Queensland **Primary Industries and Fisheries**

Coral reef fin fish spawning closures

Risk assessment and decision support

Report on outcomes from a workshop held 12–13 May 2009

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On 26 March 2009, the Department of Primary Industries and Fisheries was amalgamated with other government departments to form the Department of Employment, Economic Development and Innovation.

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Contents

Summary

A 2-day workshop involving scientists, managers and stakeholders explored 6 candidate alternatives for spawning closures to be applied to the coral reef fin fish fishery from 2009 to 2013.

The perceived merit of any single alternative rests on:

(a) *biological judgments* concerning its capacity to protect important fish species

(b) *value judgments* concerning trade-offs between protection, costs to fishery users, and other relevant considerations.

Participants varied in their judgments of both elements. Variation in biological judgments arises from uncertainty in scientific knowledge. Variation in value judgments reflects the priorities and preferences of individuals and organisations. The workshop integrated both elements in a structured decision-making framework.

The following criteria were used to assess the relative merit of each alternative:

- maximise protection of fish species
- minimise costs to fishers (commercial, recreational and charter)
- maximise broader ecosystem benefits
- maximise ease of enforcement
- maximise opportunities to learn the effect of spawning closures on fish protection and the broader ecosystem.

In assessing alternatives against these criteria, participants dealt with trade-offs. Collective compromises identify one or more alternatives that participants regard as broadly acceptable, rather than an alternative that is optimal for any subset of stakeholders or objectives.

Coral trout was seen to be the most important species group among coral reef fin fish (CRFF). Participants generally agreed that spawning closures provided added protection to coral trout, and that the magnitude of protection depended on the specific closure regime. There was less agreement on the need for additional protection above that provided by other management arrangements in place.

Across all criteria there was no clear or compelling collective preference for any of the six candidate alternatives. Some alternatives attracted distinctly divergent views. Two alternatives were broadly acceptable to most participants:

Alternative 3

Five years of 5-day closures to be applied in each of October and November.

Closures refer to all species.

Alternative 6

Five years of 5-day closures to be applied in each of October and November, plus

a 5-day September closure *if* the new moon falls after the 15th day of that month, and a 5-day December closure *if* the new moon falls before the 15th day of that month.

Closures refer to coral trout *only*.

Along with the formally captured views of participants, the decision-maker will have to give due consideration to other information, including the workshop discussions that form part of this report and criteria that were addressed only coarsely (ecosystem benefit, enforceability and prospects for learning).

We note the following regarding Alternative 3:

- It is among the best options for protection of coral trout, red emperor, large mouth nannygai, spangled emperor and camouflage cod/flowery cod.
- Protection is afforded to all coral reef fin fish; therefore, catch and release of coral trout while fishing for other species will be minimised as will disruption to spawning fish.
- Alternative 3 imposes a relatively low impact on all fishery sectors and the ecosystem benefits and ease of enforcement are moderately high.

We note the following regarding Alternative 6:

- It provides a relatively high level of protection to coral trout.
- The inclusion of specific 'if–then' configural rules relating to lunar phase in September and December represents a more sophisticated biologically-based, cost-effective approach to protection than the status quo.
- It is the worst alternative with respect to 'ease of enforcement'.
- Its effectiveness as a protective measure rests on high survivorship of caught and released coral trout and assumes minimal disruption to spawning fish as a result of fishing.

Introduction

A two day workshop explored candidate alternatives for spawning closures to be applied to the coral reef fin fish fishery from 2009 to 2013. Participants are listed at Appendix 1.

Participants nominated 12 candidate closure regimes (Table 1). Time constraints meant that only 6 of these could be considered in detail. 'No closures' was made a mandatory inclusion in the shortlist so that the relative impact of other candidates could be gauged against a 'do nothing' baseline. The remaining 5 were selected by votes cast by participants. All candidates refer to closures around the new moon.

The merit of any single alternative rests on:

(a) *biological judgments* concerning its capacity to protect important fish species

(b) *value judgments* concerning trade-offs between protection, costs to fishery users, and other relevant considerations.

Experts and stakeholders vary in their judgments of both elements. Variation in biological judgments arises from uncertainty in scientific knowledge. Variation in value judgments reflects the priorities and preferences of individuals and organisations. The workshop integrated both elements in a structured decision-making framework.

Table 1. Alternative closure regimes nominated by participants.

Shortlisted alternatives	Non-shortlisted alternatives
A1 No closures.	5 years with 1 × 90-day closure in October, November and December. Commercial fishery only.
A2 2 years no closures, followed by three years with 2 × 9-day closures in October and November.	5 years with 3 × 9-day closures in October, November and December.
A3 5 years with 2 × 5-day closures in October and November.	5 years with 3 × 5-day closures in October, November and December.
A4 5 years with 2 × 9-day closures in October and November, offshore charter exempt, no offshore charter activity 20 December–31 January.	5 years with 3 × 7-day closures in October, November and December. Coral trout only.
A5 5 years with 2 × 9-day closures in October and November (status quo).	5 years with 7-day closure in October 5-day closure in November, plus 5 days September closure if new moon after 15th 5 days December closure if new moon before 15th.
A6 5 years with 2 × 5-day closures in October and November, plus 5 days September closure if new moon after 15th, 5 days December closure if new moon before 15th, coral trout only.	5 years 2 × 5-day closures October and November, plus 5 days September closure if new moon after 15th 5 days December closure if new moon before 15th.

Methods

Two interacting flaws commonly encountered in risk assessment protocols are (a) separating risk assessment from risk management, thus disrupting essential connections between social values and the scientific knowledge necessary to predict the likely impacts of management actions, and (b) relying on expert judgment about risk framed in qualitative and value-laden terms, inadvertently mixing the expert's judgment about what is likely to happen with personal or political preferences. To buffer against these flaws, we used a probabilistic approach to cause-and-effect and multi-criteria analysis to describe and weigh social and organisational values (Maguire 2004). We incorporated the views of experts and stakeholders in an effort to overcome the motivational and cognitive biases of individuals (Failing et al. 2007).

Biological judgments

Figure 1 records participants' collective perceptions of the importance of each species/species group to conservation and the commercial, recreational and charter fisheries. While the importance of individual species (or species groups) to the three fisheries varied substantially, importance to conservation was notably invariant. Depending on the interpretation of individual participants, 'conservation' may imply intrinsic values or instrumental value for humans (Justus et al. 2009). The workshop did not define conservation values in any detail, leading to language-based ambiguity (Regan et al. 2002). Nevertheless, the consistency in importance ratings across species suggests most participants regarded intrinsic value to be a primary concern.

Based on these outcomes participants agreed to the following shortlist of species for further consideration in the workshop:

- coral trout[1] (*Plectropomus* spp. and *Variola* spp.)
- red throat emperor (*Lethrinus miniatus*)
- red emperor (*Lutjanus sebae*)
- large mouth nannygai (*Lutjanus malabaricus*)
- spangled emperor (*Lethrinus nebulosus*)
- camouflage grouper/flowery cod (*Epinephelus polyphekadion* and *E. fuscoguttatus*; to be considered together).

For each alternative closure regime and each species, participants were individually asked to estimate the probability (%) that fish numbers encountered in Great Barrier Reef Marine Park general use and habitat protection zones ('blue zones') over the past five years will be maintained over the next five years. That is, given hypothetical implementation of alternative *x*, what is the chance the number of fish of species *y* is maintained or increased over at least half of all blue zone reefs? Responses assumed all other management controls (e.g. quota, bag limits, green zones) remain unchanged from current conditions.

The point estimates of individuals ignore uncertainty. To derive a plausible interval on probabilities, we pooled the judgments of multiple experts and stakeholders (Armstrong 2001, Yaniv 2004). We considered a plausible interval to be one that encompassed the estimates provided by nine of the 13 participants.

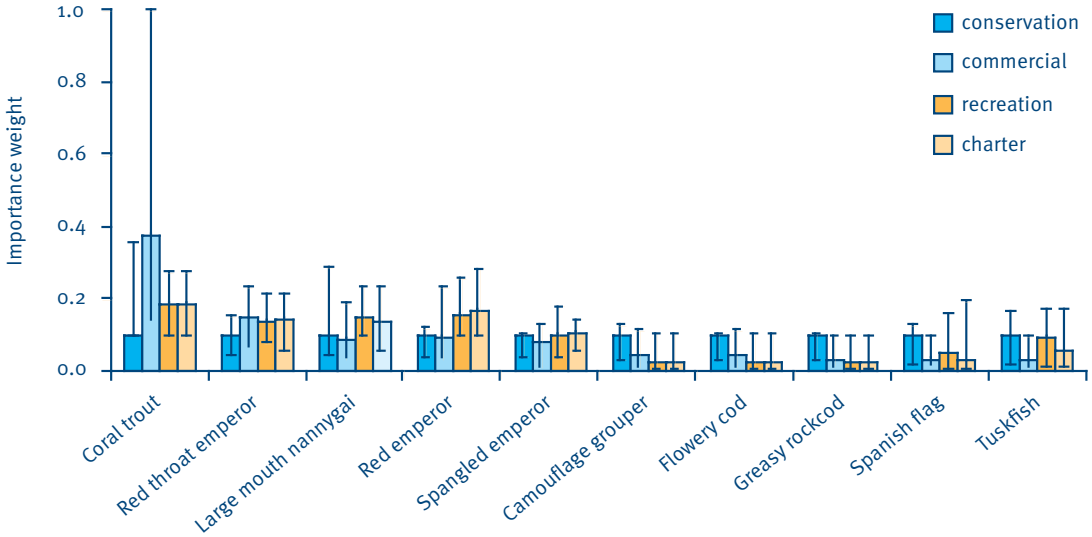

Figure 1. The median importance of coral reef fin fish species. Error bars indicate the full range of responses among 14 participants.

1. Consideration and assessment of coral trout focused on common coral trout (*P. leopardus*) as the primary species and the species with the most available biological information.

Combining biological and value judgments

Multi-criteria analysis (MCA) assesses alternatives by eliciting judgments from people about the relative importance of personal, organisational or societal values. The basic steps are:

- create a list of objectives (decide on criteria and sub-criteria relevant to the decision problem)
- identify management alternatives (options)
- identify measures of performance for each criterion
- assign performance scores to the criteria
- specify weights for criteria
- aggregate the scores, and evaluate the sensitivity of outcomes to weights and scores.

MCA can be effective for complex decision problems that include market and non-market values (Hajkowicz 2008). The objectives are used to order thinking about important attributes (criteria), to ensure no important elements are overlooked, that criteria are meaningful and decomposable, and to avoid redundancy in judgements (Keeney and Raiffa 1976).

The protection of coral reef fin fish species is not the only consideration in the decision problem. Implicit in the shortlist of alternatives is recognition that protection needs to be weighed against costs to fishers, among other criteria. Participants identified the following criteria:

- maximise protection of fish species
- minimise costs to fishers (commercial, recreational and charter)
- maximise broader ecosystem benefits
- maximise ease of enforcement
- maximise opportunities to learn the effect of spawning closures on fish protection and the broader ecosystem.

In assigning weights to these criteria, participants deal with trade-offs that usually involve outcomes that do not see maximisation (or minimisation) of objectives. Collective compromises seek to identify one or more alternatives that participants regard as broadly acceptable, rather than an alternative that is optimal for any subset of stakeholders or objectives.

Results

Biological judgments

After providing initial estimates of the probability of maintaining the number of fish in blue zones over the next five years, participants were invited to justify and cross-examine each others' perspectives. Estimates were then revised in the light of discussion. Results of revised estimates for each species are shown in Figure 2.

Among the candidate alternatives considered, the species most sensitive to spawning closures is coral trout. It is also the most important to fishery users (Figure 1). Median estimates range from a 70% chance of maintaining fish numbers under no closures (Alternative 1) to 90% under Alternative 6. A more conservative (risk-averse) assessment places greater emphasis on lower bounds. Ignoring outlier responses (i.e. the whiskers in Figure 2), Alternatives 4, 5 and 6 all appeal to a risk-averse decision-maker. They have high lower bounds.

For the species of lesser (but non-trivial) importance, Alternatives 3 and 5 are sound risk-averse options when considering red emperor, large-mouth nannygai, spangled emperor and camouflage grouper/flowery cod. Red throat emperor is essentially insensitive to the 6 alternative spawning closures because it spawns mainly in winter, outside any of the periods included in any of the alternatives.

Combining biological and value judgments

The estimated performances of the alternatives under each criterion are shown in Table 2. Protection was described as 'chance of successful maintenance of fish numbers', described above. Intervals equate to the plausible bounds plotted in Figure 2 (i.e. the boxes, ignoring outlier 'whisker' responses). The cost to each fishery sector was estimated by participants as fishing days lost over the 5-year regime. Again, uncertainty is characterised using an interval. The three criteria dealing with ecosystem benefits, ease of enforcement, and prospects for learning were scored on an arbitrary Likert scale from 1 (worst) to 4 (best).

Each of the 13 participants assigned weights to the 12 criteria shown in Table 2. The weight apportioned to any criterion reflects both the importance of the criterion and the full range of raw performance scores associated with alternatives (Steele et al. 2009).

Decision scores for each participant and each alternative were obtained using simple weighted summation (Keeney and Raiffa 1976). 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.

Table 2. Estimated performance of each alternative against identified criteria.

Criterion	Preferred direction	A1	A2	A3	A4	A5	A6
Chance (%) of 'protecting'							
Coral trout	More	29–80	35–85	50–85	66–90	69–90	62–90
Red throat emperor	More	28–96	41–96	25–96	25–95	25–96	34–96
Red emperor	More	30–90	50–90	50–91	49–90	50–91	35–91
Large mouth nannygai	More	30–90	50–90	50–90	48–90	50–90	35–90
Spangled emperor	More	44–95	50–95	50–95	50–95	50–95	44–91
Cam group/flow cod	More	29–90	39–90	49–95	49–95	50–95	40–90
'Effective' days lost to commercial fishing	Less	0	60–66	50	100–110	100–110	75
Recreational fishing	Less	0	54	50	90	90	0–5
Charter fishing	Less	0	54–60	50	100	90–100	20–30
Ecosystem benefits	More	1	2	3	4	4	2–3
Ease of enforcement	More	4	3.4	3	2.8	3	1
Prospects for learning	More	2–4	4	2	2	2	3

The importance of uncertainty in performance scores can be evaluated with sensitivity analysis. A simple approach is to conduct and compare separate analyses on plausible lower and upper bounds for the values reported in Table 2 (Burgman 2005). Results are shown in Figure 3.

Outcomes are largely insensitive to the uncertainty reported in Table 2. That is, the qualitative insights provided by lower bound calculations are consistent with those of upper bound calculations.

There is no clear or compelling collective preference for any of the six candidate alternatives. The large range associated with Alternatives 1, 4 and 5 (for both lower and upper bound calculations) imply that although their implementation is strongly supported by some participants, it would be strongly opposed by others. A less divisive approach is to consider implementing Alternative 2, 3 or 6. The 'Maxi-Min' strategy of decision-making under uncertainty appeals to those who are risk-averse. The strategy involves focusing on the minimum outcome associated with each alternative, and selecting the one with the largest minimum value (Morgan and Henrion 1990). The alternative with the largest minimum score is Alternative 6.

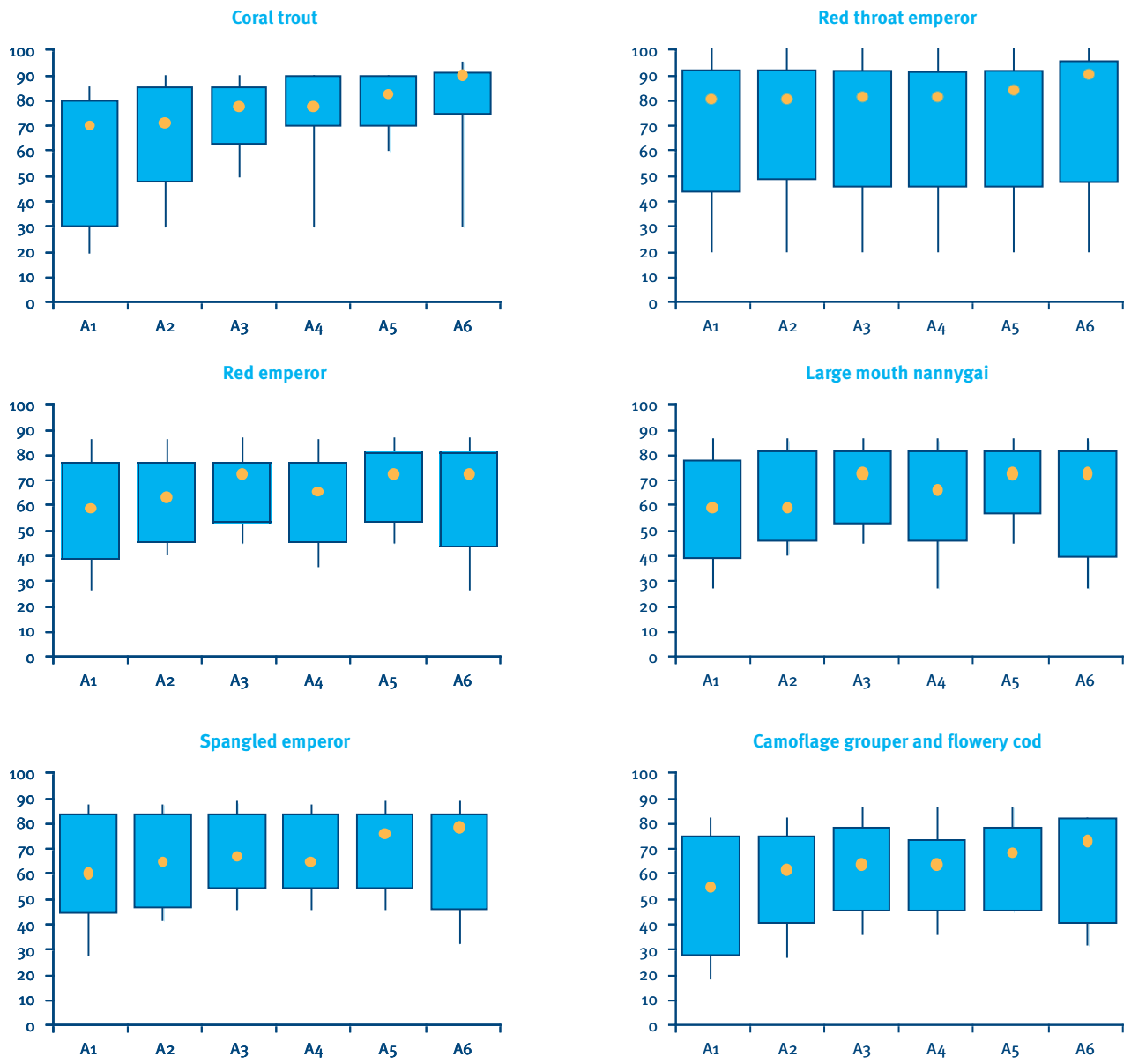

Figure 2. Participants' estimates of the chance (%) of maintaining fish numbers under 6 alternative closure regimes. Median response is indicated by a dot, the box shows the range of 9 of the 13 participants, and whiskers indicate the full range of the 13 participants.