalks	1.8	0.0	0.6
Accessibility to the water	3.6	3.5	3.5
Number of other visitors	3.0	2.8	2.9
Local plants and animals	3.9	3.3	3.6
How do you feel about the quality of the water at this site today?			
Very poor	13	0	5
Poor	0	0	0
Fair	13	0	5
Good	38	27	32
Excellent	38	73	58
To what extent does water quality affect your experience?			
Dissatisfied greatly	0	0	0
Dissatisfied slightly	0	0	0
No effect	13	0	5
Satisfied slightly	38	9	21
Satisfied greatly	50	91	74
If you were dissatisfied, please indicate why			
Water clarity or visibility	67	0	33
Water colour	0	0	0
Water odour	0	0	0
Submerged plants	0	0	0
Submerged logs	0	0	0
Litter or debris	0	0	0
Wave action	0	0	0
Visible algal growth on surfaces	33	0	17
Other	0	0	0

Respondents' views on site management, facilities and sustainability are presented in Table 3. In general, respondents felt that visitors to both sites tended to be environmentally aware. This finding is in keeping with similar surveys conducted previously, where visitors to protected areas tended to believe that visitors in natural places are attuned to environmental issues, particularly those that are immediately relevant to their activities in protected areas.

Despite a high level of environmental awareness, respondents from both sites indicated a wide range of activities that threaten the health of creeks in the region, with trampling and removal of shoreline vegetation most frequently nominated. Interestingly, only respondents from BC3, where some campsites are immediately adjacent to the stream, felt that camping represents an activity that threatens creek condition. Furthermore, almost 20 per cent of BC3 respondents nominated wildlife feeding as a threat to creek condition, suggesting that the activities of visitors at BC3 and CMP (where wildlife feeding was never nominated) may be subtly different.

Visitor views on facilities suggested that the number and quality of facilities currently meet visitor needs very well. Indeed, across both sites only 5 per cent of respondents felt that the facilities provided were insufficient. Despite these encouraging statistics, one quarter of CMP respondents and almost two-thirds of BC3 respondents felt that additional visitor facilities were warranted at these sites. Whilst CMP respondents did not nominate what types of facilities are required, respondents from BC3 identified, in descending order, signs, toilets and picnic facilities, information centres, clear zoning for different activities and limits on visitor numbers as required elements of visitor management that would improve conditions at that campground. Despite these suggested improvements, respondents from both sites tended to strongly support the statement that the sites are well managed with respect to visitor management. In this context, requests for additional facilities may more be 'a wish list' response than a strong need for improved visitor management.

Respondents were asked to rate a series of potentially threatening activities on the degree to which they might impair creek condition within protected areas. Whilst the rank order of threatening activities was generally consistent across CMP and BC3 respondents, scores from BC3 respondents were almost always one point higher than those from CMP. This result suggests that although respondents share views on threatening processes, those from BC3 attribute greater risks and concerns to those processes. Given the style of campgrounds (open grass at CMP and closed rainforest sites at BC3) and differences in site access (easy 2wd access at CMP and two creek crossings not always fordable by 2wd vehicles to get to BC3) between these campgrounds, this result is perhaps not surprising, as visitors at BC3 are likely to expect a more natural setting and be less tolerant of (and perhaps more sensitive to) impacts.

Table 3: Summary of visitor survey data relating to site characteristics and appeal from visitor surveys in October 2008 in Charlie Moreland Park (CMP) and Booloumba Creek 3 (BC3) campsites. Data also presented as combined scores pooled across both campsites

Site	CMP	BC3	Combined
Are visitors environmentally aware?			
Yes	100	82	90
No	0	18	10
Which of these activities threaten the health of creeks in this area?			
Infrastructure and development	25	18	21
Erosion and poor water quality	13	18	16
Increased nutrients and algal blooms	13	18	16
Trampling or removal of shoreline vegetation	25	36	32
Camping	0	27	16
Wildlife feeding	0	18	11
Other	13	9	11

What do you think about the infrastructure and facilities at this site?			
Excellent	50	45	47
Adequate	50	45	47
Insufficient	0	9	5
Do you think the park needs more visitor facilities?			
Yes	25	64	47
No	75	36	53
If yes, what?			
Signs	0	36	21
Toilets and picnic facilities	0	27	16
Information centres	0	27	16
Limits on visitor numbers	0	9	5
Clear zoning for different activities	0	18	11
Do you think this site is well managed with respect to visitor activities?			
Yes	100	91	95
No	0	9	5
How important are these activities as ones that can threaten aquatic systems in parks and PAs?			
Development outside park boundaries	2.8	3.5	3.2
Development within park boundaries	2.6	3.6	3.2
Nutrient inputs from camp grounds	2.6	3.7	3.2
Nutrient inputs from swimmers	2.5	3.4	3.0
Trampling of shoreline vegetation	2.5	3.7	3.2
Camping	2.0	3.2	2.7
Fishing	2.0	3.0	2.6
Powerboating	2.7	3.2	3.0
Sailing and canoeing	2.0	2.1	2.1
Feeding of wildlife	2.5	3.8	3.1
Hunting	3.2	3.8	3.5
Tourism/recreation	2.5	3.5	3.1
Other	0.0	0.4	0.2
Would you be willing to pay to access to this site?			
Yes	75	100	90
No	25	0	10
If yes, how much?			
< $2 per person	25	9	16
$2-$5 per person	38	45	42
$5-$10 per person	0	45	26
> $10 per person	13	0	5

Is tourism beneficial (=3), neutral (=2) or detrimental (=1) to the following?			
Local plants	1.9	1.7	1.8
Local animals	1.6	1.6	1.6
Forests	1.9	1.7	1.8
Waterways	1.8	1.4	1.5
Local businesses	2.5	2.3	2.4
Local residents	2.0	2.4	2.2
Community groups	1.9	2.4	2.2
Local government	2.1	2.5	2.3

The value of CMP and BC3 sites to respondents was assessed on the basis of respondents willingness to pay fees to access and use these campgrounds. Although camping fees already exist, the purpose of this question was to assess respondent's willingness to pay more for the privilege of camping at these locations. Seventy-five per cent of respondents from CMP and 100 per cent of respondents from BC3 indicated a strong willingness to pay for access to these sites. Almost two-thirds of CMP respondents and just over half of BC3 respondents indicated that they'd be willing to spend up to an additional $5 per person to these campgrounds. Some respondents from CMP were willing to pay substantially more than that, with 12.5 per cent of respondents indicating a willingness to pay more than $10 per person to access the campground. At BC3, 45.5 per cent of respondents were willing to pay between $5 and $10 per person to access the site. Overall, this data suggests that the appeal and current level of facilities are appealing enough for respondents to pay additional fees to gain access to these campgrounds.

The final survey question sought to gather information regarding visitor perceptions of the influence that tourism plays on local biota, ecosystems and human communities. Both survey groups felt that plants, animals, forests and waterways are likely to be at least slightly impacted by tourism activities in the region. In contrast, neutral at worst and beneficial at best outcomes were nominated for local businesses, local residents, community groups and local governments.

Conclusions

This survey work has identified the activities, values and perceptions of visitors to CMP and BC3. Not only are the results interesting in their own right, but in the context of managing visitors in protected areas, this is information is critical to our identification of potential impacts and our capacity to monitor the effects of threatening visitor activities. For the specific case of assessing visitor impacts on aquatic focal sites, it is certainly necessary to first establish the importance of the site and its appeal to visitors and the degree to which visitors are likely to partake in activities in and around these waterbodies. In this study, like others of similar designs (Hadwen and Arthington 2003, Hadwen et al. 2005a), visitors have identified focal swimming holes as highly appealing components of the landscape around which they base many of their activities. Establishing this fact is a critical first step to understanding visitors and for developing approaches (and indicators) to assess potential visitor impacts.

Beyond the task of establishing the appeal of focal aquatic sites and understanding the values and activities of visitors, this survey has also generated valuable information for park and campground managers that might be of use in planning and management operations. Specifically, and although visitors to CMP and BC3 generally share similar views and perceptions on site appeal and management, subtle differences in survey responses reflect the differences in site characteristics and the types of visitors these two sites attract. As visitors to BC3 tend to be seeking wilder and more natural experiences than those to CMP, it is imperative that the managers charged with ensuring the sustainability and continued appeal of these sites are acutely aware of these differences. Furthermore, suggested improvements to visitor facilities, especially at BC3 where a wide range of requests were documented, should be a good pointer for protected area managers in terms of where resources can be wisely invested and appreciated by visitors to these sites.

Chapter 2

DESIGNING VISITOR IMPACT MONITORING PROGRAMS TO ASSESS IMPACTS IN FOCAL SWIMMING HOLES IN PROTECTED AREAS

Introduction

Assessing the impacts of visitors on aquatic ecosystems requires scale-sensitive design and implementation of a monitoring program. Aspects of design that require considerable attention include the selection of appropriate indicators and the associated scale of sampling and the selection of suitable sites, especially the controls against which focal site indicator measurements will be contrasted. Indicator selection and the importance of spatial and temporal scales of influence and sensitivity were addressed in an earlier STCRC technical report (Hadwen Arthington & Boon, 2008a), so the remainder of this chapter will focus on site selection for the field trials of indicators that were selected following that first phase of research. Specifically, the general principles of the design selected in this study should, if possible, be followed in all assessments of visitor impacts in flowing-water systems (streams and rivers in particular) within protected areas, as it affords the greatest potential for inference of how indicator measures relate to the associated visitor activities at focal sites.

Using Controls to Determine Impacts in Stream Monitoring

The purpose of impacts monitoring is to assess the degree to which an activity, or stressor, is likely to influence the condition of assets or processes that are highly valued, both at the site in question and/or in adjacent, usually downstream, sites. To this end, it is useful to apply a BACI-type (Before After Control Impact) design in most monitoring programs, as this not only sets baseline conditions through time (the before samples), but it also accommodates controls in space (the control samples). The use of these spatial and temporal controls is critical to understanding indicator performance and variability (Green 1979, Underwood 1996a). Indeed, variability in indicator measurements needs to be discriminated from actual differences between sites, so it is important to include measures of variability in control sites to ensure that this natural 'variability' is not confused with 'impacts'.

In this particular study, which focused on the activities and potential impacts (as measured by a suite of indicators) of visitors in and around focal swimming holes adjacent to camping and day use areas (see Chapter 1), it was necessary to design the monitoring program in a way which could ascertain the spatial and temporal scale of impacts (should they be measureable). To this end, we selected upstream and downstream control sites that were spatially close to the focal sites (see Figure 5).

Whilst the selection of upstream and downstream controls seems like a logical and straightforward component of the study design, it is important to realise that this is not always as easy as it sounds. Indeed, focal swimming holes are focal sites for a very good reason. They often represent the best (if not only) deep pool in the stream network with the right mix of accessibility, water flow, geomorphology (landscape and channel characteristics) and habitat to appeal to visitors. To this end, selecting upstream and downstream controls, which ideally should share the same aspect, geomorphology and habitat characteristics as the focal sites, can be quite challenging, particularly in small stream systems where the large deep pools highly sought after by tourists often are the exception rather than commonplace. Nevertheless, to ensure that the selected controls are meaningful, they do need to be spatially close to the focal site of interest, so there is often a trade off to be made between the representativeness of a control site and it's geographical proximity to the focal site. As always, trade offs bring with them uncertainty and additional indicator measurement variability, but as long as the field staff undertaking the monitoring are aware of, and open about, the limitations of their design, the impact of these differences between focal and control sites can be minimised, both statistically and via the interpretation of what the differences in indicator performance might actually mean.

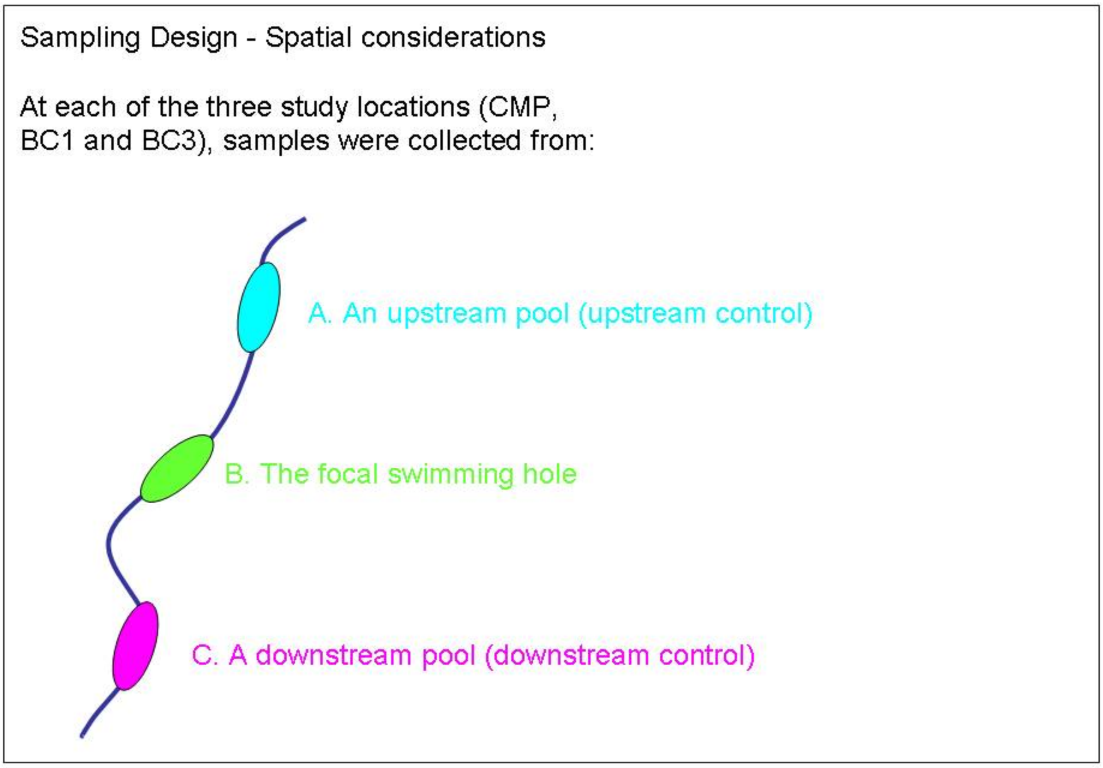

Figure 5: Graphical representation of the spatial design of the monitoring program, with upstream, focal and downstream sites

In this study we were able to identify and sample upstream and downstream controls that shared similar aspects, geomorphologies and other features with the focal swimming holes (see Figure 6), so the confidence with which we could compare indicator measurements was higher than me often be the case in naturally variable and heterogeneous settings.

After selecting appropriate upstream, focal and downstream control sites a typical BACI sampling design would require sampling to begin prior to any visitors coming to the focal sites. In addition to underscoring the natural variability examined in the control sites, this also ensures that for each of the indicators selected that there are no *a priori* differences between control and focal sites that may not reflect visitation at all and may, instead, capture some real natural differences between these sites.

As mentioned, focal swimming holes are often naturally quite different from their nearby upstream and downstream pools, by virtue of the fact that they may be deeper and wider pools and with geomorphological features and settings that set them apart. Of course, in many studies of visitor impacts in protected areas the visitation has been ongoing for some time and the typical lack of a monitoring plan (*sensu* Hadwen et al. 2007, Hadwen, Hill & Pickering, 2008b) reflects the fact that visitors and their uses of natural areas have not been planned. Regardless of the reasons behind a lack of baseline or before sampling data in protected areas, the reality is that an alternative to the true before sampling is now often required. In these cases, it is often the case that control and focal site indicators measurements are just compared directly, with the underlying assumption that these sites do not differ naturally never tested and/or articulated. Whilst this approach does open managers up to criticism and potential misinterpretation of the degree to which visitors and their activities are driving the measured differences between sites, it is often an unavoidable scenario.

One alternative approach, which offers some capacity to at least understand the role that visitors and their activities play in indicator response to perturbations, is to time the monitoring around a period of sensitivity. For example, it is well known that visitors do not use focal swimming holes evenly, or all year round. Indeed, most protected areas experience highly seasonal visitation trends (Hadwen et al. submitted) and these trends in total visitation reflect changes in the degree to which visitors are likely to stress focal swimming holes. In addition to this broad trend in visitation, it is highly likely that the activities that visitors partake in differ from one time of year to another and this, in turn, will also modify the degree to which visitors may influence the condition of focal swimming holes. Although there is some anecdotal evidence to support the assumption that visitors do different things at different times of the year, this level of visitor understanding is largely lacking for most protected areas (Hadwen, Hill & Pickering, 2008b). Once again, these limits to our knowledge of visitor use and activities (and variation spatially and temporally) hinders our capacity to adequately plan and monitor visitor impacts. It is clear that more resources should be devoted to visitor censusing, especially in high use areas within protected areas to provide more information to resource managers that are charged with the challenge of ensuring that visitors do not compromise the conservation values of icon sites (Hadwen et al. 2007).

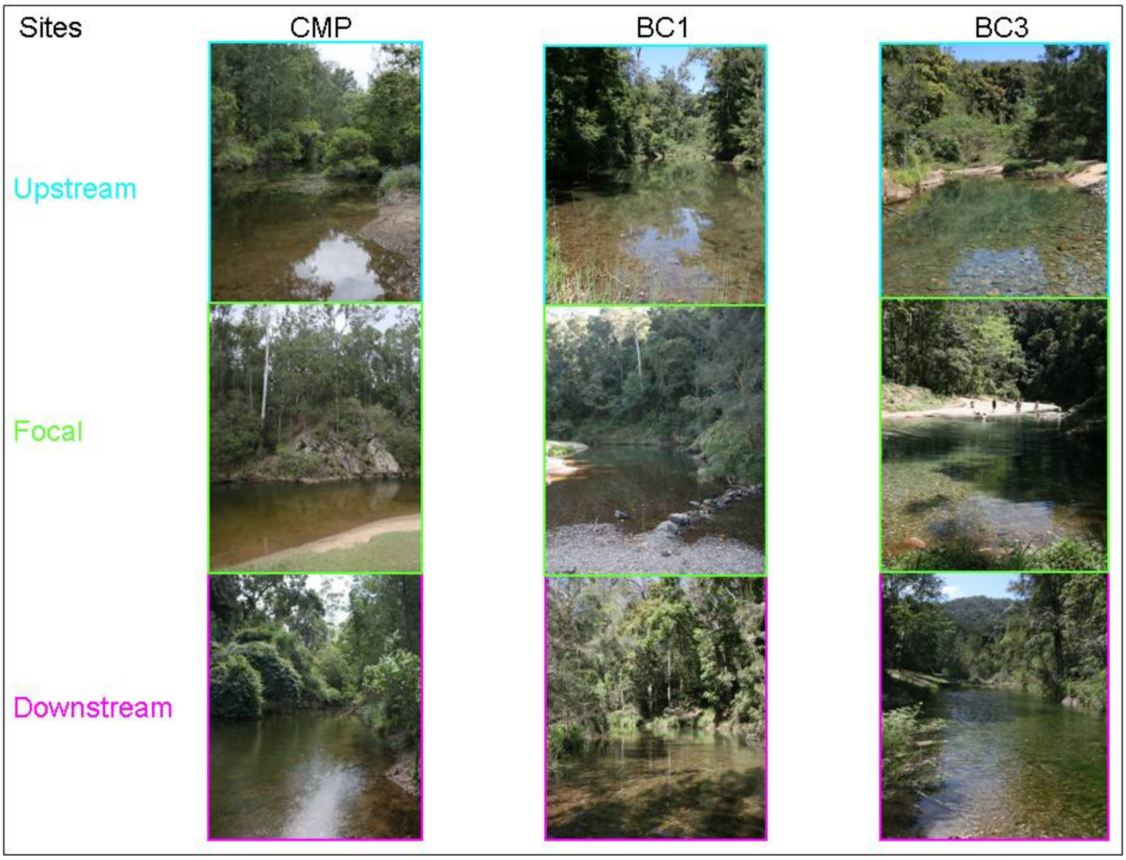

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Figure 6: Photos of upstream, focal and downstream sites at CMP, BC1 and BC3 demonstrating the shared aspect, geomorphology and flow characteristics of these sites

To make the most of visitation seasonality and changes in the stress that visitors may place on focal swimming holes, it may be appropriate to monitor ‘before’ and ‘after’ periods of high use to assess the spatial and temporal implications of visitation. This temporally restricted approach can help to get around some of the problems associated with having no true ‘before’ data. In addition, information at peak times will not only be most useful and interesting to protected area managers but this is also the time at which visitor impacts are most likely to be detected.

The fieldwork in this study, undertaken to assess visitor impacts in and around focal swimming holes, followed this type of experimental design and was driven by information provided by site-based protected area staff. Specifically, the temporal aspects of visitation that we were aware of, and interested in were:

- visitation increases at all three locations (CMP, BC1 and BC3) on weekends and falls during the week
- in addition to the weekly pattern of visitation, school-holiday periods yield the highest visitation levels.

To make the most of these temporal trends in visitation, sampling was conducted during and after a school holiday period (which included a weekend). This approach enabled us to capture indicator (and ecosystem) response and resilience to these patterns of visitor numbers and use. Details of the indicators selected for assessment and their responses through space and time are provided in the next chapter (Chapter 3).

Summary—Critical Aspects of Spatial and Temporal Controls in Stream Monitoring Programs

This chapter provides a framework and justification for the selection of spatially and temporally appropriate controls in the design of monitoring programs that aim to examine visitor impacts at (and beyond) focal swimming holes in protected areas. Spatially, the use of upstream and downstream controls not only accommodates natural variability in indicator measurements, but can also aid in the determination of the degree to which activities and impacts in the focal swimming hole may be transported either upstream or downstream from that site. Temporally, we advocate a sampling approach which captures known periods of peak and trough visitation, to determine the sensitive of indicators and the resilience of the focal swimming hole site in terms of its capacity to recover once visitors go away. Confidence in measuring the responses becomes even greater as more and more peak/non-peak periods are quantified, and the database on quantifying the impacts for a given site increases. All of the information gleaned from this study design is useful and indeed, critical, to protected area managers as they attempt to assess the appeal, use and impacts of visitors in and around popular aquatic sites.

It is recognised that the sampling design advocated in this chapter may not always be possible, or appropriate, depending on the nature of the system being monitored. For example, in systems with no flow (either seasonally, like intermittent streams, or permanently, like some lakes and wetlands) it is not possible to select appropriate upstream and downstream controls. In those systems, an approach like that employed by Hadwen, Hill and Pickering (2005b) is more appropriate, whereby controls are situated within the same body of water, but removed from the focal access point. As mentioned earlier, it is still desirable to ensure that control and focal sites share similar physical, chemical and biological traits, so locating control sites still requires considerable effort. Despite the effort required, it is essential to have meaningful control sites as assessment of visitor impacts can most reliably be determined via examination of the departure of focal site measures from those measured in control sites (Green 1979, Underwood 1996b).

Chapter 3

INDICATOR RESPONSES TO VISITATION: RESULTS FROM EXPERIMENTAL FIELD TRAILS OF SELECTED PHYSICAL, CHEMICAL AND BIOLOGICAL INDICATORS

Indicator Field Trials

To examine the impacts, if any, of visitors on indicator measurements, we undertook a field trial in the three locations that were introduced in the preceding chapters. The indicators of interest spanned a wide range of physical, chemical and biological groups which is in keeping with our interests in examining how water quality and ecosystem functioning might be affected by visitors and their activities in focal swimming holes. Indicators were selected on the basis of the analyses undertaken in an earlier phase of this project (Hadwen, Arthington and Boon, 2008a), which sought to couple the scale sensitivity and likely responsiveness of indicators to the types of activities typically undertaken by visitors in and around focal swimming holes. The indicators selected and the features that made them applicable for the field trial are presented in Table 4.

Although not all of the selected indicators were likely to be sensitive to the scale (spatial and temporal) of visitor activities at these sites, we deliberately selected a wide range to demonstrate the degree to which indicator selection can influence the results of monitoring programs. For example, assessments of nutrient concentrations are perhaps the most routinely undertaken measurements in aquatic monitoring programs and yet on the basis of our understanding of visitors and the ecology of the streams in question, we did not anticipate that dissolved nutrient concentrations. In addition, the indicators chosen came from a broad range of indicator types, from water physico-chemistry to ecosystem processes to human health to biological patterns (see Table 4). By taking this multi-indicator approach to assessing visitor impacts we were able to determine the scale of influence that visitor-mediated disturbances have on focal swimming holes.

As described in Chapter 2, we selected the spatial and temporal components of the monitoring design to optimise the likelihood of detecting visitor impacts. Specifically, we sought to account for natural variability by employing upstream and downstream controls, with the latter also enabling us to determine the degree to which impacts in focal swimming holes may also be felt downstream. In addition to these spatial design considerations, we sought to capture temporal indicator responses to changes in visitation during peak and non-peak periods. Specifically, we sampled during and after a school holiday period (which included a weekend) to capture a broad range of visitation levels over a relatively short period of time (less than one month). Ultimately, targeted and temporally-constrained monitoring like that conducted in this study is likely to be of much greater value to protected area managers than would a monthly or bi-monthly or seasonal monitoring program, which is more typical of the programs that have been designed to examine impacts from broad-scale catchment clearing and point-source pollution.

Table 4 is a list of indicators, and aspects of their scale (space and time) as well as anticipated usefulness in detecting visitor impacts in and around aquatic ecosystems within protected areas (modified from Hadwen Arthington & Boon, 2008a). Ŧ Spatial scale at which the indicator is responsive. For the purposes of this study, we have categorised the spatial scale as either local (a particular location within a reach), reach (an entire section of the system) or system (likely to affect more than just the visited reach of the system). ¥ Likely visitor activities that may lead to a change in indicator response. This feature examines whether visitor activities are actually likely to yield a measurable change in indicator response. § Usefulness refers to the likely applicability of the indicator in a tourism/recreation context. Usefulness is a function of activities (and their likelihood) and scales (spatial and temporal) of response. For the purposes of this study, we have categorised indicator usefulness as either low, medium and high.

Table 4: List of indicators and aspects of their scale (space and time) and anticipated usefulness in detecting visitor impacts in and around aquatic ecosystems within protected areas

Indicator	Indicator type*	Spatial scale Ŧ	Timeframe	Activity ¥	Usefulness §	Key References
Turbidity	water physico-chemistry	reach, system	< 1 week	sediment resuspension from trampling and erosion	medium	Lane & Sheridan 2002, Palmer, Rossouw, Muller & Scherman 2005
Salinity/conductivity/ionic composition	water physico-chemistry	system	Months	nutrient and electrolyte inputs	low	Poulson Simmons, Le Galle Le Salle & Cox 2006
Alkalinity/pH/hardness	water physico-chemistry	system	Months	nutrient and electrolyte inputs	low	Lin, Wood, Haskins, Ryffel & Lin 2004
DO—snapshot and diel measurements	water physico-chemistry	local, reach	2–4 weeks	nutrient inputs and/or resuspension (via algal activity)	medium	Fellows, Clapcott, Udy, Bunn, Harch, Smith & Davies. 2006, Udy, Fellows, Bartkow, Bunn, Clapcott & Harchm 2006

Indicator	Indicator type*	Spatial scale Ŧ	Timeframe	Activity ¥	Usefulness §	Key References
Water temperature	water physico-chemistry	local, reach	~ 4 weeks	sediment resuspension from trampling and erosion, clearing fringing vegetation	medium	LeBlanc & Brown 2000, Lyons , Trible & Paine, 2000, Harding, Classen & Evers 2006
Nutrient concentrations	water physico-chemistry	local, reach, system	< 1 week, but likely to be highly variable	on-site urination and defecation; nutrient inputs and/or resuspension	medium	Hadwen et al. 2003, Hadwen, Bunn, Arthington & Mosisch 2005b
Chlorophyll a as a measure of productivity	ecosystem processes	local, reach	~ 2–4 weeks	nutrient inputs and/or resuspension	medium	Hadwen and Bunn 2005, Hadwen, Bunn, Arthington & Mosisch 2005b
Coliform counts	human health	local, reach	< 1 week	on site urination and defecation	high	Cairns 1974, Bonde 1977, Buckley, Clough, Warnken & Wild, 1998
Tracing sewage $\delta^{15}N$	ecosystem processes	local, reach, system	1–4 weeks	nutrient inputs and/or resuspension	medium	Hadwen & Bunn 2004, Hadwen & Bunn 2005, Hadwen & Arthington 2007a
Use of $\delta^{13}C$ as a surrogate for benthic metabolism	ecosystem processes	local	?		medium	Fellows et al. 2006
Examining trophic structure $\delta^{13}C$ and $\delta^{15}N$	ecosystem processes	local, reach	months	nutrient inputs and/or resuspension	medium	Hadwen & Bunn 2004, Hadwen & Bunn 2005, Hadwen & Arthington 2007a

Indicator	Indicator type*	Spatial scale Ŧ	Timeframe	Activity ¥	Usefulness §	Key References
Structure and function of fish communities	biological patterns	reach, system	months to years	fishing	low	Kennard, Arthington, Pusey & Harch, 2005, Kennard, Arthington, Pusey, Harch & Mackay 2006a, Kennard, Harch, Pusey & Arthington 2006b
Presence of exotic species	biological patterns	reach	months to years	fishing	medium	Kennard et al. 2005, Kennard et al. 2006b

Given the abovementioned spatial and temporal design issues, we developed *a priori* expectations for indicator responses (assuming that the selected indicators would measure visitor-driven changes in the focal sites). Temporally, we knew that visitation would begin at moderate levels during the mid-week school holiday period, peak where holidays and weekends intersect, and then fall dramatically for the mid-week post-holiday period. This rise and fall of anticipated visitation is presented in Figure 7 and we anticipated that indicator responses would also follow this temporal trend, at least for those indicators that have a simple and linear response to visitation.

Spatially, we anticipated that visitor impacts would be restricted to focal sites, with little spread of impacts to upstream and downstream sites. This expected pattern is presented in Figure 8. Both of these *a priori* expectations, or hypotheses, are critical elements of the design, as deviations from these expectations may indicate a poor design and/or data problems, or alternatively, an incorrect *a priori* understanding of how visitors interact with the system. Whilst both of these potential problems are undesirable, they can both be eliminated (if you know which one was causing the results) with modification to the design. To this end, it is critical to the success of monitoring programs to have expected results prior to when monitoring gets underway.

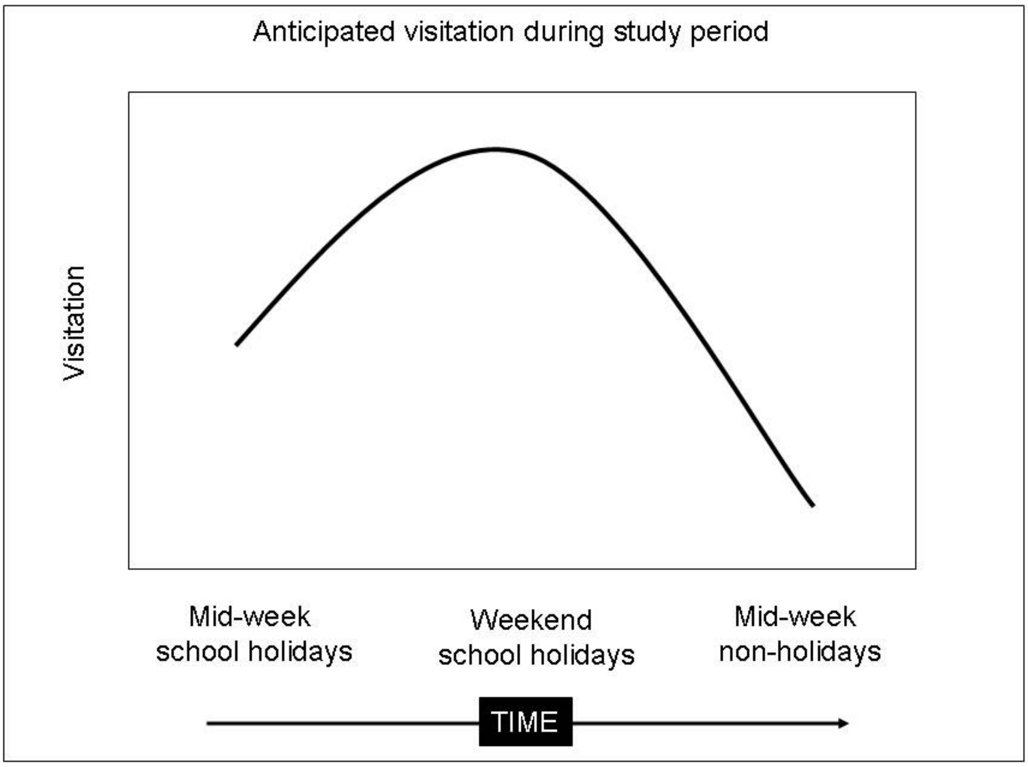


Figure 7: Anticipated changes in relative visitation levels over the course of the study period, with moderate visitation during the mid-week school holiday period, high visitation during with weekend school holiday period and low visitation during the mid-week non-holiday period

Indicator Responses

The response of the selected indicators to visitation was highly variable, with some indicators being very sensitive to disturbance, whereas others showed no significant differences either spatially (between sites) or temporally (across the busy and low visitation periods). Since the main questions of interest in monitoring programs are:

- What is the spatial extent of the impact?, and
- How long does the impact remain?,

We sought to evaluate indicator response at these spatial and temporal scales. In order to have higher statistical power and to determine the general applicability of visitation and visitor activities in driving indicator responses, we therefore lumped the data across all three study locations. The indicator responses (including the trends and the significance levels) are broken into temporal and spatial results in Table 5.

The most responsive indicators in this field trial were turbidity, *E. coli* counts and filtered reactive phosphorus (FRP). These three indicators all demonstrated significant temporal and spatial responses to visitation, although the way they responded was not consistent (ie the peaks and troughs in measured values did not align with the predicted patterns). Three other indicators, namely benthic algal chlorophyll a concentrations, oxides of nitrogen and presence of exotic fish species exhibited either spatially (oxides of nitrogen and exotic species) or temporally (benthic algal chlorophyll a concentrations) significant responses, but not both. The remainder of this section will focus on the significant results (as presented in Table 5).

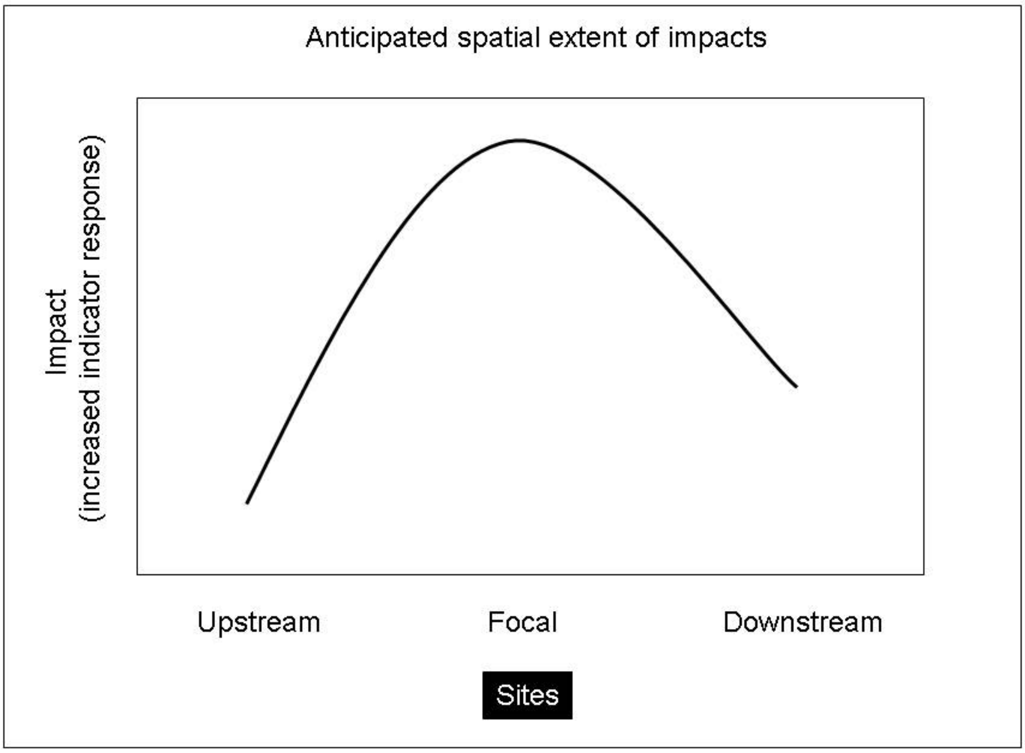


Figure 8: Anticipated spatial extent of impacts (indicator response), with highest response at focal sites, some downstream effects (moderate response at downstream control sites) and no response at upstream control sites

Physical indicators

Turbidity values across all three sites exhibited strongly significant temporal and spatial trends (Table 5). Furthermore, these trends matched those that were anticipated (Figure 7 and Figure 8), with the highest readings during the period of highest visitation and with values at the focal sites significantly higher, in general, than those from the upstream and downstream controls.

Chemical indicators

For FRP, concentrations followed the anticipated temporal trend, with highest concentrations recorded on the holiday weekend sampling occasion and lowest during the mid-week post-holiday period (Table 5). Spatially, FRP and oxides of nitrogen exhibited higher concentrations at downstream control sites than at the focal sites themselves suggesting significant transport and/or transformation of nitrogen from focal sites.

Biological indicators

Data for *E. coli* counts (a measure of faecal contamination by warm-blooded animals) demonstrates the importance of temporally and spatially well resolved sampling. *E. coli* counts fell throughout the study period, with highest values at the beginning and lowest values at the end of the study (Table 5). Although this pattern represents a departure from the anticipated peak in the middle of the study, the fact that values fell dramatically after the end of the school holidays is consistent with the prediction that *E. coli* has a short residence time and does not persist very long once visitors have left the site. Spatially, there is strong evidence for downstream contamination of *E. coli*, suggesting that this human indicator of faecal contamination was entering the system at focal sites and travelling downstream to the downstream control pools.

Benthic algal chlorophyll *a* concentrations rose throughout the study period, suggesting an accumulation of algal biomass. Since algae is a biological indicator, this increase may be due to either nutrient inputs and resuspension over the course of the study period (October), or simply an increased metabolism as spring progresses to summer and water temperatures and light availability increase.

The presence of exotic species is a clear indication of human activities within an aquatic ecosystem. In the case of this field trial, an exotic species of fish (swordtail, *Xiphophorus helleri*), was only found at focal sites (two of the three sampled). This result suggests two things. First, that this fish species is likely to have been released directly to the focal swimming holes and second, that the resident exotic species at the focal swimming holes have not yet successfully moved into neighbouring upstream and downstream pools. Previous work has shown that this species has spread quite widely from release points in urban streams around Brisbane (Arthington, Milton & McKay, 1983). Further work is required to both confirm the suggestion that fish have been released, presumably by visitors, at the focal sites and to determine the local dispersal capacity of this species and from that, the likelihood that the species will successfully colonise the upstream and downstream pools over the coming months and years.

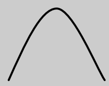
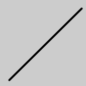
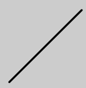
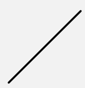
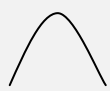
Conclusions

In this field trial we tested 13 indicators, across a wide range of indicator types (see Table 4), to examine their response, relevance and ease of application in a real world visitor impact monitoring scenario. Six of the 13 indicators responded significantly, temporally and/or spatially, suggesting that visitors and their actions in and around focal swimming holes can elicit substantial changes in indicator values.

Three indicators, turbidity, filtered reactive phosphorus and *E. coli* counts, responded both spatially and temporally to the patterns of visitor use outlined in Chapter 2. Significantly, these indicators span the physical (turbidity), chemical (filtered reactive phosphorus) and biological (*E. coli* counts) indicator groups and thus can broadly characterise visitor impacts in and around high use aquatic sites.

The success of the field trials highlights not only the validity of the experimental design employed in this study, but also the relevance, responsiveness and ease of application of the indicators trialled, especially those that responded significantly to the patterns of visitor use of the focal swimming holes. To this end, we strongly advocate that the approach outlined in this report should be employed in all future efforts to measure visitor impacts in and around high use aquatic sites.

Table 5: Indicator response and trends through time and space in field trials at three sites near Kenilworth, Southeast Queensland in October 2008

Indicator	Temporal	Temporal trend	Spatial	Spatial trend
Turbidity	$p < 0.001$		$p < 0.001$	
Conductivity	NS	none	NS	none
pH	NS	none	NS	none
Snapshot dissolved oxygen	NS	none	NS	none
Water temperature	NS	none	NS	none
Filtered reactive phosphorus	$p < 0.001$		$p < 0.001$	
Ammonia	NS	none	NS	none
Oxides of nitrogen (NOx)	NS	none	$p < 0.001$	
Benthic algal chlorophyll a concentration	$p = 0.046$		NS	none
Total coliform counts	NS	none	NS	none
E. coli counts	$p = 0.009$		$p < 0.001$	
Structure of fish communities	NS	none	NS	none
Presence of exotic species	NS	none	$p < 0.01$	

Chapter 4

HOW TO APPROACH VISITOR IMPACT MONITORING—HIGHLIGHTING THE NEED FOR COLLABORATION BETWEEN RESEARCHERS AND PROTECTED AREA STAFF

Knowing Your Systems and Knowing Your Visitors

Critical to all monitoring programs is the requirement that the ecological and social systems, including natural variability within the system, and the pressure from the stressors of concern, are well understood (Green 1979, Underwood 1996a). In other words, without adequate knowledge and understanding of the ecology of aquatic ecosystems, it is very difficult to design and implement appropriately scaled monitoring programs. Similarly, knowing visitors, their demographics, their perceptions, their attitudes and the activities they partake in is critical to the establishment of a monitoring program which aims to examine visitor impacts. In addition, it is vitally important to incorporate temporal sampling (of both visitors and indicators) to ensure that changes through time can be interpreted. This is particularly important for sites where the mix of visitors and the types of visitor activities are highly seasonal. For example, some activities in summer may be replaced by other activities in winter and the interplay between these activities and how they influence the ecology of aquatic sites may make all the difference between intense local impacts or long term chronic impacts.

Indicator Selection

As mentioned earlier in this report and in the earlier report on indicators of visitor impacts produced as part of this project (Hadwen, Arthington & Boon, 2008a), the selection of indicators is driven by a range of factors which will influence the degree to which aquatic ecosystems are successfully monitored. Not only are aspects of the temporal and spatial resolution of indicator response important, but there is no doubt that indicators that are easy to implement and relatively cheap to analyse are favourable in the context of protected area management where resources and staff may limit the capacity to monitor visitors and their impacts (Hadwen et al. 2007, Hadwen, Hill & Pickering, 2008b). To this end and building on the results of our indicator trials, there are several indicators that stand out in terms of their relevance, responsiveness and ease of implementation. These indicators are turbidity, filtered reactive phosphorus concentrations, benthic algal chlorophyll a concentrations, E. coli counts and the presence of exotic fish species. Their characteristics are highlighted in Table 6.

Approach, Not Indicators, Fits All

Although the indicators nominated above (and presented in Table 6) did respond well to the presence of visitors in the field trials undertaken in this study, it is important to remember that it is the outlined approach to indicator selection (Hadwen, Arthington and Boon. 2008a and this report) and implementation (this report) that should be followed in future monitoring efforts. For example, in some systems, such as those heavily dominated by bedrock, turbidity is unlikely to respond to visitor presence to the degree that it did in the current study, simply due to the very different nature of the landforms and erosive tendencies of the system. To this end, it is important to consider each and every focal site of interest individually, to ensure that the selected indicators are going to be responsive and relevant in the system being investigated.

Further to the need for careful consideration of indicators that will respond to visitor presence and specific activities, it is equally important to incorporate understanding of differences in visitor behaviour and perception in future studies. Some sites may be held in higher regard by visitors than others, for example, and this will not only influence the activities they partake in, but it will also strongly influence the degree to which visitors will tolerate change and/or management intervention. This interplay between visitors needs and demands and the challenge of simultaneously maintaining site integrity is what makes protected area management such a complex, challenging but highly worthwhile activity.

Given differences in site characteristics (physical, chemical and biological) and visitors, protected area staff are advised to follow a three step approach, which requires them to first assess the sites of interest, then to census visitors and their activities and then, and only if deemed to be necessary, to begin selecting indicators and implementing a monitoring program.

Table 6: Recommended indicators (and their characteristics that make them appropriate for visitor-impacts monitoring) for visitor impact monitoring in aquatic ecosystems. Justification for recommendation based on desktop review of literature (Hadwen, Arthington & Boon 2008a) and the results from field trials conducted around Kenilworth (Qld) in October 2008

Indicator	Indicator type	Spatial scale	Timeframe	Activity	Temporal response in field trials	Spatial response in field trials
Turbidity	water physico-chemistry	reach, system	< 1 week	sediment resuspension from trampling and erosion	$p < 0.001$	$p < 0.001$
Filtered Reactive Phosphorus (FRP)	water physico-chemistry	local, reach, system	< 1 week, but likely to be highly variable	on site urination and defecation; nutrient inputs and/or resuspension	$p < 0.001$	$p < 0.001$
Oxides of nitrogen	water physico-chemistry	local, reach, system	< 1 week, but likely to be highly variable	on site urination and defecation; nutrient inputs and/or resuspension	NS	$p < 0.001$
E. coli counts	human health	local, reach	< 1 week	on site urination and defecation; leaking toilet systems	$p = 0.009$	$p < 0.001$
Benthic algal chlorophyll a concentration	ecosystem processes	local, reach	~ 2–4 weeks	nutrient inputs and/or resuspension; trampling	$p = 0.046$	NS
Presence of exotic species	biological patterns	reach	months to years	fishing and release of exotic species at focal sites.	NS	$p < 0.01$

Future Engagement Between Managers and Aquatic Ecologists

It is well known that skills, resources and staffing limit monitoring capacity in many protected areas. Whilst this may ultimately determine the shape, size and/or existence of a monitoring program, there are some mechanisms by which protected area managers can facilitate a broader and more comprehensive monitoring program. As highlighted by Buckley (2003), increased interaction and collaboration between environment scientists and protected-area staff can greatly enhance their capacity and raise the awareness of visitor impact monitoring and visitor impacts in general.

The case for this sort of collaboration is even stronger when aquatic ecosystems are involved, as earlier studies have shown that many protected area staff have little or no training or experience in aquatic ecosystem research and management (Hadwen et al. 2005a). This is not surprising given that protected areas are generally based around terrestrial features and attractions and the area encompassed by aquatic ecosystems within protected areas is typically less than 5 per cent of the total protected area (Hadwen et al. 2005a). Nevertheless, the obvious importance of focal aquatic sites for tourism and recreation (including camping) opportunities suggests that these systems do need to be monitored and managed closely. To this end, increased collaborative relationships between protected area staff and aquatic environment specialist's promises to yield more meaningful results and improved sustainability of these highly valued environments.

In addition to the value of collaborative arrangements between researchers and protected area staff, it is clear that detecting impacts, and understanding the mechanisms underpinning physical, chemical and ecological responses, and implementing and maintaining monitoring programs represent two very different pieces of the same puzzle. To this end, Hadwen et al. (2008b) developed a conceptual diagram (see Figure 9) which demonstrates how and why research and monitoring should be linked to achieve visitor impacts assessment goals. Although interaction and collaboration is a key component of this process, certain elements of this flow chart are best managed either by researchers or protected area staff. For instance, identifying systems at risk, on the basis of visitor surveys and an understanding of aquatic ecosystems, is more within the skills base of researchers. In contrast, implementing monitoring programs and collecting monitoring data is clearly within the range of roles and responsibilities that fall to protected area managers. Together, a joint approach between researchers and protected area staff is likely to lead to the development of a stronger monitoring program and the collection of more valuable data, both for monitoring and other (research and management) purposes.

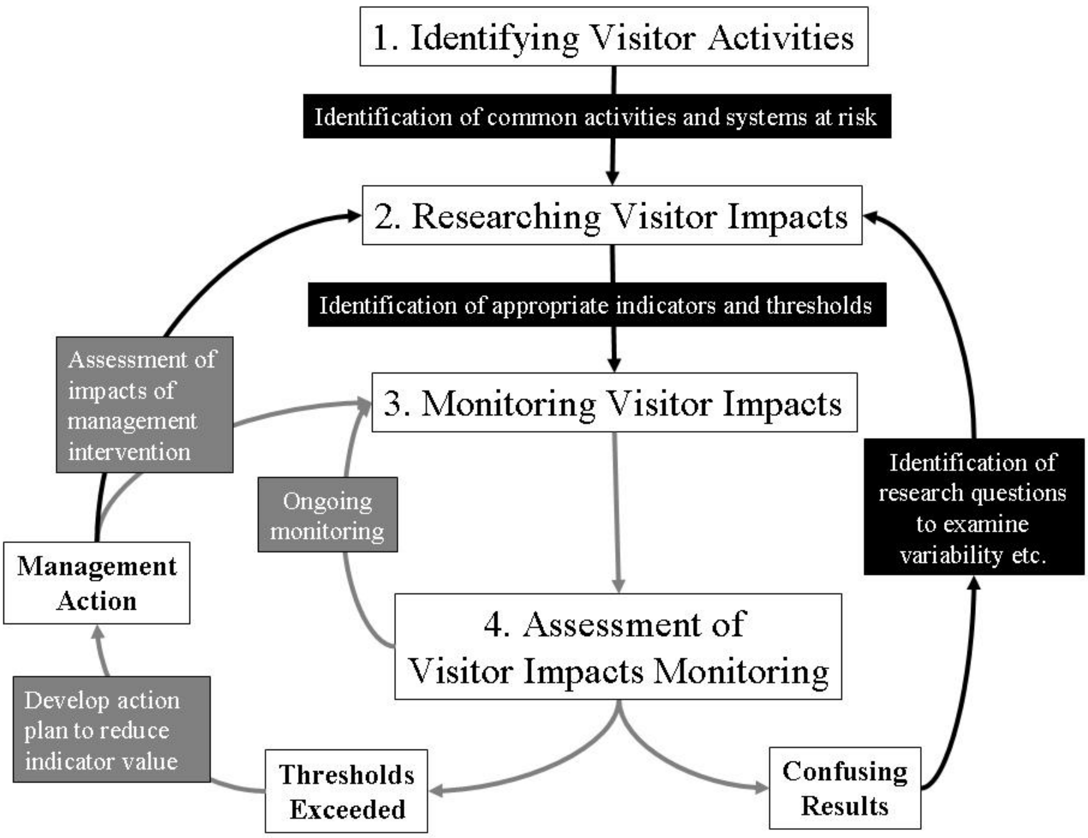


Figure 9: Visitor impact assessment flow chart. Conceptual flow diagram showing the links and differences between visitor impacts research and visitor impacts monitoring in protected areas. (Black arrows represent components of the process likely to be undertaken by research scientists, grey arrows represent the components of the process likely to be undertaken by protected area agency staff.). Figure modified from Hadwen et al. (2008b)

APPENDIX A—SURVEY INSTRUMENT DESIGNED TO ASCERTAIN THE IMPORTANCE OF AQUATIC SITES TO VISITORS IN PROTECTED AREAS

Assessing Visitor Values and Behaviours in and Around Aquatic Ecosystems in Protected Areas

Survey coversheet

Research team:

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Survey aims:

This survey forms part of a project funded by the Sustainable Tourism Cooperative Research Centre. The project aims to investigate the impacts of visitor behaviours in and around aquatic ecosystems. To this end, we have designed the following survey to gain a better understanding of the values and behaviours of visitors to protected areas. The information we gain from this survey will influence our approach to the development of indicators and monitoring programs to assess aquatic ecosystem responses to visitor activities.

Confidentiality and risk:

Your responses to the questions in this survey will be treated as confidential. There is no risk of the information you provide in this survey being reported in any media in a manner that will identify you.

Your participation is voluntary:

Please note that your participation in this survey is voluntary and you are free to withdraw from the survey at any time. Completion and return of the survey reflects your consent to participate in the research.

Ethical conduct of research:

This survey is distributed through Griffith University. Griffith University conducts research in accordance with the *National Statement on Ethical Conduct in Research Involving Humans*. If you have any concerns or complaints about the ethical conduct of this research project please contact the Manager, Research Ethics on +61 7 3735 5585 or research-ethics@griffith.edu.au

Thank you for taking the time to contribute to this research project.

Have you been to this site before? (Please tick appropriate response)

☐ no, this is my first time visiting this site.

☐ yes

If 'yes', tick all that apply from the following:

☐ I am a nearby resident

☐ I visit this location < 5 times a year

☐ I visit this location > 5 times a year

What sort of group are you with today?

☐ alone	☐ couple or family
☐ friends	☐ community group
☐ tour group	☐ other (please specify) _____________

What is your gender?

☐ male	☐ female

To what age group do you belong?

☐ under 18	☐ 19–24
☐ 25–34	☐ 35–44
☐ 45–54	☐ > 55

What is your usual place of residence?

Australian town/city and state ______________ or country of residence ______________

How long do you intend to stay at this site?

☐ less than 2 hours

☐ between 2 and 6 hours

☐ all day

☐ 1–2 days

☐ 3–5 days

☐ more than 5 days

How do you feel about the number of visitors to this area today?

- ☐ far too many
- ☐ too many
- ☐ about right
- ☐ too few
- ☐ far too few

Nominate how important the following factors were in influencing your decision to visit this site. Please circle the most appropriate response for all factors, where 1 = not at all important, 2 = not very important, 3 = important, 4 = extremely important, NA = not applicable.

Resident animals	1	2	3	4	NA
Resident plants	1	2	3	4	NA
Streams and swimming spots	1	2	3	4	NA
Forests	1	2	3	4	NA
Scenery	1	2	3	4	NA
Toilet and camping facilities	1	2	3	4	NA
Boating facilities	1	2	3	4	NA
Bushwalking trails	1	2	3	4	NA
Nearby accommodation	1	2	3	4	NA
Nearby towns	1	2	3	4	NA
Site reputation/ word of mouth	1	2	3	4	NA

During your visit to this site, which of the following activities do you intend to partake in? (Please tick all relevant activities)

- ☐ swimming
- ☐ bird watching
- ☐ water sports
- ☐ hiking and bushwalking
- ☐ relaxing/picnicking
- ☐ camping
- ☐ fishing or hunting
- ☐ kayaking/canoeing
- ☐ land-based sports
- ☐ photography
- ☐ sunbathing
- ☐ other (please list) ____________

What factors influenced your arrival time at this destination? (Please tick all relevant factors)

- ☐ avoiding peak sun times
- ☐ avoiding visitors elsewhere
- ☐ arrived for lunch
- ☐ other (please list) _________________________
- ☐ avoiding peak heat times
- ☐ avoiding visitors at this site
- ☐ arrived for a swim

How do you rate the following features of the swimming hole at this site? Please circle the most appropriate response where 1 = poor, 2 = average, 3 = good, 4 = excellent, NA = not applicable.

Water colour	1	2	3	4	NA
Water clarity	1	2	3	4	NA
Water odour	1	2	3	4	NA
Water taste	1	2	3	4	NA
Water temperature	1	2	3	4	NA
Distance from carpark/campground	1	2	3	4	NA
Distance from facilities (toilets/showers)	1	2	3	4	NA
Quality of access track(s)	1	2	3	4	NA
Educational signage	1	2	3	4	NA
Site hardening (steps, boardwalks etc)	1	2	3	4	NA
Condition of swimming hole	1	2	3	4	NA

In terms of general site condition, how would you rate the presence of the following factors at this site? Please circle the most appropriate response where 1 = none, not present, 2 = present, 3 = common, 4 = very common, NA = not applicable.

Non-biodegradable litter plastic, metal)	1	2	3	4	NA
Biodegradable litter (i.e. food scraps)	1	2	3	4	NA
Track erosion	1	2	3	4	NA
Track widening	1	2	3	4	NA
Track compaction	1	2	3	4	NA
Campsite compaction	1	2	3	4	NA
Presence of weeds	1	2	3	4	NA

Do you intend to wade or swim at this site today?

☐ no
☐ yes

If yes, how long do you think you will be in the water?

☐ 10 minutes or less
☐ between 10 and 30 minutes
☐ longer than 30 minutes

To what extent does the water quality at this site influence your enjoyment and satisfaction of water-based activities?

☐ dissatisfied greatly
☐ dissatisfied slightly
☐ no effect
☐ satisfied slightly
☐ satisfied greatly

If you were *dissatisfied* with the water quality today, please indicate why you felt this way (Tick any appropriate reasons):

☐ water clarity or visibility
☐ water colour
☐ water odour
☐ water temperature
☐ submerged plants
☐ submerged logs
☐ litter or debris
☐ wave action
☐ visible algal growth on surfaces
☐ other (please specify) ________________________________

What do you think about the infrastructure and facilities available to people at this site?

☐ excellent
☐ adequate
☐ insufficient

If *insufficient*, what other facilities would you like to see?

____
____
____

Do you feel that the site needs more facilities to ensure sustainable use of resources and a greater understanding and appreciation by visitors?

☐ no
☐ yes

If yes, please tick any of the following options that you think could help:

☐ educational signs
☐ improved pathways (including boardwalks)
☐ improved toilet and/or picnic facilities
☐ information centres
☐ limits on visitor numbers or areas of visitor access
☐ clear zoning for different activities
☐ other (please specify): ____________________

On balance, do you think that tourism and recreation is beneficial, neutral or detrimental to the following (please circle one of either B = beneficial, N = neutral or D = detrimental)?

Local plants	**B**	**N**	**D**
Local animals	B	N	D
Forests	B	N	D
Waterways (streams, rivers, lakes and estuaries)	B	N	D
Local Businesses	B	N	D
Local Residents	B	N	D
Community Groups	B	N	D
Local Government	B	N	D

Any other comments?

____
____
____
____
____

Thank you for taking the time to contribute to this research.

+

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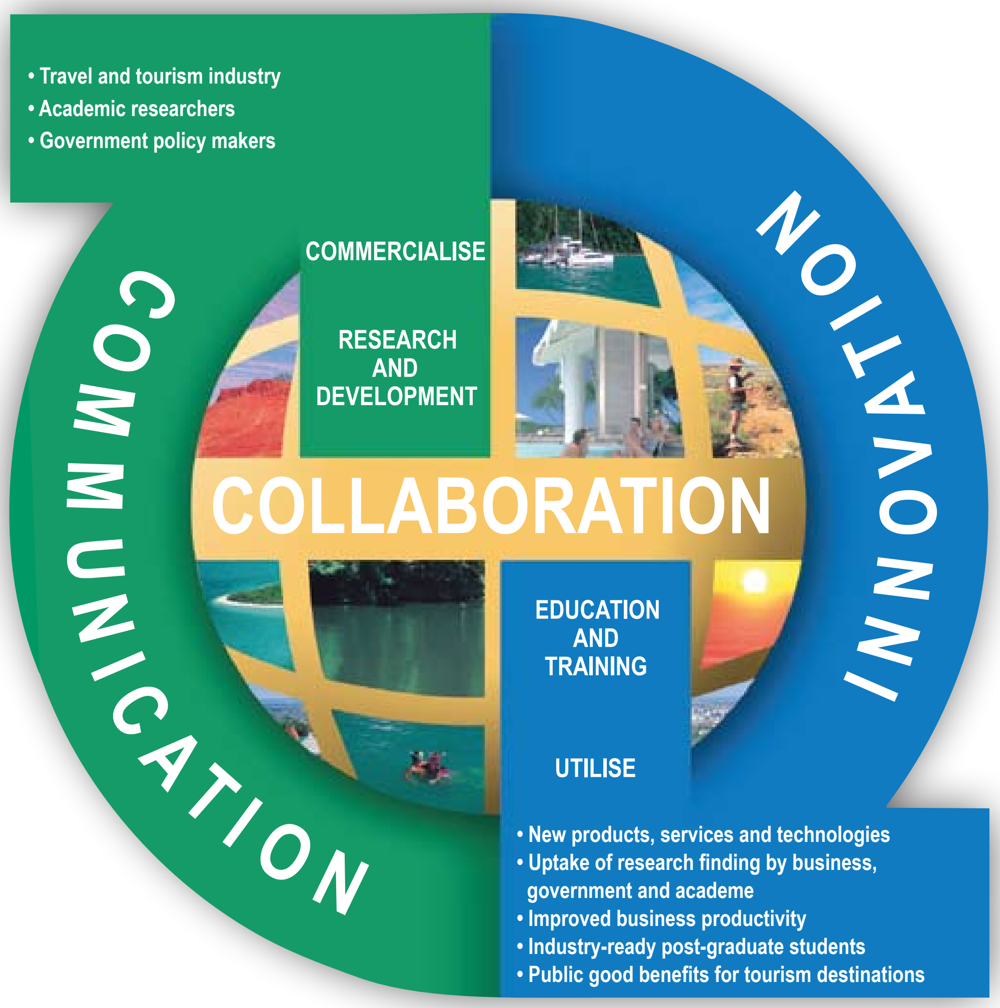

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STCRC has grown to be the largest dedicated tourism research organisation in the world, with $187 million invested in tourism research programs, commercialisation and education since 1997.

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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.

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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 searchers and industry or other users; and
- efficiency in the use of intellectual and other research outcomes.