Marine Biodiversity Hub

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An assessment of alternative management interventions for treatment of Tropical Fire Ants on Ashmore Reef

Report on workshop – 11 July 2017

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Project B1 - Road testing decision support tools via case study applications

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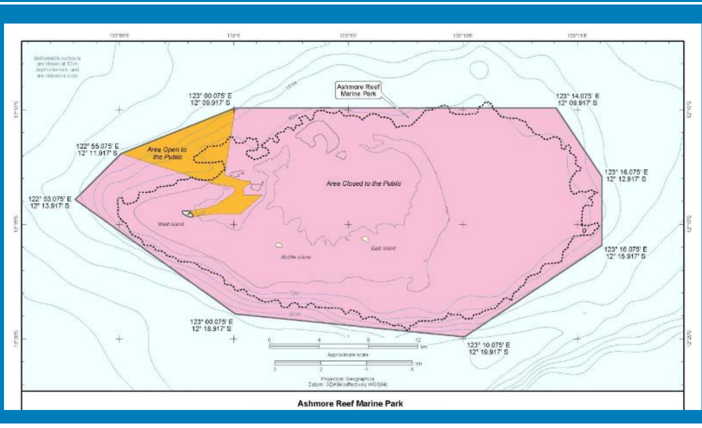

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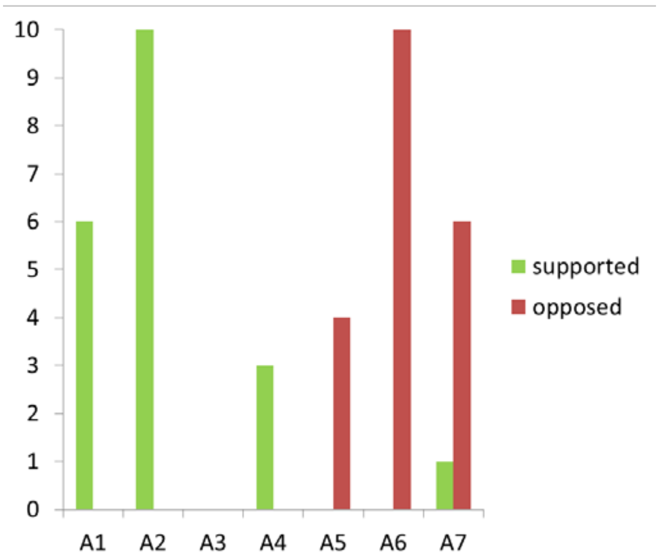
Contents

EXECUTIVE SUMMARY

This report describes outcomes of deliberations of a group of experts and managers in a workshop held on 11 July 2017. In arriving at preferred alternatives among seven candidates (comprising four options for eradication, two for control and a monitor only option), each of ten workshop participants articulated trade-offs among the following set of objectives:

- Conserve seabirds (more is better)
- Conserve turtles (more is better)
- Protect character and naturalness (more is better)
- Avoid adverse side effects (more is better)
- Cost of implementation (less is better)

The outcome of those trade-offs was broad support for an eradication strategy involving ten bait applications over two years, with subsequent detection, mop-up and monitoring operations.



Overall outcomes of workshop. For any single participant, an alternative was considered 'supported' if it ranked in the top two and 'opposed' if it ranked in the bottom two. A7 represents monitoring only. A1 and A2 involved a relatively intense eradication effort, differing only in the use (A2) or non-use (A1) of a partnership with Border Force allowing coordinated access to a vessel. A3 and A4 involved less intense eradication attempts. A5 and A6 were control options. For detailed description of alternatives, see Section 2.2 and Appendix 2.

Under the monitor only option, over a 20 year time horizon, the workshop judged that:

- Despite the continued presence of Tropical Fire Ants, populations of most seabird species would be stable or improve modestly due to removal of pressures caused by

rats. The workshop noted that this encouraging scenario may not extend to Red-tailed or White-tailed Tropicbirds.
- Recruitment rates for turtles would be less than that required for a stable population.
- Ecological character and naturalness will continue to be compromised.

The difference in estimated cost between the preferred eradication alternative A2 and the monitor only option A7 is $1.753M – $0.636M = $1.117M. The tentative recommendation to pursue implementation of A2 assumes Parks Australia would be willing to commit an additional $1.117M in order to gain:

- a recovery in seabird populations amounting to an approximate 30% improvement over the monitor only alternative,
- recruitment of turtles consistent with a stable population, and
- improved ecological character and naturalness.

Despite managerial concerns about side effects of chemical treatments, the pooled judgment of workshop participants was a benign impact on the hermit crab population at *the end* of a 20 year time horizon for all eradication and control options, relative to current conditions. It was noted that this judgment does not preclude the possibility of a critical bottleneck in the crab population in response to chemical treatment at some stage *within* the 20 year period.

Should a partnership approach be infeasible, implementation of alternative A1 implies a willingness to pay an additional $2.575M above monitoring only for the same outcomes.

The recommendations arising from this exercise are not prescriptive. In almost all decision contexts there are considerations beyond those invoked in a formal decision analysis. Before committing to a course of action Parks Australia may wish to consider (a) whether or not better conservation outcomes can be 'bought' for $1.117M - $2.575M elsewhere in its estate, and (b) the merit of delaying action to take advantage of emerging bait and drone technology.

1. BACKGROUND

Ashmore Reef Commonwealth Marine Reserve (CMR) is mainly an IUCN Category 1a sanctuary zone, with a restricted area open to the public (Figure 1). The reserve supports significant populations of seabirds, shorebirds, dugongs and turtles, as well as a range of other terrestrial and marine species. Established in August 1983 for the purposes of protecting its outstanding and representative marine ecosystem and to facilitate scientific research, Ashmore Reef CMR is also an internationally significant Ramsar wetland. As a Ramsar site, it is important to preserve the 'ecological character' of the wetland through conservation and wise use.

Introduced tropical fire ants (*Solenopsis geminata*), also known as ginger ants, were first recorded on the islands of Ashmore Reef in 1992. Risks to conservation values stemming from the introduction of tropical fire ants include most notably impacts to seabirds and nesting turtles. As an exotic species, the presence of these ants also inherently compromises ecological character.

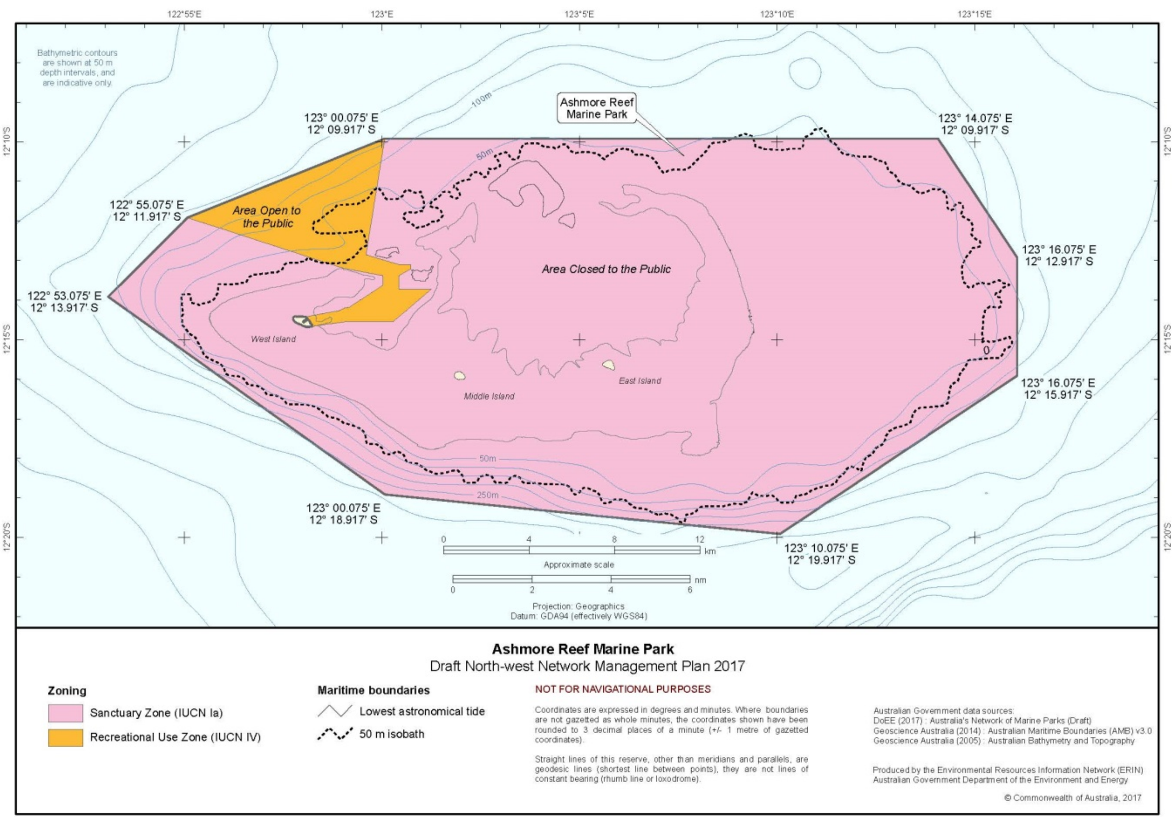


Figure 1. Ashmore Reef Commonwealth Marine Reserve.

In 2011 the Department of Environment managed a pilot control program for tropical fire ants at Ashmore Reef CMR for a period of 14 months. A review of the program concluded that baiting was successful, nest success was higher on the treated island than control islands for Brown Booby and Red-footed Booby, and that evidence of an adverse impacts from baiting on non-target hermit crabs was inconclusive. Based on these encouraging outcomes and a perception that the viability of populations of birds and turtles was under immediate threat, an eradication plan for tropical fire ants was developed in 2014 (Hodgson et al. 2014). But since 2014, more recent and detailed surveys of seabirds (Clarke and Herrod 2016) and turtles (Guinea 2017) suggest the conservation imperative for management may not be so urgent, despite the ant population recovering after cessation of the pilot control program (Hodgson 2015).

This report describes the process and outcomes of a full day workshop involving researchers and managers, held Tuesday 11 July 2017. The aims of the workshop was to develop a collective understanding of plausible trends of key conservation values under a monitor only scenario and, should these trends be considered unacceptable, assist Parks Australia develop a preferred course of action for the management of Tropical Fire Ants on Ashmore Reef. Participants are listed in Appendix 1.

Candidate actions include various options for eradication or control. The workshop used the steps and processes of structured decision-making to work through arguments for and against alternative interventions and to arrive at a preferred course of action. Steps of structured decision making include (Gregory et al. 2012):

- Identify objectives
- Specify alternatives
- Assess the consequences of each alternative against each objective
- Engage in trade-offs among objectives to arrive at a preferred alternative

2. STRUCTURED DECISION ANALYSIS

2.1 Objectives

There is a raft of concerns associated with management of any invasive species. For Ashmore Reef and its status as an IUCN 1a conservation reserve and Ramsar wetland, the presence of an exotic species itself generally detracts from the naturalness and ecological character of the sanctuary. The risks that Tropical Fire Ants pose to seabird and turtle populations are more specific considerations that may motivate intervention. The upside of any attempt at eradication or control needs to be weighed against the possibility of adverse ecological impacts and the monetary costs of implementation.

The workshop included in its considerations the five objectives shown in Table 1, together with a set of performance criteria to assess the merit of each alternative against each objective. There are three kinds of performance criteria – direct indicators, proxies and constructed scales (Keeney and Gregory 2005). In general, direct indicators are better than proxies or constructed scales, because they make trade-offs more accessible. But for many objectives there are no natural units and proxies may fail to capture relevant concerns. Here we used a mix of all three types of performance criteria.

Population size and monetary units are direct indicators for seabirds and cost, respectively. 'Focal seabirds' in Table 1 refer to the aggregate population of a subset of five species the workshop considered at highest risk of local extirpation. Specifically, Red-tailed Tropicbird (*Phaethon rubricauda*), White-tailed Tropicbird (*Phaethon lepturus*), Lesser Frigatebird (*Fregata ariel*), Great Frigatebird (*Fregata minor*), and Red footed Booby (*Sula sula*). None of these species are currently listed as nationally threatened under the Environment Protection and Biodiversity Conservation Act 1999 (*Cth*). In total, it was estimated that the current population size summed over these five species is 5,000.

The hatching success rate of turtles is a proxy. For species as long lived as turtles, direct estimates of population size was considered inappropriate because the full impact of predation by ants may not be apparent for several decades. Success refers to hatching *and* nest emergence. As a rule of thumb, the workshop used 560 successes per 1000 eggs as an estimate of the success rate required to maintain a stable population. This estimate is based on a hatching rate of 80% and subsequent emergence rate of 70%. The two main species nesting on Ashmore Reef, Green Turtle (*Chelonia mydas*) and Hawksbill Turtle (*Eretmochelys imbricata*), were considered collectively. Both turtles are listed as *vulnerable* under the Environment Protection and Biodiversity Conservation Act 1999 (*Cth*).

The relative population size of hermit crabs is also a proxy. Hermit crabs occur at very high densities on Ashmore Reef. Direct estimates of the population size of crabs under alternative management scenarios were considered too difficult to quantify.

'Ecological character' and 'naturalness' are key considerations of RAMSAR wetlands, and IUCN 1a sanctuary zones, respectively. Here we used a constructed scale describing the expected density of Tropical Fire Ants and assumed character and naturalness was diminished with increasing density, such that 1 = uncontrolled high density, 2 = partially controlled medium density, 3 = partially controlled low density, and 4 = absent.

A time horizon of 20 years was used to assess the performance of alternatives against objectives. This time horizon provides an opportunity to assess the risks of reintroduction under eradication options. Beyond 20 years, the task of prediction becomes very difficult.

Table 1. Objectives associated with assessment of candidate actions for management of Tropical Fire Ants on Ashmore Reef.

Objective	Performance criterion	Preference
Conserve seabirds	population size of focal group seabirds in 20 years	more is better
Conserve turtles	success rate per 1000 eggs in 20 years	more is better
Protect character and naturalness	status in 20 years described by a Likert scale	more is better
Avoid adverse side effects	relative population size of hermit crabs in 20 years	more is better
Cost of implementation	monetary cost ($)	Less is better

2.2 Alternatives

Although a micro-wasp is being used to treat Yellow Crazy Ants on Christmas Island, no biological agent has been identified for control of Tropical Fire Ants. Under currently available technology[1], only chemical treatment is available for eradication and control at Ashmore Reef. There are two broad classes of chemical: insect growth regulators (IGRs) and toxins. IGRs are designed to disrupt the life cycle of target insects and pose a relatively lower risk to non-target species, however, their effectiveness in unclear. Although non-target species may be more exposed to harm via toxins, their use may be necessary for effective eradication or control programs.

The number of applications needed under an eradication program has been estimated as being a minimum of ten delivered over 18 months (Hodgson et al. 2014). For ongoing control programs, a minimum of two doses may be required per year. While increasing the number of treatments improves the prospects for success, it also carries with it additional monetary costs and possible adverse side effects. The workshop explored two alternatives for eradication:

[1] The viability of target specific RNA-interference and *Bacillus thuringiensis* (Bt toxin) bait is currently being investigated. While these new technologies offer the potential for nil-effects on non-target species, additional development is required to produce the bait and understand its effectiveness

- Eradication 'heavy'[2] - 10 applications over two years, comprising four applications of IGR, four applications of toxin and two applications of both IGR and toxin.
- Eradication 'lite' - 5 applications over one year, comprising two applications of IGR, two applications of toxin and one application of both IGR and toxin.

All applications were assumed to involve dispersal of granular ant bait treatments across land areas using a helicopter fitted with an underslung bucket. Evaluation of the effectiveness of bait applications is included in alternatives.

The application phase is preceded by a preparatory phase, involving engagement of contractors and specialists, development of detailed work plans (including quarantine procedures), risk assessments and procurement of supplies. After the application phase, detection and monitoring phases are undertaken to locate and mop-up any remaining nests. Typically this would involve the use of detector dogs, which require a minimum of 12 months to train for this application. In total, an eradication strategy is expected to take five years to implement. Full details are described in Hodgson et al. (2014).

The costs borne by Parks Australia may be reduced if a partnership arrangement can be negotiated, whereby vessel support in the detection and monitoring phases is provided by Border Force. The remote location of Ashmore Reef makes the cost of chartering a vessel one of the more substantial expenses involved in eradication. This cost is estimated at $15,000 per day. For both eradication heavy and eradication lite, we included companion alternatives that reduced costs through provision of a vessel in the detection and monitoring phases as in-kind support. At the time it was noted that Border Force had given no indication of its capacity to provide vessel support. Due to operational priorities, Border Force provide intermittent and irregular support to Parks Australia when opportunities arise. Support may be cancelled at the last minute and cannot be reliably scheduled.

Two alternatives for control were also developed in the workshop:

- Control 'heavy' - 2 applications of toxin per year, ongoing.
- Control 'lite' - 1 application of toxin per year, ongoing.

The costs and benefits of the anticipated consequences of these alternatives need to be considered alongside the monitor only option, which involves a five yearly commitment to monitoring and evaluation.

A summary of the alternatives considered at the workshop is shown in Table 2. Appendix 2 provides further details.

2.3 Consequences

Expert judgment was used to estimate the performance of each of the seven alternatives against objectives associated with conservation of seabirds, turtles and side effects (using hermit crabs as a proxy indicator). The ten workshop participants made individual judgments

[2] Eradication 'heavy' was the recommended option documented in Hodgson et al. (2014).

for each of the three performance criteria, first for the monitor only option A7 (Figure 2), then each of the other alternatives. Judgments were pooled to buffer against overconfidence and motivational bias among individuals (McBride et al. 2012). Studies in expert judgment show that use of this protocol in a group setting will tend towards better judgments than those of the most credentialed or most accurate individual expert (Burgman 2015). The group arithmetic mean was used as the best available point estimate of the consequences of each alternative against each of the three objectives.

Assuming successful operations, the consequences for ecological character and naturalness were auto-populated (Table 3).

Alternatives A1 to A4 involve attempts at eradication. Judgments involving seabirds, turtles, crabs and ecological character and naturalness were made assuming

- successful eradication within the 5 years of implementation , and
- no subsequent reintroduction of Tropical Fire Ants over the ensuing 15 years.

Participants were then asked for estimates of

- the probability of successful eradication under each of the four alternatives, A1 – A4, and
- assuming eradication is achieved by 2022, the probability of reintroduction of Tropical Fire Ants in the subsequent 15 years (to 2037).

These probabilistic judgments are reported in Table 4. Judgments for the probability of successful eradication among the ten participants ranged from 0.70 to 0.99 for A1 and A2 (eradication heavy) and 0.20 to 0.85 for A3 and A4 (eradication lite). We note that judgments concerning the probability of successful eradication benefited from recent modelling work (Baker et al. 2017). Divergent views were held on the probability of reintroduction, with estimates ranging from 0.005 to 0.50.

Table 2. Alternative strategies considered at the workshop.

Alternative	Description	Number of applications	Number of detection trips	Number of monitoring trips	Number of evaluations
A1	eradication heavy - full cost	10 over two years	3	3	2
A2	eradication heavy - partnership	10 over two years	3	3	2
A3	eradication lite - full cost	5 over one year	2	2	1
A4	eradication lite - partnership	5 over one year	2	2	1
A5	control heavy	2 per year, ongoing	na	na	1 every five years
A6	control lite	1 per year, ongoing	na	na	1 every five years
A7	monitor only	na	na	1 every five years	1 every five years

Table 3. Consequences for the ecological character and naturalness under each alternative. Note that scores for A1 – A4 assume successful eradication and no subsequent reintroduction. These scores were subsequently adjusted according to probabilistic judgments for eradication success and reintroduction (see Figure 3).

Alternative	Description	Likert score – Tropical Fire Ant density
A1, A2, A3 and A4	eradication	4 (absent)
A5	control heavy	3 (partially controlled low density)
A6	control lite	2 (partially controlled medium density)
A7	monitor only	1 (uncontrolled high density)

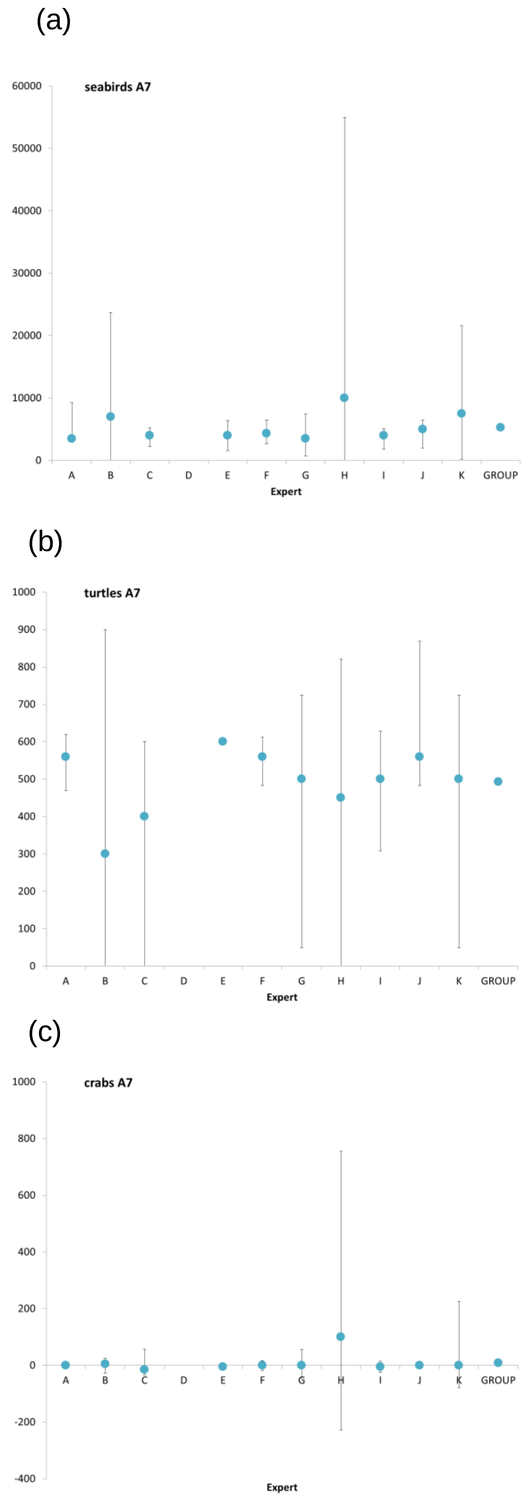


Figure 2. The range of judgments under the monitoring only alternative A7 for (a) focal group seabirds, (b) turtles, and (c) hermit crabs. For each of 10 workshop participants, blue dots indicate best estimates with 90% uncertainty intervals. Group judgments are the arithmetic mean of individual judgments. Note that participant D was absent.

Table 4. Individual and pooled judgments used to condition estimates of consequences for seabirds, turtles, side-effects and ecological character and naturalness.

Participant	Probability of successful eradication [A]		Probability of reintroduction
	A1 and A2	**A3 and A4**	
A	0.95	0.20	0.050
B	0.99	0.80	0.400
C	0.85	0.80	0.500
D	0.90	0.70	0.500
E	0.99	0.30	0.040
F	0.85	0.85	0.500
G	0.80	0.25	0.100
H	0.70	0.60	0.500
I	0.70	0.40	0.010
J	0.75	0.40	0.005
mean	**0.85**	**0.53**	**0.260**

[A] Judgments for A1 and A2 and A3 and A4 were assumed to be insensitive to whether or not a partnership approach was used for vessel support.

Expected outcomes for each eradication alternative, A1 – A4, were then conditioned by group mean probabilistic judgments (Figure 3). So for example, the expected population size of focal seabird species under A1, 20 years hence uses

- the estimated population size under monitoring only (A7) = 5,280
- the estimated population size under A1, assuming successful eradication and no subsequent reintroduction = 7,980
- the probability of successful eradication = 0.85, and
- the probability of reintroduction = 0.26.

The expected outcome under A1 sums the probability weighted outcomes of the three branches of the logic tree. That is, 0.85 × 0.26 × 5,280 + 0.85 × (1 – 0.26) × 7,980 +0.15 × 5,280 = 6,973.

The costs of implementation for each alternative were estimated using figures provided by Hodgson et al. (2014), with an 8% increase to allow for inflation from 2014 to 2017. Detailed costings are included in Appendix 2. Ongoing costs associated with control options (A5 and A6) were exponentially discounted at 3% per annum, so that the totals reported in Appendix 2 refer to present value (i.e. costs in 2017 $AUD). Note that cost estimates do not include contingencies.

Expected consequences of each of the seven alternatives against each of the five objectives are shown in Table 5.

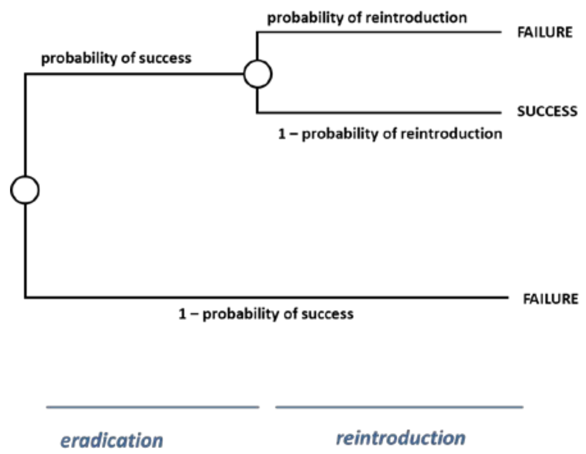


Figure 3. Logic tree for estimating expected outcomes under probabilistic uncertainty associated with prospects for eradication success and subsequent reintroduction of Tropical Fire Ants. Branches ending in failure are assumed to lead to the same outcome as the monitoring only alternative.

Table 5. Consequence table describing the estimated performance of each alternative against each objective at the end of a 20 year time horizon. Red cells indicate consequences that are at least 10% worse than the corresponding performance under the monitor only alternative, A7. Green cells indicate consequences that are at least 10% better.

Objective	**Performance indicator**	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**
Conservation of seabirds	population size of focal group seabirds in 20 years	6973	6973	6370	6370	6140	5230	5280
Conservation of turtles	success rate per 1000 eggs in 20 years	573	573	543	543	568	540	493
Protect eco character and naturalness	verbal scale describing TFA density	2.9	2.9	2.2	2.2	3.0	2.0	1.0
Population size of non-target species	% change in population of hermit crabs in 20 years	12	12	11	11	-4	1	8
Cost of implementation	monetary cost ($ million)	3.211	1.753	2.254	1.694	4.751	2.545	0.636

We note the following with respect to alternative A7 (monitoring only):

- The pooled judgment of workshop participants for seabirds under A7 suggests focal species are not expected to decline further in the absence of management intervention for Tropical Fire Ants. The estimated population size of 5,280 for focal seabird species 20 years hence under monitor only is a slight improvement on the current population size estimate of 5,000. Although seabird populations may have suffered losses in the recent past as a consequence of negative impacts associated with Tropical Fire Ants and rats, recent success in the management of rats has arrested declining trends.
- The success rate of 493 per 1000 eggs under A7 is 12% less than the estimated success rate required for stable populations of turtles (560 per 1,000). Over time, turtle populations are expected to decline under A7.
- Ecological character and naturalness will continue to be compromised under A7.

Among the alternatives involving eradication or control, the following estimated consequences are noteworthy:

- Under eradication strategies A1 – A4 there is an expected recovery in focal species seabird populations of approximately 25 – 40% relative to the current estimate of 5,000 individuals. Under control options (A5 and A6) the expected recovery is limited to 5 – 25%.
- The estimated population size for seabirds is marginally less under the control lite alternative (A6) than monitor only (A7) because at least some participants believed that a modest reduction in ant densities would not compensate for the disturbance associated with annual control operations.
- Only 'heavy' options for eradication (A1 and A2) and control (A5) are expected to improve the hatching rate of turtles consistent with a stable population (560 per 1,000 eggs).
- With the exception of control heavy (A5) the net impact of chemical treatments on non-target hermit crabs after 20 years is expected to be marginally positive. A5 was marginally negative. Although transient negative side-effects were anticipated, workshop participants judged that after 20 years these would generally be compensated by improved resource availability as a consequence of reduced or zero densities of Tropical Fire Ants.

2.4 Trade-offs

In the structured decision analysis undertaken here, trade-offs were articulated via weights. Weights can be elicited using a variety of techniques (Hajkowicz et al. 2000), not all of which are credible. The weight assigned to any single fundamental objective is a function of two elements; (a) the inherent importance of the objective, and (b) the range of the consequences estimated across all alternatives. For example, in Table 5 the range from best to worst for seabirds is 6,973 – 5,230 = 1,743. For costs, the range is $4.751 - $0.636 = $4.115M. An individual who assigns equal weights to seabirds and costs would be willing to pay about $4M to conserve an additional 1,700 focal species seabirds. Another individual who assigns a weight to seabirds that is double that assigned to cost implies a willingness to pay of $4M for about 850 birds.

Decision scores for each participant and each alternative were obtained using simple weighted summation (von Winterfeldt and Edwards 1986). That is, the decision score *V* for alternative *i* is,

$$V_i = \sum_{j=1}^{n} w_j X_{ij} ,$$

where w_j = weight for criterion *j*, and X_{ij} = normalised score for alternative *i* on criterion *j.*

Ten participants provided weights. A very common mistake in assigning weights is to ignore the range of consequences (Keeney 2002, Steele et al. 2009). To account for the range of consequences under each objective, we elicited swing weights using worst case and best case scenarios (see von Winterfeldt and Edwards 1986 and Appendix 3).

3. OUTCOMES

Examples of decision scores for two participants are shown in Figure 4. Despite considerable differences in emphases across objectives, both participants rated alternative A2 (eradication heavy using a partnership approach) highly. Graphs of decision scores for all individual participants are shown at Appendix 4. The collective outcome across all 10 participants is shown in Figure 5. The support for Alternative A2 illustrated in Figure 4 for two participants is broadly evident in the trade-off judgments of the full collective. All participants included A2 as their highest or second highest preference. Alongside A2 there was considerable support for A1, suggesting many participants considered eradication heavy a worthwhile strategy even if the full costs were to be borne by Parks Australia. The majority of participants saw little merit in control options (A5 and A6) or the monitor only option (A7).

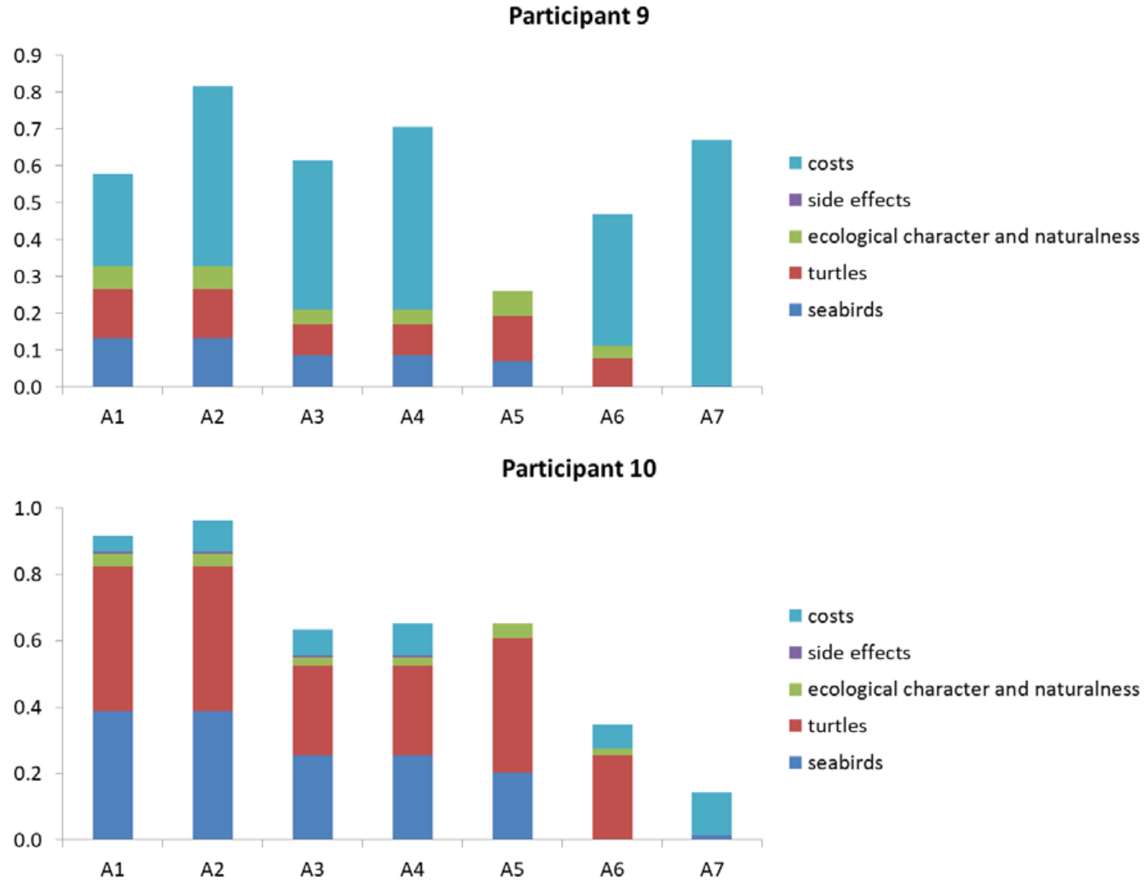


Figure 4. Decision scores for two participants.

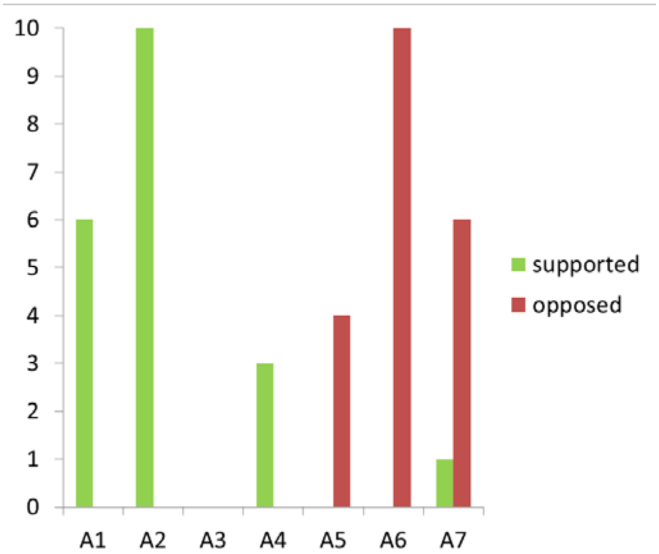


Figure 5. Overall outcomes of the trade-offs workshop. For any single participant, an alternative was considered ‘supported’ if it ranked in the top two and ‘opposed’ if it ranked in the bottom two.

4. DISCUSSION

The strong preference for A2 is not surprising. In Table 6, the consequences of each alternative relative to A2 are highlighted. A2 either outperforms or performs equally as well as all other alternatives on all objectives with the exception of implementation costs under the do nothing alternative, A7. The difference in the cost between A2 and A7 is $1.753M – $0.636M = $1.117M. The tentative recommendation to pursue implementation of A2 assumes Parks Australia would be willing to commit an additional $1.117M in order to gain:

- A recovery in seabird populations amounting to an approximate 30% improvement over the monitoring only alternative,
- Recruitment of turtles consistent with a stable population,
- Improved ecological character and naturalness, and
- A small improvement in the population of hermit crabs.

Should a partnership approach be infeasible, implementation of alternative A1 implies a willingness to pay an additional $2.575M for the same outcomes.

Figure 5 illustrates clear outcomes from the workshop. While insights and outcomes provide a good foundation for decision-making by Parks Australia, it is important to recognise that the value judgments underpinning the assignment of weights by workshop participants may not reflect organisational views of sound use of finite resources. The trade-off between conservation outcomes and monetary cost is difficult. Cognitive psychologists refer to trade-offs between sacred values and secular values as 'taboo' trade-offs (Lichtenstein et al. (2007), Tetlock (2000)). The tendency is to avoid the dissonance created by taboo trade-offs by assigning ill-considered large weights to sacred values and lesser weights to secular outcomes, leading to exaggerated willingness to pay estimates. The extent to which this tendency was manifest among workshop participants is unknown. But at the very least, before committing to a course of action Parks Australia needs to consider whether or not better conservation outcomes can be 'bought' for $1.117M - $2.575M elsewhere in its estate.

Table 6. Consequence table describing the estimated performance of each alternative against each objective. Red cells indicate consequences that are at least 10% worse than the corresponding performance under A2, the most broadly supported alternative. Green cells indicate consequences that are at least 10% better.

Objective	**Performance indicator**	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**
Conservation of seabirds	population size of focal group seabirds in 20 years	6973	6973	6370	6370	6140	5230	5280
Conservation of turtles	success rate per 1000 eggs in 20 years	573	573	543	543	568	540	493
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Population size of non-target species	% change in population of hermit crabs in 20 years	12	12	11	11	-4	1	8
Cost of implementation	monetary cost ($ million)	3.211	1.753	2.254	1.694	4.751	2.545	0.636

In general, the approach to structured decision analysis described in this report represents a distinct improvement on the processes adopted by many groups in many settings. Nevertheless, there were inevitable shortcomings. We note the following:

- Pressures and threats beyond Tropical Fire Ants were not considered explicitly in the estimation of consequences.
- In retrospect it would have been desirable to treat seabirds with higher resolution than grouping five focal bird species together. Of the estimated current population size of 5,000 individuals, most are Frigatebirds. The Red-tailed Tropicbird population at Ashmore Reef is estimated at 20 pairs, and the White-tailed Tropicbird at 10 pairs. In contrast with populations of most seabird species at Ashmore Reef which are generally stable or increasing since rat eradication, the trend for Tropicbirds appears less encouraging.
- A 20 year time horizon was considered too short to directly assess impacts on populations of long-lived turtles. The proxy we used – hatching success rate – was difficult for both cause-and-effect judgments of consequences under each alternative, and value judgments underpinning weights and trade-offs.

Finally, we emphasise that the workshop was only able to countenance a limited subset of the many objectives and alternatives that could potentially be considered relevant to the problem of Tropical Fire Ant management on Ashmore Reef. Here we note:

- While unavailable now, novel treatments involving biological control and/or target-specific insecticides may be ready for deployment in the near future. While chemical treatments were expected to have negligible adverse impact on hermit crab population in the long-term, the intensity of baiting required for a successful eradication program may have serious short term effects on the hermit crab population which would require mitigation measures, such as collecting insurance populations. The effects of bait on aquatic life and other non-target species were not considered during the workshop. The option to delay an eradication or control program until new technology bait is developed may carry limited upside, depending on the duration on the delay and the effectiveness of the bait.
- All alternatives for eradication and control assumed use of a helicopter for bait application. Drone technology may offer considerable cost savings and reduced environmental impacts via reduced disturbance to seabirds from noise and down winds. Note that hand-baiting was not recommended due to greater disturbance to seabirds and the labour intensive requirements of this approach.
- All alternatives assumed vessels for operational support would be chartered. We did not consider options involving the acquisition of a vessel by Parks Australia. Although a large capital expense, a vessel owned by Parks Australia would provide operational efficiencies and many opportunities for other management and research initiatives beyond ants on Ashmore Reef.
- Similarly, eradication alternatives A1 and A3 would allow enhanced management and research opportunities via exclusive use of a chartered vessel. Alternatives A2 and A4 are constrained by the vessel needs of Border Force.

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APPENDIX 1 - WORKSHOP PARTICIPANTS

Note that the order of participants has been randomized and does not correspond to the order of outcomes shown in Appendix 4.

Rebecca McBride, Cth Department of Agriculture

Jarrod Hodgson, University of Adelaide

Amanda Parr, Parks Australia

Rohan Clarke, Monash University

Jordan Crabbe, Cth Department of the Environment & Energy

Ben Hoffman, CSIRO

Jennifer Hoy, Parks Australia

Michelle Heupel, AIMS

Mick Guinea, Charles Darwin University

Regulus Fogagnolo, Parks Australia

APPENDIX 2 - ALTERNATIVES

A1 eradication heavy - full cost, and A2 eradication heavy - partnership

Phase*	Year	Description		cost
Pre	1	Lab based experiments for non-target bait impacts	$	32,400
Pre	1	Aerial baiting bucket	$	54,000
Pre	1	Readying helicopter for project	$	61,452
Pre	1	Deposit of mainland fuel cache	$	2,160
Pre	1	Procurement of cache containers and spill kits	$	37,800
App	1	Vessel charter	$	158,890
App	1	Bait application 1	$	63,871
App	1	Bait application 2	$	54,659
App	1	Bait application 3	$	54,659
App	1	Bait application 4	$	54,659
App	1	Bait application 5	$	54,659
App	1	Evaluation 1	$	158,890
App	2	Bait application 6	$	54,659
App	2	Bait application 7	$	54,659
App	2	Bait application 8	$	54,659
App	2	Bait application 9	$	54,659
App	2	Bait application 10	$	63,871
App	2	Evaluation 2	$	158,890
App	1,2	Project management (2 yrs FT)	$	345,600
App	1,2	Research supplies/budget	$	54,000
		SUBTOTAL (preparation and application)	$	1,629,094
Det	3	Detector dogs	$	172,800
Det	3	Detection 1	$	185,760
Det	3	Detection 2	$	182,520
Det	3	Detection 3	$	178,740
Det	3	Project management	$	172,800
Det	3	Research supplies/budget	$	27,000
		SUBTOTAL (detection)	$	919,620
Mon	4	Monitor 1	$	165,240
Mon	4	Monitor 2	$	165,240
Mon	5	Monitor 3	$	174,960
Mon	4,5	Project management	$	129,600
Mon	4,5	Research supplies/budget	$	27,000
		SUBTOTAL (monitoring)	$	662,040
	all	emergency response (SAR etc)		not costed
	all	contingency for additional trips for detection/monitoring		not costed
		TOTAL (A1)	**$**	**3,210,754**
		TOTAL with in-kind contribution of vessel for detection/monitoring (A2)	**$**	**1,752,754**

***Phase: Pre = preparation, App = application, Det = detection and Mon= monitoring.*

A3 eradication lite - full cost, and A4 eradication lite - partnership

Phase	Year	Description		cost
Pre	1	Lab based experiments for non-target bait impacts	$	32,400
Pre	1	Aerial baiting bucket	$	54,000
Pre	1	Readying helicopter for project	$	61,452
Pre	1	Deposit of mainland fuel cache	$	2,160
Pre	1	Procurement of cache containers and spill kits	$	37,800
App	1	Vessel charter	$	158,890
App	1	Bait application 1	$	63,871
App	1	Bait application 2	$	54,659
App	1	Bait application 3	$	54,659
App	1	Bait application 4	$	54,659
App	1	Bait application 5	$	54,659
App	2	Evaluation	$	158,890
App	1,2	Project management (0.75 FTE 2 yrs)	$	259,200
App	1,2	Research supplies/budget	$	54,000
		SUBTOTAL (preparation and application)	$	1,101,298
Det	3	Detector dogs	$	172,800
Det	3	Detection 1	$	185,760
Det	3	Detection 2	$	182,520
Det	3	Project management (0.75 FTE 1 yr)	$	129,600
Det	3	Research supplies/budget	$	27,000
		SUBTOTAL (detection)	$	697,680
Mon	4	Monitor 1	$	165,240
Mon	4	Monitor 2	$	165,240
Mon	4,5	Project management (0.75 FTE 1 yr)	$	97,200
Mon	4,5	Research supplies/budget	$	27,000
		SUBTOTAL (monitoring)	$	454,680
	all	emergency response (SAR etc)		not costed
	all	contingency for additional trips for detection/monitoring		not costed
		TOTAL (A3)	**$**	**2,253,658**
		TOTAL with in-kind contribution of vessel for detection/monitoring (A4)	**$**	**1,694,218**

A5 control heavy

Phase	Year	Description		cost
		One-off up-front costs		
Pre	1	Lab based experiments for non-target bait impacts	$	32,400
Pre	1	Aerial baiting bucket	$	54,000
Pre	1	Readying helicopter for project	$	61,452
Pre	1	Deposit of mainland fuel cache	$	2,160
Pre	1	Procurement of cache containers and spill kits	$	37,800
		Annual costs		
App	1 to 20	Bait application 1 (incl. support vessel)	$	112,320
App	1 to 20	Bait application 2 (incl. support vessel)	$	112,320
App	1 to 20	Project management (0.25 FTE ongoing)	$	43,200
		Five yearly costs		
Mon	5,10, 15,20	Evaluation	$	158,890
		Total cost over 20 years discounted at 3% pa	$	4,750,744

A6 control lite

Phase	Year	Description		cost
		One-off up-front costs		
Pre	1	Lab based experiments for non-target bait impacts	$	32,400
Pre	1	Aerial baiting bucket	$	54,000
Pre	1	Readying helicopter for project	$	61,452
Pre	1	Deposit of mainland fuel cache	$	2,160
Pre	1	Procurement of cache containers and spill kits	$	37,800
		Annual costs		
App	1 to 20	Bait application 1 (incl. support vessel)	$	112,320
App	1 to 20	Project management (0.16 FTE ongoing)	$	27,648
		Ten yearly costs		
Mon	10, 20	Evaluation	$	158,890
		Total cost over 20 years discounted at 3% pa	$	2,545,042

A7 Monitoring only

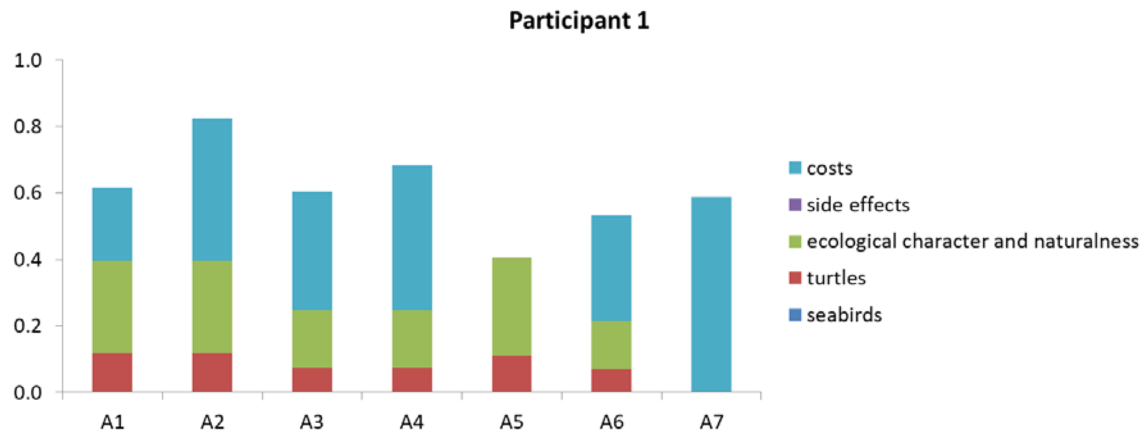
Phase	Year	Description		cost
		Five yearly costs		
Mon	5,10, 15,20	Evaluation	$	158,890
		Total cost over 20 years discounted at 3% pa	$	635,558

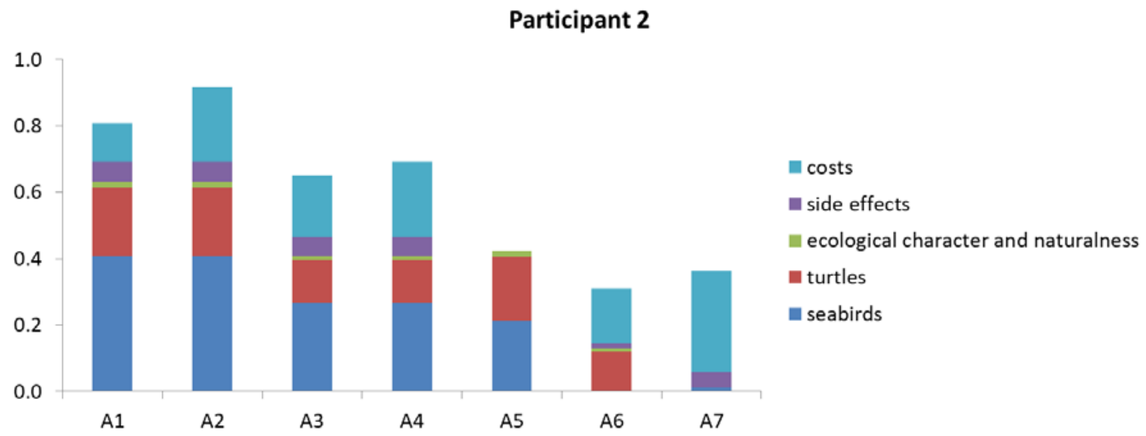
APPENDIX 3 - SWING WEIGHTING EXERCISE

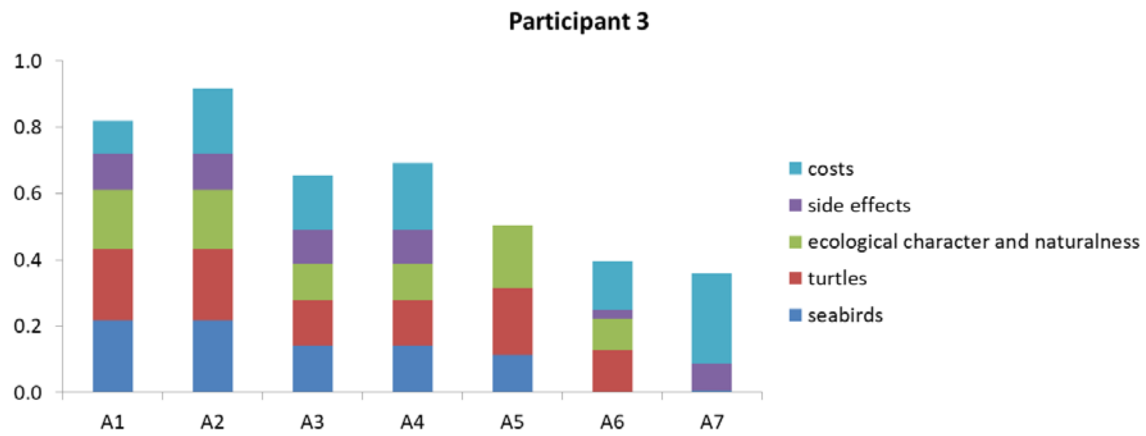
Name:

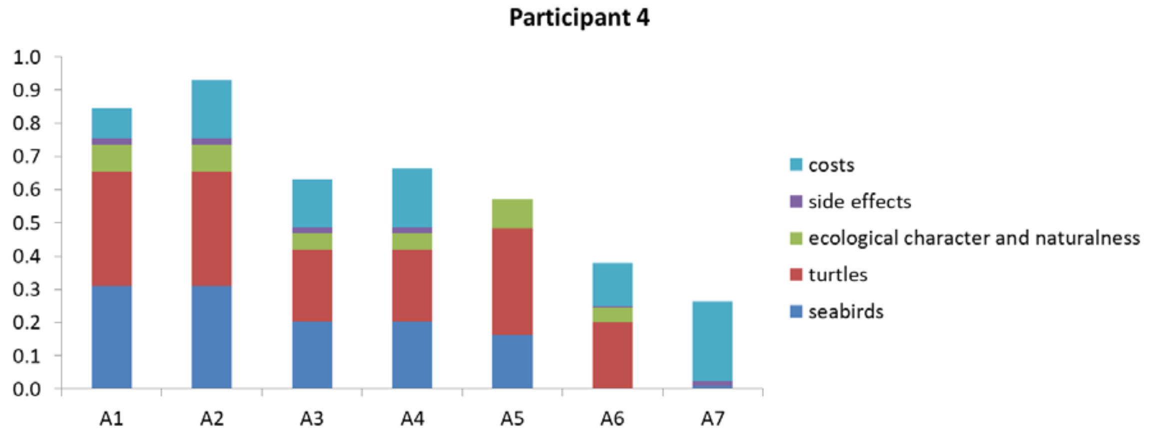
Objective	worst	best	rank	weight
Conservation of seabirds (population size of focal group seabirds in 20 years)	5,230	6,973		
Conservation of turtles (success rate per 1000 eggs in 20 years)	493	573		
Protect ecological character and naturalness (Likert scale)	1.0	3.0		
Population size of non-target species (% change in population of hermit crabs in 20 years)	-4	12		
Cost of implementation (monetary cost, $)	$4,750,743	$635,558		

APPENDIX 4 - OUTCOMES FOR INDIVIDUAL PARTICIPANTS





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0.2
0.1
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A1
A2
A3
A4
A5
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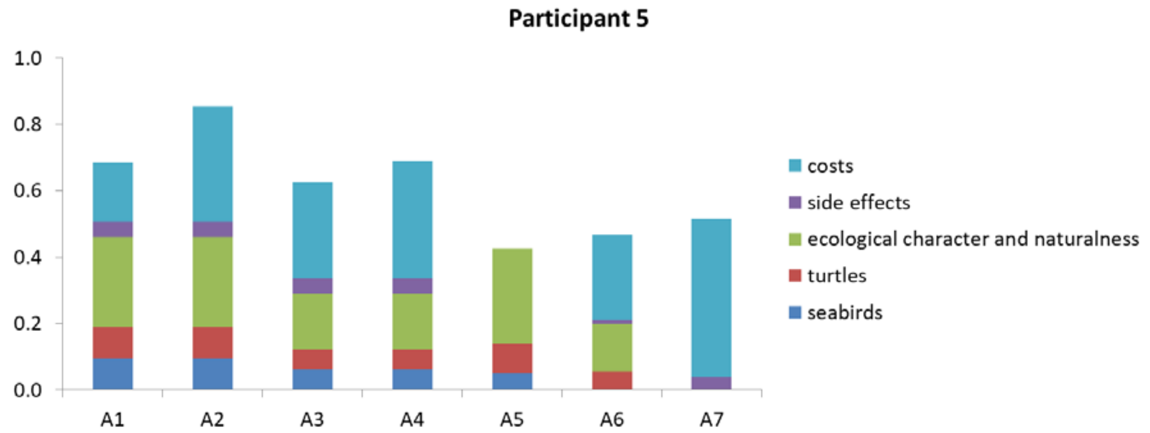
A7
costs
side effects
ecological character and naturalness
turtles
seabirds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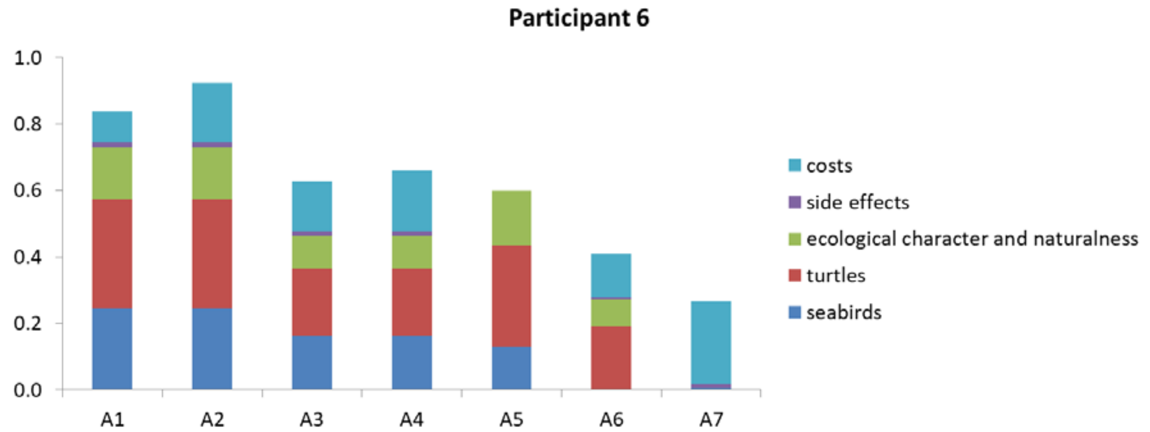
costs
side effects
ecological character and naturalness
turtles
seabirds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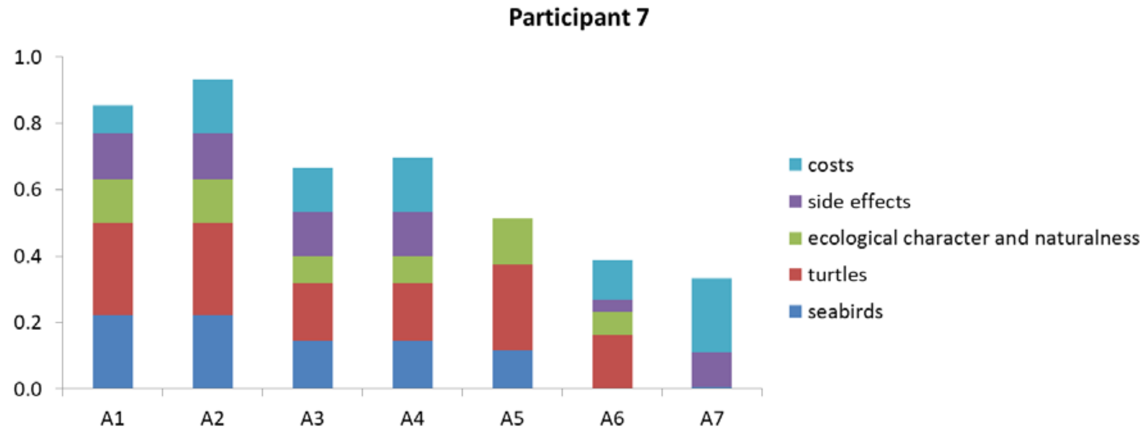
costs
side effects
ecological character and naturalness
turtles
seabirds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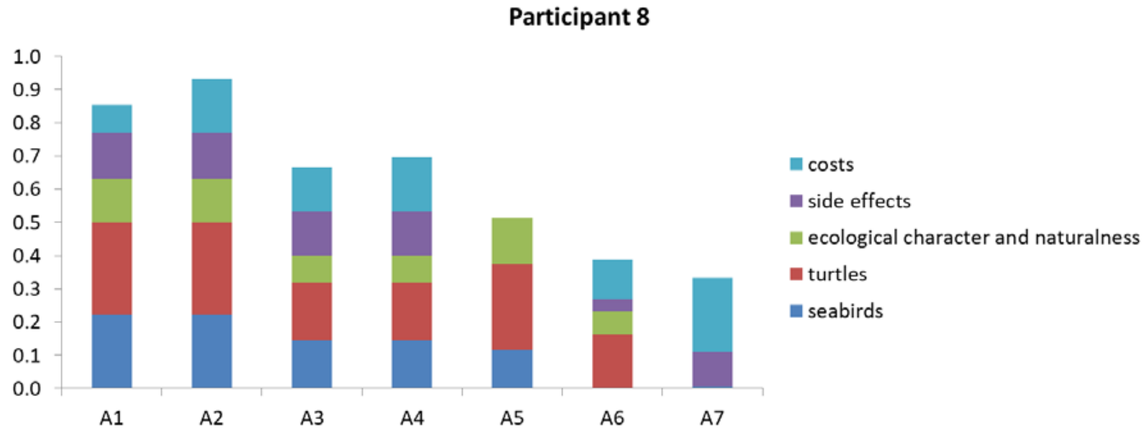
costs
side effects
ecological character and naturalness
turtles
seabirds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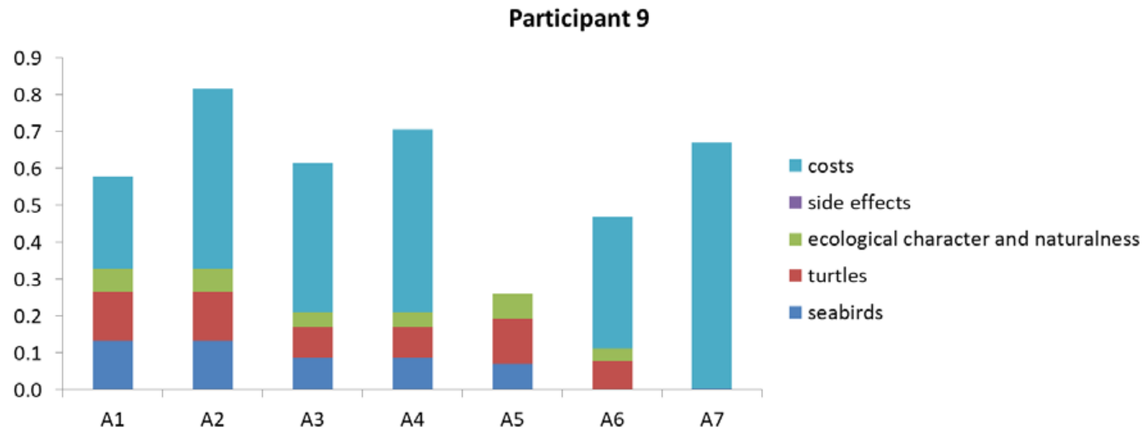
costs
side effects
ecological character and naturalness
turtles
seabirds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