Title: Towards a better understanding of protected-area management costs

Article type: Methods

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Key Words: parks, spending, effectiveness, prioritization, accountancy, forecasting

Abstract

Data on protected area (PA) management costs are essential for effective conservation planning and management. To be most useful, these data should be at high resolution, in terms of individual management units within PA systems and individual management actions. Ideally, data would also capture temporal changes in management costs in relation to disturbance events, and variations in biophysical and social context. Yet there remains no generally accepted method to collect these important high-resolution data. Here we present a new method for the collection of data on current management spending and the costs of managing PAs to explicit, and usually higher, standards than presently achieved. The method allows the gathering of data at higher spatial, temporal, and thematic resolution than has been achieved before. We highlight the strengths and potential pitfalls of this type of data collection and offer insights into how these data can be used for the benefit of PA managers, conservation planners, and policy-makers. The methods presented here could be adapted to be used by other PA management agencies and jurisdictions to better understand the costs of managing PAs effectively.

Introduction

It is widely recognised that protected areas (PAs) provide a wide range of benefits, including biodiversity conservation and human recreation (Juffe-Bignoli et al. 2014). It is also recognised that data on PA management costs are fundamental to effective conservation planning and management (Bode et al. 2008; Green et al. 2012). However, we have a poor understanding of the financial resources needed to manage PAs to ensure they continue to provide their benefits in the long term. We know that a key limitation of effective management of PAs has been lack of adequate investment (Bonham et al. 2014), which decreases management effectiveness (Leverington et al. 2010), in turn leading to poorer biodiversity outcomes (Geldmann et al. 2015); but a more in-depth understanding of PA management costs has been elusive.

Previous estimates of management costs have several limitations. Firstly, global or continental assessments (James et al. 1999; James et al. 1999; James et al. 2001; Balmford et al. 2003; Balmford et al. 2004; Moore et al. 2004; McCarthy et al. 2012) have used highly aggregated data or extrapolated widely from sparse samples of PAs. The resulting models are difficult to apply within regions to individual PAs that might differ in characteristics that are important in determining management costs. Second, like most global analyses, studies applicable to individual PAs within regions (Wilkie et al. 2001; Frazee et al. 2003; Blom 2004; Armsworth et al. 2011; Green et al. 2012) are limited by little or no breakdown of costs by action (e.g., control of invasive species, maintenance of visitor facilities, monitoring). An ideal approach would estimate costs of individual management actions for a given set of characteristics and objectives at the resolution of individual PAs (Frazee et al. 2003). Third, cost estimates based on inadequate existing spending, as opposed to required spending, in samples of PAs will understate funding requirements. Fourth, those studies that have estimated required, as distinct from current, management spending have not used an explicit set of standards against which required spending can be estimated. Without explicit criteria for defining standards of management and rigorous elicitation methods to estimate

corresponding costs, figures for shortfalls have unknown reliability. Fifth, the existing data typically consider costs only for a single year, making it difficult to quantify the temporal variability of costs, say in relation to age of PAs, or events such as fires or storms. Overall, there is considerable scope for improving data and their collection methods to improve our understanding of PA management costs.

The main reason for the presently poor understanding of PA management costs is the lack of high-resolution data on what is currently spent in PAs, what needs to be spent to achieve management objectives, and the factors that influence required costs. We refer to high-resolution data in three ways: spatial (for individual PAs or management units, or parts of large PAs); thematic (for individual management actions); and temporal (over time, but recognising between-year variation and its causes).

PAs have been established in diverse physical, social, and economic environments, so managers spend their management budgets on a highly heterogeneous range of actions that differ in relative importance between management units and over time. We need to understand how the costs of different management actions vary, what explains and predicts those costs, and how costs are likely to change with the age of PAs and with changing internal uses or external pressures. Only high-resolution quantitative data allow reliable statistical models to be developed that explain the patterns observed in existing PAs and predict the costs for PAs yet to be established (Wenger et al. 2017). In this paper we present a transferable set of methods that can be used to obtain high-resolution financial data from an extensive PA system. Our financial data have several advantages for PA managers and conservation planners (Table 1).

In developing and applying our method for estimating high-resolution data on management costs, we had to overcome obstacles that are probably typical of many PA systems. In many PA agencies, there is a poor connection between the systems recording financial data and those connected to on-ground conservation actions.

Financial information in management agencies is commonly stored, encoded, and arranged for the purposes of auditing rather than management. This means that, while most PA management agencies know precisely how much is spent at broad scales on resources such as salaries or vehicles, they would be unable to accurately say where and on what management actions those resources were spent. Additionally, those financial data that are available are typically based on the amounts spent rather than amounts required. These limitations prevent managers from understanding, explaining, and predicting management costs, and reduce the value of existing cost estimates in conservation planning.

Table 1. Main advantages of high-resolution data on management costs

1	Estimating the required costs of different levels of management performance
2	Estimating the differences between current spending and required costs for different levels of management performance
3	Stronger basis for modelling management costs, both to identify the drivers of current costs and to predict the costs of new or changed management units
4	Basis for modelling the costs of individual management actions
5	Stronger basis for business cases to government departments and donors
6	Tracking of temporal changes in spending and required costs
7	Basis for redeploying staff, equipment, and funds between management units or regions to fill large shortfalls
8	In combination with data on social and economic benefits of PAs, estimation of return on investment

These difficulties call for a practical approach, such as the one we describe in this paper, to deriving high-resolution data on management costs, developed here for a large set of PAs. We distinguish between “spending”, which refers to current financial outlays, and “costs”, which refer to the investments required to achieve explicit management objectives. The method is presented in four parts: 1. Defining the questions; 2. Sampling design; 3. Eliciting the data from managers; and 4. Data processing. We conclude with recommendations for future applications of the method to other settings and agencies.

Study area

The methods described here were developed in Queensland, Australia, in collaboration with the Queensland Parks and Wildlife Service (QPWS). QPWS is a state government agency that manages the majority of an extensive PA system (8.7 million ha, >500 reserves and national parks, excluding nature refuges) spread across a state of 1.72 million km^2 (Figure 1, CAPAD 2014). The PAs within the system show extreme diversity among many key characteristics including size (1 ha to >1 million ha), remoteness (suburban parks to >1000 km from a city), and ecology (including wet tropical, desert, and temperate). Significantly, the PA system features five World Heritage Areas, including the islands of the Great Barrier Reef. This level of variation provided a robust testing ground for our methods, increasing the transferability of our methods to other regions and management agencies.

In recent years QPWS has had two prime and equally prioritised objectives for PA management: biodiversity conservation, and providing public access to wild spaces (NPRSR 2015). Entry to the QPWS estate is largely fee-free and other fees, such as those for camping, are low. QPWS management is funded largely from state tax revenues and, like other public services, has experienced shrinking budgets for several years, leaving the PA system highly resource-constrained. Compared to other regions around the world, Queensland has relatively simple institutional and tenure structures managing its PAs, with a large proportion of PAs managed and funded solely through QPWS and the remainder managed in collaboration with one or two other agencies, typically local councils and indigenous groups. The relative simplicity of management authority and tenure improved the feasibility of collecting comprehensive financial data, but is unusual globally (Iacona et al. 2016).

Overcoming the data shortcomings

The main aims of our study were to answer the following questions with data of higher spatial, temporal, and thematic resolutions than have been available previously, in Queensland or any other study area:

a) What is the current spending on PA management?

b) What are the costs of achieving stated management objectives?

c) What is the current funding shortfall?

d) How are management spending and costs related to potential cost drivers?

Initially efforts were made to extract recent spending data from existing financial recording systems. These records contained relevant data for spending on physical infrastructure and broad patterns of staff locations. However, the available records did not contain any information on which management actions were being completed with the available resources. Additionally, the coarse spatial resolution of the records meant that it was not possible to identify the total resources allocated to individual protected areas. This meant that much of the data required for this study needed to be elicited directly from QPWS managers. There was no other source of suitable data available.

Our method

The procedure to collect and analyse the required financial data had four steps:

1. Defining the questions
2. Sampling design
3. Eliciting the data from managers
4. Data processing

1) Defining the questions

Defining the management actions

Effective management of PAs requires a wide range of different actions (e.g. invasive species control, maintenance of visitor facilities). The proportion of financial resources dedicated to each action will vary greatly across different PAs and through time. Thus to fully understand the management costs of PAs, it is necessary to disaggregate total spending within a PA into different types of management actions. To do this consistently across PAs with diverse characteristics required the development of a defined typology of management actions.

In developing our typology, there was a clear tradeoff to be made. The fewer actions considered, the less time needed for data collection and the more PAs that could be covered. However, too much aggregation of actions would reduce the thematic resolution of the data, potentially obscuring important results. It was also necessary to consider how the definitions of actions would affect the accuracy of the data elicited from managers. A higher thematic resolution would help with accuracy, by breaking spending down into recognisable and memorable portions that could be estimated easily by managers. Higher resolution also helps to highlight actions that are under-funded by prompting direct questions about actions to which no resources are currently dedicated, which might otherwise be overlooked.

The first draft typology was based on a pre-existing internal QPWS classification scheme, which was then further refined. A challenge to overcome in developing the typology was the difficulty of avoiding overlap between actions, which was necessary to ensure resources were allocated unambiguously to the correct actions. Several iterations of the typology were developed during testing with field managers before a final scheme with 24 separate actions was finalised (Table 2). In practice, several of the management actions in the typology were rarely allocated any resources while others were used for every PA.

199 To adapt our typology to other PA systems and agencies we suggest that the categories
200 of actions be guided by the operational structure and priorities of the local management
201 agency. A distinctive feature, at least in a global context, of PA management in
202 Queensland is the minor nature of compliance and enforcement. There might be benefit
203 in further disaggregating this category of actions in regions where related actions are
204 more diverse and form a larger proportion of PA management.
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207 Table 2. Typology of management actions used for data elicitation.

Action name	Examples of management tasks in this category
Historic cultural heritage	Historic cultural heritage research, monitoring, planning, and management
	Cultural heritage infrastructure maintenance and protection
	Advisory committees
	Monitoring and surveying of historic heritage values
	Planning and management of cultural resources
	Recording of cultural resource inventories
Indigenous cultural heritage and engagement	Indigenous cultural heritage research, monitoring, planning, and management
	Actions relating to native title negotiations
	Development of indigenous partnership agreements and memoranda of understanding
	Indigenous cultural heritage sites maintenance and protection
	Indigenous partnership collaborative works and activities
	Planning and management of indigenous cultural resources
Management information and reporting systems	Park Info Management System[1]
	Capital works prioritisation system
	Strategic Asset Management System (SAMS) [1]
	Built infrastructure condition audit reports
	National Integrity Statements[1] and reporting of natural values
	Environmental Management Plans (EMPs) [1]
Natural resource monitoring	Natural resource research, monitoring, and reporting
	Flora and fauna surveys on estate
Conservation and management planning	Management plans and statements
	Consultative processes for management planning
Fire management	Fire management activities and prescribed burns
	Development and maintenance of fire infrastructure (i.e. fire breaks) and equipment
	Fire training
	Liaison with neighbours and external agencies
	Wildfire control
	Fire management planning
	Fire monitoring
Weed management	Liaison with neighbours and external agencies
	Training and/or accreditation
	Research, strategies, and trials
	Monitoring, planning, and control programs
Feral animal management	Liaison with neighbours and external agencies
	Training and/or accreditation

	Research, strategies, and trials
	Monitoring, planning, and control programs
Rehabilitation of degraded systems	Land management activities relating to rehabilitation of degraded systems
	Erosion control
	National park recovery projects
	Revegetation works
Land acquisition	Liaison with affected stakeholders regarding land acquisition
	Surveying of boundaries in relation to acquisitions and agreements
Stakeholder relations and community engagement	Liaison with interest groups, issues groups, and community groups
	Liaison with neighbours
	Advisory committees
	Volunteer coordination and activities on estate
Investigation, compliance, and enforcement	Investigation, compliance, and enforcement Patrols
Management and services infrastructure	Construction and maintenance of offices, workshops, residences, barracks, fences
	Construction and maintenance of roads and water services
Native species utilisation	Take, use, and keep (scientific sample collection)
	Forest practices
	Macropods
	Protected plants
	Turtles / dugongs
	Biodiscovery
	Compliance
Threatened species	Conservation plans
	Recovery plans
Other wildlife interaction	Conservation
	Human nuisance
	Human safety
	Other (e.g. whale entanglements)
Visitor use	Research, monitoring, planning, and management
	Visitor impacts monitoring and research
Visitor infrastructure	Development and maintenance of visitor infrastructure
	Campground facilities cleaning and maintenance
	Integrated Environmental Management System – IEMS[1] - for visitor tourism infrastructure
Public communication	Visitor interpretation, community education, promotion, and media management
	Face-to-face interpretive programs
	Group activities - visitor management

	Interpretive planning, signage, and displays
	Media liaison and promotions
	Park information sheets
	Visitor liaison
	Website administration
Commercial tourism	Commercial tourism and group activities planning, research, monitoring, and management
	Investigation and development of commercial tourism opportunities
	Law enforcement actions relating to commercial activities
	Liaison with commercial operators and tourism industry
	Assessment and issuing of commercial activity permits
	Commercial filming and photography
	Commercial operator compliance inspections
Use of natural resources	Public infrastructure built on QPWS estate (i.e. roads, towers, public utilities)
	Grazing, bee keeping, quarrying, gas extraction, petroleum exploration on QPWS estate[2]
Non-specific administration	Routine meetings and communication
	Staff management
	Informal reporting
Nature refuges[3]	Agreements
	Incentives tender
	Systems and support
Staff training and capacity building	Staff training and capacity building

Footnotes:

1: These refer to internal databases and data recording systems used by the Queensland Parks and Wildlife Service

2: Extractive land uses and exploration are permitted on leased land within certain protected-area types such as state forests, but not in national parks.

3: This category refers primarily to duties related to inspection and evaluation of proposed nature refuges rather than direct management of nature refuges, which are privately owned and managed.

Four components of costs

Different management actions require very different types of resource input. It is beneficial to record these inputs separately to increase the resolution of the data and to ensure that all types of costs are covered in elicitation. For further work, it might be necessary to adapt these input types.

We recognised four types of inputs (components) of cost: labour, consumables, vehicles/transport, and infrastructure. Labour makes up the largest cost component of most actions, so obtaining an accurate estimate is important. Labour costs consist of salaries and other financial outlays required to support people in their management duties. A full understanding of labour costs requires time-and-motion studies for each management action that are beyond the capacity for most conservation organisations. However, experienced managers often have an excellent understanding of how much labour is required to complete various tasks and this knowledge can be captured through well-structured elicitation. Many actions have some sort of consumable component. Typically, this is a minor component of an action's costs, although it can be substantial for certain actions such as the use of herbicide for eradication of invasive plants. Any management action that takes place away from a management base will require resources to be allocated to staff transportation. For large and remote PAs the cost of transport can be significant. Infrastructure includes the built infrastructure and large plant and equipment required to manage a PA effectively. Depending on the context, on-site infrastructure is likely to include items such as firefighting equipment and road grading vehicles.

The advantages of avoiding 'dollar value' elicitation

Conventionally, management cost data are collected in units of the local currency. However, this presents a number of difficulties that can be overcome by collecting management cost data in non-currency units. For labour resources, this means recording effort in units of time (e.g. hours, person-days, proportions of full-time equivalent positions, or FTEs). Other examples of non-currency units are amounts used (e.g. litres of herbicide) for consumables, and type of vehicles and durations of use. There are three key advantages of collecting cost data in non-currency units. First, it aids in the collection of accurate elicited values from managers who typically find it easier to recall tangible memories about previously completed actions than about financial

outlays. For example, managers might not be able to accurately estimate the salary costs of a completed action, but they are likely to recall the size of the team and the length of time the action took to complete. Second, non-currency units allow the elicitation process to be completed more rapidly: by recording data directly in units of the manager's preference, avoiding any time-consuming need for translation into financial units. Third, by recording non-currency units the data collected are much easier to compare to cost data from different management agencies and time periods. Data are much more transferrable between agencies, for example, if it is known that a particular management action requires two ranger FTEs than if only the salary costs ($190,000) are recorded. The disadvantage of using non-currency units is that substantially more post-collection processing of the data is required to derive comparable currency units for analysis but, in practice, this can be semi-automated using lookup tables for items such as salary costs.

Classification of costs used for elicitation

Our initial intention was to elicit costs disaggregated into the four components described above: labour, consumables, vehicles/transport, and infrastructure. However, trial elicitations revealed a complication that required some reorganizing of the question structure. The trials showed that it was necessary to differentiate between routine management spending and spending associated with special projects, which were typically funded from temporary or external sources and often had budgets exceeding the totals for routine spending. Differentiation was necessary in order to understand what would otherwise have appeared to be very large temporal variations in management spending from year to year without obvious explanation. This extra layer of complexity may not be required if the methods presented here were to be adapted for use in a different PA management agency.

We therefore elicited costs grouped initially into three higher categories, labelled as labour, recurrent, and non-recurrent (Table 3A). The four cost components described

279 above were nested inside these three higher-level categories (Table 3B). These
280 categories were defined after pilot workshops demonstrated the key role of non-
281 recurrent funds for disaster relief and rebuilding in PA management in some regions.
282 After severe flooding, the disaster-relief funding was greater than the total for recurrent
283 operational and staff costs in some PAs. The advantage of disaggregating this short-
284 term, non-recurrent funding from recurrent expenditure was that it allowed tracking of
285 recurrent spending that would otherwise have been obscured by occasional major
286 episodes of non-recurrent spending. Additionally, managers can and should budget for
287 recurrent expenditure but they cannot easily predict budgetary needs for non-recurrent
288 work.
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290

Table 3. Grouping of management costs for elicitation

A. Categories of costs

Type	Description	Examples
Labour	Staff time and salary grade if senior role	Days, weeks, and proportions of full-time equivalent (FTE) staff time
Recurrent	Predictable and regular costs, including consumables and maintenance of infrastructure	Fencing materials, vehicles, fuel, plant, and equipment (e.g. chainsaws), herbicide
Non-recurrent	Special project funding, new infrastructure, disaster-relief funding	Short-term specific projects e.g. pest and weed eradications, and capital expenditure for new visitor facilities or rebuilding infrastructure after floods and fires. These often include external labour, consumables, and vehicle costs that are funded under contracts rather than from annual operational budgets and resources

B. The three categories of costs in relation to the four cost components

	Cost component			
Cost category	Labour	Consumables	Transport	Infrastructure
Labour	✓[1]			
Recurrent		✓	✓	✓
Non-recurrent	✓[2]	✓	✓	✓

Footnotes

1: This labour component consisted of QPWS staff.

2: This labour component usually consisted of contract workers but not QPWS staff.

Actual spending vs. estimated costs of effective management

Knowing that QPWS budgets had been shrinking for some years, it was important to collect estimates of the funding required, over and above current spending, to achieve good management outcomes. Otherwise the spending data alone were likely to underestimate the true costs of achieving management objectives. Additionally,

underfunding is likely to be non-randomly distributed across management units and management actions. For example, iconic PAs with World Heritage status and/or high rates of visitation are likely to be better funded overall than lesser known PAs, and to have a larger proportion of total spending directed towards visitor facilities. It is therefore necessary to estimate the costs of effective management for each defined management action. For the purposes of our project we collected cost data for three pre-defined levels of management performance described as Fair, Good, and Very Good (Table 4). The Poor level was included to cover the possibility that this applied to current management for some actions. More precisely defined performance levels would have been beneficial to avoid inconsistency of interpretation. However, these levels were selected as a compromise that enabled achievable elicitation, because managers could relate to them, and they also allowed comparability across PAs.

Table 4. Definitions of performance levels assigned to each management action

Level	Definitions
Poor	Below the Fair standard e.g. footpaths in poor state or closed (Visitor Infrastructure), invasive alien species increasing in abundance (Weed and/or Feral animal management)
Fair	Management meets statutory obligations and/or conditions of concern are prevented from deteriorating e.g. footpaths are safe and open, abundance of invasive alien species is stable
Good	Management achieves desired outcomes e.g. footpaths clean and in good condition with good signage, invasive alien species well controlled so they are having little impact on biodiversity and/or visitor values
Very Good	All objectives met or exceeded to a high standard; world's best practice; difficult for managers to see how performance could be improved

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2) Sample design

It was clear from the outset that PAs in Queensland are highly heterogeneous and that, in order for the data collected to be representative of the whole State, it would be necessary to sample strategically. Data collection from all PAs was not viable due to the large number of PAs and resource constraints on the project. We therefore collected data using a stratified sample strategy by which we first identified the main management regions within the organisation and selected three regions from which to sample relatively intensively. This choice was also guided by the interest of QPWS in management costs in certain regions. The selected management regions were South East Queensland, the Wet Tropics, and Western. The regions contained a substantial proportion of the iconic PAs within the State whilst also being highly heterogeneous with respect to physical and biological characteristics and landscape contexts of PAs. Within each of the selected regions, PAs were targeted for data collection in order to capture examples of PAs across ranges of characteristics likely to affect management costs (e.g. size, visitation levels, presence of endangered species and ecosystems). We selected 20 PAs in each of the three regions.

Wherever possible we obtained data for individual PAs. In some cases, however, the structure of operational management was not aligned with the names of individual reserves, and data collection was adapted accordingly. This meant data were collected for aggregations of very small parks (e.g. Gold Coast PAs) managed as single units. Conversely, some very large PAs (e.g. Carnarvon Gorge NP) with rugged terrain were managed from separate management bases with separate budgets. In these cases, PAs were subdivided and the parts were treated as separate units for the purposes of data collection. Attempts were made to disaggregate groupings of small PAs, but it was impossible for managers to provide plausible estimates for the individual PAs. This is a common challenge when collecting these types of data (Green et al. 2012). In all cases, the temporal resolution of the data collected was per full financial year.

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353 **3) Eliciting cost data from managers**

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355 In order to collect the large amount of data required from staff, and to ensure
356 consistency between PAs, a well-structured formal elicitation procedure with in-person
357 facilitation was required. There has been an improvement in our understanding of the
358 challenges and pitfalls of using expert-elicited data in recent years (Burgman 2016). For
359 our project, considerable thought was put into designing the elicitation to minimise bias
360 and maximise accuracy while still allowing the required data to be collected in the time
361 available. We identified a number of biases that were likely to affect the managers'
362 responses during elicitation (McBride et al. 2012) and sought strategies to counteract
363 them.

364

365 The main challenges to overcome during elicitation were groupthink - domination of
366 responses by senior participants - and anchoring estimates to values already provided
367 (Burgman et al. 2011; Martin et al. 2012). Proactive facilitation was the main tool used
368 to counteract these issues by promoting participation from all workshop attendees and
369 asking for specific locations and durations of actions being costed to ensure tangible,
370 feasible actions were being elicited. Additionally, participants were regularly shown the
371 definitions of management actions and examples were discussed to ensure there was no
372 misallocation of resources into potentially overlapping categories.

373

374 One of the first decisions to be made was whom to target for elicitation. It was clear
375 that the overall manager of each PA (termed Ranger in Charge) was an essential
376 workshop participant due to his or her role in planning and implementing management
377 actions. Additional staff functions that appeared to be useful were experienced rangers
378 with detailed knowledge of the PAs' working practices and staff from the management
379 tier above the Rangers in Charge (termed Senior Rangers) who, compared to rangers,
380 often had a broader perspective of management requirements and in-depth knowledge

of budgets. Having identified the key workshop participants for each PA (Ranger in Charge, Senior Ranger, and other experienced rangers) we sought wherever possible to have the staff in these roles attend each workshop. There was pressure from QPWS to minimise the number of participants attending each workshop to reduce lost time on normal duties. Consequently, the ideal set of attendees was not always achieved. Elicitation was always carried out with at least two members of staff present, though typically four staff attended workshops. Pilot elicitations showed that the estimates produced were more reliable with more than one participant because of the advantages of discussion, cross-referencing, and complementary perspectives. This accords with recent research on elicitation methods (Martin et al. 2012).

The methods used to elicit cost data from managers were developed and refined through a number of pilot workshops. Initially, attempts were made to use a version of the Delphi method where the managers were asked to estimate the upper bound, lower bound, best estimate, and confidence in the estimate, across two rounds of questions with discussion in between. This procedure is thought to generate consensus estimates relatively efficiently (Burgman 2016). In practice, this method proved to be too time-consuming. Additionally, the method was not suitable because the small number of elicitation participants already knew each other well, so providing independent estimates was therefore resisted by participants.

Elicitation workshops took place in the PAs or at the nearest management base and were facilitated by a single researcher, taking between half and a whole day per PA, depending on management complexity. Data were collected with questionnaires and spreadsheets projected onto a screen or wall so that all participants could view the data being recorded. In total around 30 data-collection workshops were carried out with one or two PAs being covered at each workshop.

The overall structure for the elicitation

Elicitation workshops involved questions on three topics:

1) Past spending broken down for each management action, with the support of written records where available. These data were collected for the past 3 financial years.

2) Perceptions of the level of management performance (Table 4) currently being achieved for each management action.

3) Estimates of the resources required for each management action to meet Fair, Good, and Very Good levels of management performance, except for actions already meeting one of those levels.

Eliciting estimates of past spending

Managers were asked to estimate the previous resources allocated to each of the 24 defined management actions (Table 2) broken down into the types of costs in Table 3B. The estimates provided were cross-validated using existing records of spending on specific projects, typically related to fire and invasive species management. Spending on maintenance of infrastructure was also well recorded and these values were transferred to the dataset largely intact in some cases. At the end of each workshop session where spending on individual management actions was estimated, the total resources allocated were summed and compared with the total resources known to have been allocated to the PA. Managers had extremely accurate recall of how many staff in total had worked in the PA during the past years. In over 90% of the workshops, the tally of resources the managers said they had allocated to labour was within 10% of the number of FTEs known to have worked in the PA. For a minority of workshops at which discrepancies between these two figures were apparent, the managers were questioned further to discover the sources of the differences and then the elicited figure was corrected. Discrepancies were both positive and negative and had different causes on each occasion. One example was failure to remember hire of temporary staff.

Estimating costs of effective management

Eliciting data to estimate the costs of effective management was challenging due to the subjective nature of the questions being asked and the tendency for staff to anchor their responses to the values provided for the estimates of previous spending. To overcome this challenge, where available, management plans with specific objectives were used to frame the questions to ensure there were tangible examples of tasks for the managers to cost. However, for the majority of PAs, management plans were either absent or too generic in their objectives to be used to guide the elicitation process.

In these situations, the management performance levels (Table 4) of Fair, Good, and Very Good were first translated into site-specific statements of objectives. Managers were then asked to describe the specific outcomes they sought and the actions that would be required to achieve them. Our pilot workshops demonstrated that action-specific guidance developed for one PA would not be useful for a different PA with different characteristics and management priorities. Uncertainty was created by our inability to develop generally applicable, narrow definitions of what would constitute Fair, Good and Very Good among different PAs. However, this uncertainty was often unavoidable and highlights the importance of PAs having management plans that contain specific and measurable management objectives to enable the estimation of the costs of meeting those objectives.

In practice, most managers had a sound grasp of the resources that would be required for each action to be considered completed to the Good level. The procedure developed to elicit the costs of effective management was to first ask managers to specify their perceptions of the level of management performance currently being achieved for each management action in turn. Then, through facilitated discussion, values were estimated for the resources needed to achieve the other tiers of performance. This key advantage of this procedure was that it avoided introducing unidirectional upward bias that would have occurred if the elicitation questions just asked ‘how much extra is required?’. Our procedure meant that, if managers described the current level of performance of an

action as Good or Very Good, then they were also required to estimate the reduced costs required to meet the lower tiers of Fair or Good. In practice, it proved difficult for managers to estimate required spending substantially lower than current levels. On some occasions, managers stated that, to reach a higher level of performance, a multi-year project would be required. This occurred most commonly when the required action was control of invasive species needing multiple rounds of treatment over a number of years. Spending on multi-year projects was likely to vary between years, so the managers were asked to estimate the total cost of the project and the project length in years (up to 5 years). The average annual cost was then calculated and recorded.

It was clear throughout the elicitations that the data being collected were seen as politically sensitive and that the uses of the data needed to be stated clearly. It was advantageous for us to represent a relatively independent external party motivated by a research question rather than people who would directly influence future decisions about budget allocations. If the researchers had been perceived to be working for the senior managers of QPWS then it is unlikely the workshop participants would have been candid. The managers would have likely 'second-guessed' the answers to the questions to make them politically acceptable and also inflated the estimates for required costs in anticipation that they might directly increase the size of subsequent years' budgets.

4) Data processing

Translating the elicited units such as weeks of labour into currency units for analysis required the compilation of data about the costs of each component within QPWS. Much of this information, such as salary rates and vehicle costs, was readily available because it is required for internal budgeting. Relatively simple arithmetic was then used to produce annual costs for each of the three categories of costs and the four components of each management action nested within them. Cost shortfalls were calculated as the difference between the current level of spending and the values needed to meet the Good and Very Good levels of management performance. If

required, the costs can be projected into the future by incorporating estimates of future cost inflation (i.e. 3% per annum) into the calculations.

It can be difficult to incorporate (or disaggregate) head/regional office support and administration costs from on-reserve costs for individual conservation actions. These more remote costs relate to the infrastructure and processes required to run any large public-facing organisation (e.g. administration, human resources, information technology, policy development). It can therefore be expected that the management of any PA involves some amount of these centralised costs. When calculating total reserve management costs, the solution used for this study was to add the costs of regional office support to the salary costs of ranger staff. No single method can be offered to the problem of estimating off-site labour costs, given the diversity of organisational structures among management agencies. However, whenever financial data are reported, clear statements are needed about what was and was not included in the figures.

Discussion

This article demonstrates and discusses a methodology for collecting high-resolution PA management cost data using a survey of agency staff in the state of Queensland, Australia. The advantages of obtaining high-resolution cost data are substantial (Table 1), including the ability to estimate shortfalls in current funding levels broken down by individual management actions, which in turn allows relatively accurate estimation of how much extra funding is required for PAs to meet specific management objectives. The data collected with this method can also be used for statistical modelling to understand the drivers of current management costs, to predict additional costs of new PAs or changing demands on PA management, and to account for future funding in conservation planning.

524 Despite recognition that budget shortfalls are a key challenge for PA management
525 (McCarthy et al. 2012) there remains a remarkably crude understanding of the cost of
526 managing PAs effectively (Armsworth 2014). A key reason for this poor understanding is
527 a lack of fine-grained cost data (Sutton and Armsworth 2014), which underlies an
528 inability to quantify and model the drivers of management costs. For our case study, we
529 now have cost data at the resolution of individual management units and individual
530 actions, corrected to yearly averages for 2015. This study has improved on previous
531 work on management costs which have typically been forced to use data of much
532 coarser resolution (e.g. Balmford et al. 2003; Gravestock et al. 2008; Bovarnick et al.
533 2010) or have been confined to smaller and less heterogeneous samples (e.g.
534 Armsworth et al. 2011; McCrea-Strub et al. 2011).
535
536 Our method contains four main steps which could easily be applied to other PA systems
537 and management agencies – defining management actions, designing the sample,
538 elicitation, and data processing. Of primary importance is the definition of the actions to
539 be costed. Actions need to be specific to the study system and at a thematic resolution
540 to allow both feasible data collection while also capturing sufficient detail for analysis.
541 Sufficient PAs of sufficient variation in important characteristics related to management
542 costs need to be sampled to allow the data to be predicted for PAs not in the sample.
543 Finally, the method used to elicit the data from managers needs to be carefully and
544 collaboratively designed to avoid a number of the possible pitfalls of elicitation
545 identified in the literature (Martin et al. 2012; Burgman 2016).
546
547 Our methods are not a perfect example of how to collect cost data from PAs by any
548 means. For example, lack of specificity in the definitions of the levels of performance
549 will have increased the variability of the values elicited as managers interpreted the
550 levels inconsistently. We do hope, however, that they are a first step upon which other
551 workers can build future research efforts and iteratively improve on our attempt. There
552 are steps that could be taken to improve the methods used here. A key step would be to

553 link the levels of performance to quantitative and measurable objectives in
554 management plans, which was often impossible in our study. Another improvement
555 would be to increase the extent and number of PAs sampled. The limited resources for
556 this study and the challenging logistics of dealing with head-office and on-ground
557 managers in QPWS limited our sample of PAs to 50.
558 Our sample size is sufficient to allow development of statistical models that will allow
559 reasonable prediction of costs to PAs in the three management regions selected by us
560 and senior QPWS managers. However, prediction into other regions involves the unsafe
561 assumption that the same predictor variables and the same relative importance of those
562 variables apply to quite different parts of the State, in terms of biodiversity, visitation,
563 and pressures on PAs that need to be managed. There would be benefits for
564 Queensland and more widely to extend this study to a much larger number of reserves.
565 This would enable researchers to selectively remove data (e.g. by reducing the size of
566 the sample, lumping management units, lumping actions) to test the sensitivity of the
567 models, and identify the cost-benefit relationship between investment in elicitation and
568 reliability of models.
569
570 Several critical audit reports on management spending on Australian PAs (NSW National
571 Parks and Wildlife Service 2004; Queensland Audit Office 2010; Victorian Auditor
572 General 2011) have shown a highly unsatisfactory use of data recording systems and
573 lack of accountability. Despite these audits, there are still no agreed accounting or
574 reporting principles for the costs of management actions, and each agency has its own
575 standards and methods. A policy shift is needed to promote consistent, transparent
576 recording of spending and estimates of costs across Australian states and territories, and
577 preferably more widely. Management of PAs and planning for additional PAs would
578 benefit from the development of a comprehensive, consistent set of cost accounting
579 principles and approved collection methods. This would encourage conservation
580 agencies to enhance the usability and transferability of the data they collect. Global
581 efforts are underway to systematically collect data on PA management effectiveness

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(PAME). However, an acknowledged weakness of the current methods used to collect these data is their inability to capture PA funding and resource data in adequate detail (Geldmann et al. 2015). Some future version of the methods we present here could be used to augment the PAME collection tools.

Financial data are often perceived as being politically sensitive, especially within public bodies in which senior managers seek to minimize the risk of public criticism. This risk aversion often prevents access to critical data to allow research progress and improve conservation outcomes. Our project is notable in that a small number of far-sighted senior managers within QPWS saw the potential advantages of this project and were willing to accept the risks. The most obvious risk at the outset of the study was the public acknowledgement of a reliably estimated shortfall in management funding. Against that risk, those managers saw several advantages: a stronger basis for justifying spending on management and requests for increased funding; a basis for rationalising the spatial distribution of current spending; and the ability to anticipate the management costs of new PAs. We hope that managers in other agencies and future QPWS managers can make use of these methods and the models and analyses of funding shortfalls that will be produced from the data collected. Finally, we hope that one day the methods outlined in this paper will become redundant as PA management agencies design their data management systems to gather and report these types of data routinely to avoid time-consuming elicitation from managers.

Acknowledgements

We are grateful for the vision shown by Alan Feely and Annie Moody for initiating the study and to the dozens of QPWS staff who enthusiastically contributed support and time to this research. RLP acknowledges the support of the Australian Research Council.

Figures:

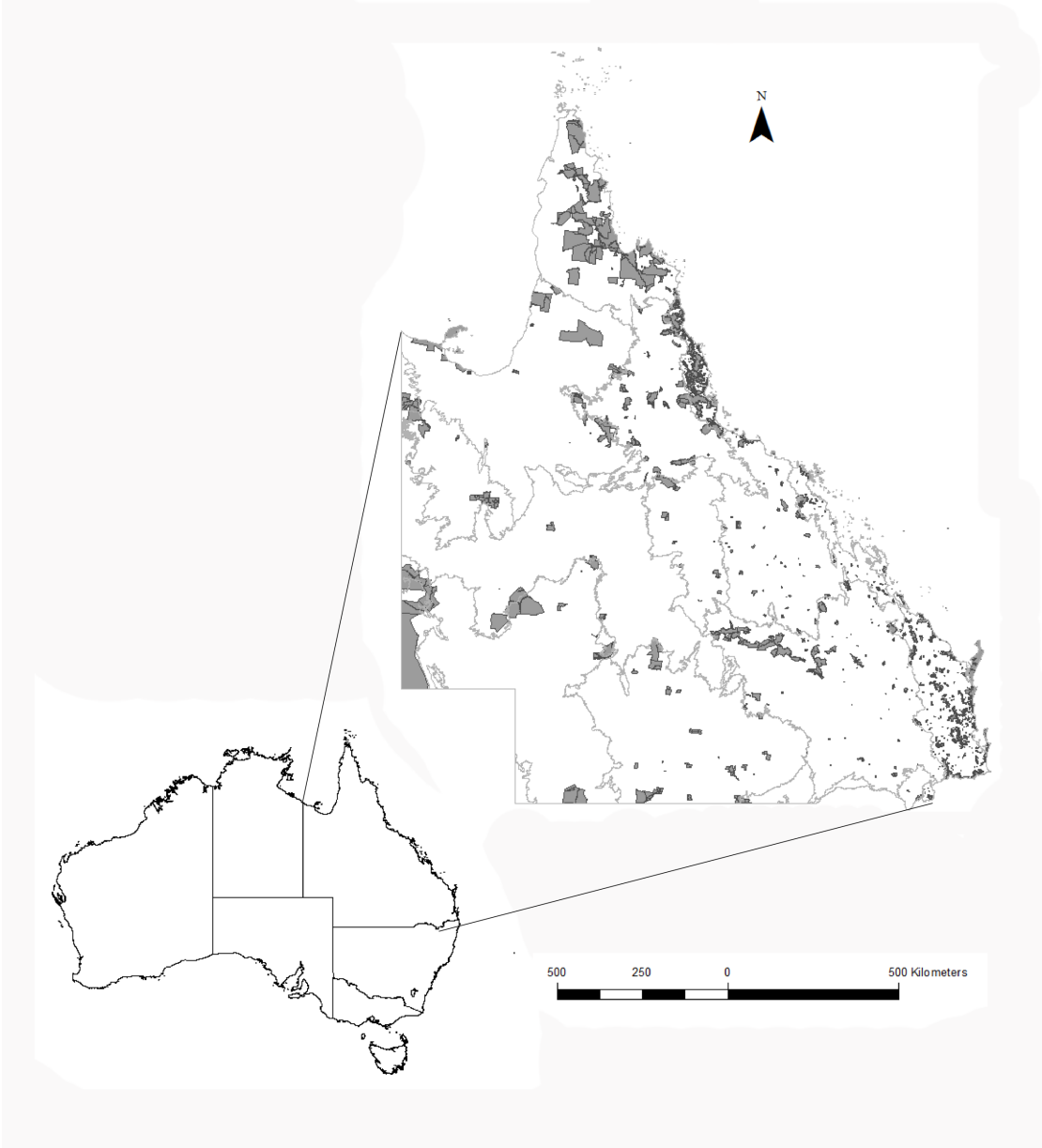

Figure 1. The study area, Queensland, Australia. Large map shows the boundaries of all protected areas managed by the Queensland Parks and Wildlife Service. Grey lines are the boundaries of Queensland's 13 biogeographic regions (https://www.environment.gov.au/land/nrs/science/ibra/australias-bioregions-maps)

Supplementary data

(MS Excel file containing complete questionnaire)

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