

The socio-cultural benefits and costs of the traditional hunting of dugongs *Dugong dugon* and green turtles *Chelonia mydas* in Torres Strait, Australia

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Abstract Signatory states of the Convention on Biological Diversity must 'protect and encourage the customary use of biological resources in accordance with traditional cultural practices that are compatible with conservation or sustainable use requirements'. Thus the management of traditional hunting of wildlife must balance the sustainability of target species with the benefits of hunting to traditional communities. Conservation policies usually define the values associated with wild meats in terms of income and nutrition, neglecting a wide range of social and cultural values that are important to traditional hunting communities. We elicited the community-defined benefits and costs associated with the traditional hunting of dugongs *Dugong dugon* and green turtles *Chelonia mydas* from communities on two islands in Torres Strait, Australia. We then used cognitive mapping and multidimensional scaling to identify separable groups of benefits (cultural services, provisioning services, and individual benefits) and demonstrate that traditional owners consider the cultural services associated with traditional hunting to be significantly more important than the provisioning services. Understanding these cultural values can inform management actions in accordance with the Convention on Biological Diversity. If communities are unable to hunt, important cultural benefits are foregone. Based on our results, we question the appropriateness of conservation actions focused on prohibiting hunting and providing

monetary compensation for the loss of provisioning services only.

Keywords *Chelonia mydas*, cognitive mapping, cultural values, dugong, *Dugong dugon*, green turtle, Torres Strait, traditional hunting

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Introduction

The hunting of terrestrial and marine wildlife is typically considered to be a matter of conservation concern, even though it can be an important source of livelihood to local communities (Nasi et al., 2008), particularly indigenous communities. Scientific studies have described the negative impacts of hunting on wildlife, particularly on the native biota in Africa (e.g. Bowen-Jones & Pendry, 1999; Brashares et al., 2004). Research on the hunting of marine mammals and turtles is somewhat less common (Sohou et al., 2013) despite the fact that, since 1990, people in at least 114 countries have consumed one or more of at least 87 marine mammal species (Robards & Reeves, 2011). Green turtles *Chelonia mydas* are still harvested legally for food in several range states despite being categorized as Endangered at a global scale (Seminoff, 2004).

Historically, the development of species management tools has generally been guided by knowledge of the species' biology, with limited attention to the broader context of management and the impacts of actions on the users of wildlife. However, the impacts of conservation actions such as hunting regulations on local communities, and their rights to be involved in management, are now being acknowledged. Hence, wildlife managers and conservation organizations face the challenge of minimizing the negative impacts of hunting on the long-term sustainability of wildlife while enhancing the positive impacts (Nasi et al., 2008; Nyaki et al., 2014; Duffy et al., 2016).

In the 1970s, as wildlife managers and conservation practitioners began to recognize the important links between biodiversity and people, there was a concurrent movement to recognize the rights of indigenous peoples. These

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processes led to the explicit international recognition of the role of indigenous peoples in the conservation and sustainable use of biodiversity. Two articles (article 8(j) on traditional knowledge, innovations and practices, and article 10(c) on customary sustainable uses of biodiversity) were included in the Convention on Biological Diversity. Article 10 (c) requires signatory states (Parties) to ‘protect and encourage the customary use of biological resources in accordance with traditional cultural practices that are compatible with conservation or sustainable use requirements’. Both articles thus bind Parties to the Convention to respect, protect and promote traditional knowledge, innovations and practices. These articles also oblige Parties to protect and encourage customary uses of biological resources in accordance with traditional cultural practices. The articles can be adapted at the national and local levels to strengthen indigenous involvement in decision making in the sustainable use of biodiversity (Sutherland, 1995).

Cultural dimensions of hunting

The most obvious positive outcomes of hunting are its contributions to nutrition, food security, income generation and livelihoods in rural and remote areas (Bassett, 2005; Nasi et al., 2008). These outcomes apply not only to the hunters themselves but also to others along the supply chain (Crookes & Milner-Gulland, 2006; Allebone-Webb et al., 2011). Nevertheless, the range of motivations, benefits and costs associated with hunting can be more comprehensive than these values, especially for indigenous and traditional groups. Indigenous communities have particularly strong connections with nature, as their way of life often depends on their access to natural resources (United Nations Environment Programme, 2003), and traditional cultures can help maintain the diversity and resilience of natural systems (Bélair et al., 2010).

Anthropologists and ethnoecologists have studied the cultural values of hunting (Cocks et al., 2011; Peterson, 2013), emphasizing the important cultural role that the hunting and sharing of wild meats (which may include terrestrial and marine species of conservation interest) plays in the transmission of traditional ecological knowledge, cultural identity, and medicinal and spiritual values, and in the maintenance of community cohesion (van Vliet et al., 2011; Kalland, 2012; Reo & Whyte, 2012; Baggio et al., 2016; BurnSilver et al., 2016; Watkin Lui et al., 2016a). However, the incorporation of the social and cultural dimensions of hunting is still relatively undeveloped in contemporary management practices (Nasi et al., 2008), and conservation policies based on Western concepts usually define the values of wild meats solely in terms of income and protein (Nyaki et al., 2014). Even a widely discussed concept such as food security, often regarded as a direct benefit of hunting, is often based on a Western definition focusing on nutrition,

calories and purchasing power rather than the holistic nature of food security held by indigenous people such as the Alaskan Inuit, who consider food security to encompass both cultural and environmental systems (Inuit Circumpolar Council-Alaska, 2015).

The difficulties of incorporating the social dimensions of indigenous hunting into contemporary management are compounded when the target species (marine and terrestrial) are of conservation concern (e.g. dugongs *Dugong dugon* and green turtles *Chelonia mydas* in Australia; beluga *Delphinapterus leucas* and bowhead whales *Balaena mysticetus* in the Arctic). Policies are usually defined according to the predominant discourse based on a value system that narrowly defines hunting values and does not reflect the spectrum of values identified by direct resource user groups (Turner et al., 2008). Moreover, the costs and benefits associated with hunting (or the conservation policies regulating such activity) are generally more salient to the members of indigenous communities than to the outside organizations that typically develop conservation policies (Nyaki et al., 2014). Thus, clarifying the range of benefits and costs associated with hunting, and their relative importance from the perspective of indigenous hunting communities, can help the development of understanding about the potential impacts of conservation policies on these communities. The risks of not considering the range of impacts resulting from policies may have severe negative consequences for indigenous peoples (Turner et al., 2008); for example, researchers have highlighted eight invisible losses experienced by First Nation communities in western North America as a result of a lack of recognition of cultural values during the development of environmental policies that affected their access to traditional lands and resources (Turner et al., 2008). Losses included lifestyle losses, loss of identity, health losses, loss of self-determination, emotional losses, loss of order in the world, knowledge losses, and indirect economic losses (Turner et al., 2008).

Such social impacts are not confined to indigenous groups. In the development of marine national parks, managers in New South Wales, Australia, did not fully recognize social impacts on commercial fishers of banning commercial fishing in some areas. Fishers reported that the managers considered only economic impacts when making their decision, and ignored the loss of well-being and community cohesion (Momtaz & Gladstone, 2008). As a result, fishers became distrustful of the local management authority (Voyer et al., 2014).

A potential explanation for the lack of recognition or legitimacy of cultural values in the policy arena may stem from the types of assessments used to describe non-market values. Policy makers and managers may respond better to market values such as income because they are quantifiable for comparison with other values. Moreover, research indicates that decision makers are more inclined to use ecological indicators

and market studies rather than non-market valuation studies, at least partially because of the complexity of the methods (Rogers et al., 2015). Non-market valuation studies such as contingent valuation have also been criticized as being unsuitable for research in indigenous communities (Adamowicz et al., 1998; Venn & Quiggin, 2007).

The sharing of food (BurnSilver et al., 2016) is a cornerstone of whaling by indigenous communities in the Alaskan Arctic and is integral to maintaining community cohesion. Nonetheless, the system has been described mostly in a qualitative rather than a quantitative manner (BurnSilver et al., 2016). Baggio et al. (2016) and BurnSilver et al. (2016) analysed social networks, harvest and household economic data to quantify the importance of indigenous whaling in the Alaskan Arctic. This quantitative assessment combined with more descriptive studies of the complex values associated with indigenous hunting can assist in formulating a narrative and policies looking at the future of indigenous communities in the face of global environmental change (Baggio et al., 2016; BurnSilver et al., 2016).

A participatory approach to understanding costs and benefits of indigenous hunting

The ecosystem services concept has been used widely to identify the values people derive from ecosystems, including through extractive activities such as hunting and fishing (Millennium Ecosystem Assessment, 2005; Chan et al., 2012a). Most users of the Ecosystem Services Framework emphasize the economic valuation of tangible services over the identification of intangible benefits associated with social and cultural values (Chan et al., 2012b). Using economic valuations to inform decision making can be problematic, as the intangible benefits associated with Ecosystem Services can matter more to people than the monetary benefits (Chan et al., 2012b). Accordingly, the effective identification and prioritization of the values derived from ecosystems requires the use of qualitative and participatory methods that include the perspectives of communities that are more closely linked with such ecosystems and are therefore potentially affected by management actions (Chan et al., 2012a).

We used a participatory modelling approach known as cognitive mapping to investigate the costs and benefits of the traditional hunting of two culturally significant species in an area inhabited by indigenous, natural resource dependent communities. Our approach avoids the use of contingent valuation but still defines costs and benefits, as non-market valuation estimates are generally part of a cost-benefit analysis (Supplementary Material 1). Cognitive mapping is an umbrella term that encompasses such techniques as causal, semantic and concept mapping. A cognitive map is a qualitative model describing the elements of a given system. The map uses defined variables and describes

their relationships. The variables can represent physical or abstract ideas (Özesmi & Özesmi, 2003). The person making the cognitive map decides on the important variables that affect a system and then either draws causal relationships among these variables (i.e. causal mapping), with the possibility of indicating the relative strength of the relationships with a number between -1 and 1 (i.e. fuzzy causal mapping), or decides how the variables are interrelated (i.e. concept mapping). Such techniques are used to study decision making and people's perceptions of complex social systems (Axelrod, 1976; Brown, 1992; Carley & Palmquist, 1992) and have been applied successfully in natural resource management to improve decision making, define management objectives and analyse stakeholders' perceptions of ecosystems (Radomski & Goeman, 1996; Özesmi & Özesmi, 1999; Hobbs et al., 2002; Mendoza & Prabhu, 2003). Cognitive mapping and other mental model techniques have been particularly useful in describing how various stakeholder groups perceive a similar natural resource management issue. In cases of human-wildlife conflict, the reasons and potential solutions can vary between policy makers and other stakeholder groups (Mosimane et al., 2014). A better understanding of how various people interpret a similar problem can identify areas of agreement and disagreement, and can be the precursor in establishing a closer working relationship towards effective environmental policy and decision making (Mosimane et al., 2014). All cognitive mapping techniques try to understand how an individual interprets concepts, and describe those concepts and their relationships in a graphical layout (Fiol & Huff, 1992).

We used cognitive mapping to address the following questions: What are the social-cultural costs and benefits associated with traditional hunting of marine megafauna from the perspective of an indigenous community? How are the costs and benefits linked/grouped, and what is their relative importance? The cultural significance of the species and the fact that the meat cannot be sold helps to emphasize the social and cultural rather than the monetary values of hunting.

Case study: traditional fisheries in Torres Strait, Australia

Most of the people living in the Torres Strait region between Australia and Papua New Guinea are indigenous (ABS, 2011) (Fig. 1). Dugongs and green turtles (hereafter turtles) have significant cultural importance for Torres Strait Islanders and have been hunted for millennia. The turtle harvest originated at least 7,000 years ago (Wright, 2011), and the dugong harvest at least 4,000 years ago (Crouch et al., 2007). The remains of thousands of dugong bones in middens indicate that the harvest has been substantial for at least 400–500 years (McNiven, 2010), pre-dating European settlement in the 19th century.

Torres Strait currently supports the largest population of dugongs globally (Marsh et al., 2011b). A population decline

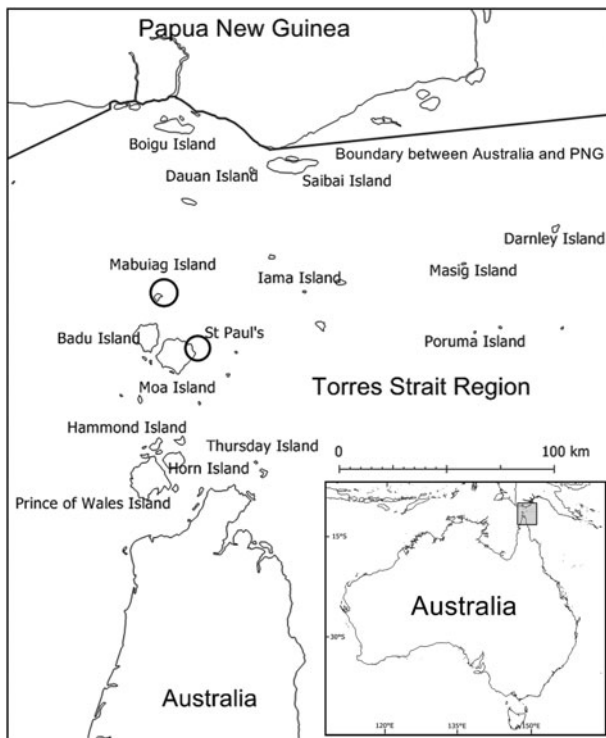


FIG. 1 Locations of the study communities of Mabuiag and St Paul's (circled) in Torres Strait, Australia.

has not been detected by aerial surveys of dugongs conducted during 1987–2013 (Marsh et al., 2015; Hagihara et al., 2016), probably because dugongs are harvested in only 5% of the 5,268 km² of very high dugong density habitat as the result of cultural and government controls on the harvest, and socio-economic factors. Contemporary evidence thus suggests that the dugong harvest in Torres Strait is sustainable (Marsh et al., 2015; Hagihara et al., 2016; Urwin et al., 2016).

Torres Strait also provides foraging grounds for abundant stocks of juvenile and adult turtles (Limpus, 2008; Fuentes et al., 2015; Hagihara et al., 2016) and is an important corridor for populations migrating between eastern Indonesia, the Arufura Sea, the Gulf of Carpentaria and the northern Great Barrier Reef (Limpus & Parmenter, 1986). The level of hunting of green turtles in Torres Strait is likely to be sustainable (Hagihara et al., 2016). However, there are concerns about the long-term future of the turtle stock, largely because of mounting evidence of environmentally caused recruitment failure at Raine Island in the northern Great Barrier Reef, the largest green turtle rookery (Limpus, 2008).

As a signatory to CITES and the Convention on Biological Diversity, Australia has multiple responsibilities associated with the conservation and management of dugongs and turtles. For example, commercial trade in these species (both of which are listed in Appendix I of CITES, 2017) is prohibited. Traditional owners in northern Australian coastal indigenous communities have the right

to hunt dugongs and turtles in their Sea Country (an Australian indigenous term that relates to the 'authority held and responsibilities of particular groups of traditional owners to particular areas of sea, and is based on cultural relationships with these areas'; Plagányi et al., 2013). This right is upheld under the Australian Native Title (e.g. Native Title Act 1993) and environment laws in accordance with the Torres Strait Fisheries Act 1984, which facilitate the Torres Strait Treaty between Australia and Papua New Guinea (Havemann & Smith, 2007). Operationally, these fisheries are managed at the community level through 15 non-statutory community-based turtle and dugong management plans (Marsh et al., 2011a).

Our research was conducted in two remote indigenous island communities in the Australian waters of Torres Strait (Fig. 1). In 2011 there were close to 6,000 Torres Strait Islanders and/or Aboriginal people living in the region (OESR, 2013), including c. 250 and 235 residents in our study communities of Mabuiag and St Paul's, respectively (Fig. 1).

Dugongs and green turtles are cultural keystone species in Torres Strait (Butler et al., 2012), defining Torres Strait Islanders wherever they reside (Watkin Lui et al., 2016b). The hunting and distribution of dugong and turtle meat are part of Ailan Kastom (island custom). The Cambridge Expedition (Haddon, 1912) reported that green turtles and dugongs were an essential part of the diet of Mabuiag Islanders, a fact confirmed by subsequent studies in Torres Strait (Nietschmann, 1981; Bliege Bird & Bird, 1997; Bliege Bird et al., 2001; Kwan et al., 2006). Both species are also important for ceremonies (Fitzpatrick-Nietschmann, 1980), and hunting confers prestige and recognition within the community on the hunters of eastern Torres Strait (Bliege Bird et al., 2001).

In common with other indigenous peoples, the residents of the two study communities are at a significant socio-economic disadvantage compared with the wider community. Almost 70% of jobs in Mabuiag and St Paul's are available only to residents who participate in an employment benefit scheme (Delisle, 2013). Residents earn c. 50% of what their Australian counterparts earn. Each community has only one general store at which to purchase food, and the mean price of commodities is c. 53% higher than on the mainland. Community residents thus face the double burden of low income and high prices, with real incomes substantially below those of their non-indigenous mainland counterparts.

The spending pattern of residents is also different from that of the average Queensland household (Delisle, 2013). For example, in St Paul's c. 40% of all expenditure is on food and beverages, compared to 20% for the average Queensland household (ABS, 2011), which is an indicator of the financial pressures on the residents of these remote communities.

Methods

Data collection

After obtaining ethical approval from local institutions (Torres Strait Regional Authority and each island's traditional owner institution, called a prescribed body corporate), AD travelled to each of the study communities, meeting with leaders to describe the project and discuss appropriate research methods and associated community consultation. The communities requested that we hold regular community meetings to keep them informed of progress, and conduct interviews with a cross-section of individuals from each community.

During May 2009–December 2010 AD undertook eight field trips, each of 2–3 weeks duration, to the two study communities to (1) elicit the community members' perceived benefits and costs associated with hunting, (2) understand how those benefits and costs were related (using cognitive mapping exercises), and (3) determine the perceived importance of each benefit and cost (by asking individuals to rate them).

Information from (1) and (2) was used to identify separable groups of benefits and costs associated with hunting. Information from (2) and (3) was used to estimate the average importance of groups of separable benefits and costs, and mean values were compared. Statistical tests were used to determine if the differences were significant, so we could determine the relative importance of groups of benefits and costs.

Eliciting the benefits and costs of traditional hunting

We used free listing to identify, via interview, a broad range of benefits and costs associated with hunting. Interviewees were selected from a list, provided by community representatives, of people who were deemed knowledgeable (in that they had sufficient knowledge of hunting and of the community to provide sound information) and included males and females, young and old. Each interviewee was asked two focal questions: (1) What are the benefits of traditional dugong and turtle hunting? (2) What are the costs of traditional dugong and turtle hunting?

Responses were recorded in writing, and audio-recorded if permitted by the participant. At the beginning of each interview the participant was shown the list developed in previous interviews and encouraged to contribute any items that he/she believed should be on it. We stopped conducting these interviews once saturation was reached (i.e. no new elements were identified by new interviewees; Stark & Torrance, 2006). Saturation occurred after interviewing 10 participants (six men and four women) on Mabuiag Island, and AD decided to interview the same number of participants (five women and five men) in St

Paul's, even though saturation occurred with fewer participants there.

The wording used during free listing sometimes varied between individuals. The content of the list and the various themes elicited were analysed qualitatively for similarity. A final list was generated, accounting for the similarities between the ideas of participants and discarding redundancies. The final lists of benefits and costs were reviewed collectively by the interviewees of each island to check for accuracy and to develop an agreed set of definitions for each item.

Identifying groups of benefits and costs

We then used cognitive mapping to test for the separability (or lack thereof) of the costs and benefits elicited in the previous step.

The 10 people from each island who had participated in the free-listing activities were invited to take part in the cognitive mapping exercises, as were additional members of each community, who were recruited using snowball sampling, with the goal of speaking to a broad cross-section of the population.

Each participant was invited to view and categorize individual values (Rosenberg & Kim, 1975; Coxon, 1999) via a sorting activity using two sets of cards (benefits and costs). Each card had a description of one of the items identified from the free-listing exercises. Respondents were asked to place the cards into groups that 'went well together' (ideally, not a single group), and provide a name or label for each group of cards. The exercise was performed twice, once using cards that related to benefits, and once with cards relating to costs.

The groups of benefits and costs were coded into separate binary matrices. The name of each benefit or cost appeared as a header on both the columns and the rows of each matrix. If a respondent had placed two items in a group together, then the entry in the cell of the matrix corresponding to those two items was 1; otherwise it was 0. We then constructed a single aggregate matrix for each community (Mabuiag and St Paul's); simplistically, the sum of all individual matrices. These aggregate matrices were then analysed using multidimensional scaling. We used both metric (which deals with interval or ratio-level data) and non-metric multidimensional scaling (which deals with ordinal data) to obtain visual representations of the relationships between the numerous benefits and costs identified in the free-listing exercises, using normalized raw stress scores to determine the optimal number of dimensions. With these visual representations we were able to identify separable groups of benefits and costs. Following Blake et al. (2003) we calculated the Euclidean distance between all values in the matrices, for each community, and then calculated Pearson's *R* to determine if the observed differences

between communities were statistically significant (Blake et al., 2003).

Representativeness of participants

On Mabuiag Island 40 residents were asked to participate in the cognitive mapping and 38 agreed (29 men and nine women; 38% of the permanent adult population of the island). In St Paul's, 45 residents were asked to participate and 40 agreed (31 men and 9 women; 31% of the permanent adult population). Hunting is a male-only activity in Torres Strait. Our sample included male hunters and non-hunters, including elders who no longer hunt but teach the younger generation about hunting, and women, who do not hunt but prepare the food products of the hunt. Based on discussion with community members who defined an age cut-off of 35 years between younger and older men, our sample included a total of 32 older men (> 35 years) and 28 younger men (\leq 35 years). Twenty households (108 people) on Mabuiag and 27 (93 people) in St Paul's (43 and 39% of the total population, respectively) were asked to provide information on hunting patterns. Using this approach we were able to interview 75% of all active hunters.

The demographic composition of the surveyed households was analysed and compared with the secondary socio-demographic data available from the 2006 census (ABS, 2006a,b). There were no statistically significant differences (ascertained using one-sample *z*-tests for population proportions) between the household composition of the sampled population and the socio-demographic data from the census (ABS, 2006a,b). Thus we have no reason to believe that our sample was not representative of the general population of these communities.

Estimating the relative value of each group of benefits and costs

We used the sets of cards that had been provided for the sorting session, and asked interviewees to score each item on a scale from 0 = not important to 10 = very important. To account for individual differences, scores were normalized, so the sum of all the scores given by any single individual equalled 1.

We then calculated the mean value of each of the separable groups of costs and benefits identified in the multidimensional scaling (hereafter clusters, *k*), and their mean value relative to the other clusters. For each participant: mean value of *k* = sum of individual item values/number of items, and relative value of *k* = mean value of *k*/sum of value of all clusters.

For each participant the relative value thus represents the proportion of total value captured by each cluster *k*. A Wilcoxon test was used to determine if differences between

cluster means and cluster relative values were statistically significant.

Results

The benefits and costs of traditional hunting

Eighteen benefits and 11 costs were identified through the free-listing exercises (Table 1). The graphical representations of the results of the multidimensional scaling analyses (Fig. 2) helped identify three clusters each of benefits (community, family, individual) and costs (community, family, environmental; Table 1).

The typology of the benefit clusters was identical for the two study communities. The two representations of the benefits of hunting were highly correlated ($R^2 = 0.989$, $P = 0.01$ level); thus we present the combined cognitive map of benefits. All stress values for the multidimensional scaling outputs were acceptable (Kruskal & Wish, 1978) and indicated that a three-dimensional solution produced the best fit at both the aggregated and individual levels.

The analyses also identified three distinct clusters for costs associated with hunting for Mabuiag respondents, and four distinct clusters for St Paul's. The two aggregated representations based on the island of residence were perfectly correlated ($R^2 = 1.0$, $P = 0.001$). As a result, we analysed the cognitive maps of respondents from Mabuiag and St Paul's combined. When data from all respondents were combined, the analyses identified the same three distinct clusters defined by the Mabuiag respondents.

There were no statistical differences between Mabuiag and St Paul's regarding the relative importance of community and family benefits (community benefits, $P = 0.686$; family benefits, $P = 0.330$; Mann-Whitney test). The mean importance of the community benefits cluster was significantly greater than that of family benefits, which in turn was greater than that of individual benefits, and these differences were statistically significant (Fig. 3a).

There were no statistically significant differences in the importance of cost clusters between communities. The importance of community costs was significantly greater than that of both family and environmental costs. There was no significant difference in the importance of family and environmental costs (Fig. 3b).

The age of male residents was a statistically significant determinant of the relative importance of a cluster. Younger men placed more importance on family benefits ($P = 0.000$; Mann-Whitney test), whereas older men placed more importance on community benefits ($P = 0.000$; Mann-Whitney test). Age had no significant effect on the relative importance of individual benefits ($P = 0.094$; Mann-Whitney test). Older men considered community costs to be more important than the younger men did ($P = 0.000$; Mann-Whitney test), whereas younger men

TABLE 1 Benefits and costs of hunting perceived by Torres Strait Islanders from the communities of Mabuiag and St Paul's (Fig. 1), elicited during free-listing exercises, grouped into clusters identified through multidimensional scaling. The numbers in parentheses are mean \pm SD of raw rating scores (range 0–10).

Benefits	Costs
Community	Community
Keeps tradition (9.12 \pm 0.98)	No respect for cultural protocols (7.94 \pm 1.64)
Keeps culture (9.09 \pm 1.17)	Bad hunting (8.42 \pm 1.22)
Sharing (7.95 \pm 1.40)	Less sharing (7.80 \pm 1.54)
Unity of community (8.24 \pm 1.24)	Injuries; i.e. an injured hunter cannot provide to the community (4.06 \pm 1.69)
Islan Pasin; i.e. traditional island way of life (7.81 \pm 2.01)	
Teaching the children (8.13 \pm 1.45)	
Spiritual connection to the sea (6.66 \pm 1.72)	
Food for ceremonies (7.60 \pm 1.37)	
Shows knowledge of the hunter (6.26 \pm 1.54)	
Essence of being an Islander (5.94 \pm 2.03)	
Family	Family
Food for home consumption (6.60 \pm 1.70)	Fuel (8.08 \pm 2.06)
Fresh food (4.45 \pm 1.33)	Time (7.08 \pm 1.74)
Tasty food (4.02 \pm 1.55)	Pressure for results when in need of food (4.13 \pm 1.74)
Cost-effective practice (6.00 \pm 1.80)	Pressure for results when asked to go hunting (3.47 \pm 1.82)
Individual	Environmental
Shows skills of the hunter (4.05 \pm 1.55)	Few animals (6.01 \pm 1.66)
Shows strength of the hunter (3.96 \pm 1.55)	Cleaning animal waste on the beach (4.72 \pm 1.88)
Prestige (2.90 \pm 1.46)	Disturbance of animals from noise (4.83 \pm 1.90)
Health (3.90 \pm 1.16)	

considered family costs to be more important than the older men did ($P = 0.003$; Mann–Whitney test). The relative importance of environmental costs was independent of age ($P = 0.548$; Mann–Whitney test).

Discussion

The free-listing exercises confirmed the multidimensional nature of the benefits and costs of traditional hunting of marine megafauna for two communities in Torres Strait. The cognitive mapping exercises demonstrated that traditional hunting provides bundles of benefits and costs to these communities. Community-defined benefits associated with traditional hunting in this region are clearly separable into one market and two non-market-based clusters (in terms of benefits to family, community and individuals).

Family benefits were all related to meat/market values and were thus closely associated with provisioning services, highlighting the importance of food for sustenance and to indirectly supplement incomes by foregoing the need to purchase other types of protein (Penny & Moriarty, 1977; Altman, 1987). Individual benefits encapsulated health benefits (Rose, 1996; Burgess et al., 2009), but also acknowledged that hunting gives men an opportunity to demonstrate their skills (Bliege Bird et al., 2001), which is important to their sense of identity. Community benefits included a broad range of cultural benefits, including, but not limited to, sharing (Wenzel, 1995; Bliege Bird & Bird, 1997), the maintenance of culture (Severance et al., 2013; Vaughan

& Vitousek, 2013), and the provision of food for ceremonial purposes (Nietschmann, 1981, 1984; Kwan, 2002).

Our cognitive mapping exercises did not separate clearly market and non-market costs. Fuel and time costs (both linked to the market) grouped together with 'pressure for results when in need of food and/or when asked to go hunting' (in a group termed family costs). However, community costs were deemed to be significantly greater than family costs, confirming previous observations that socio-cultural (community) values (be they costs or benefits) are more important than market values. People are motivated by both extrinsic and intrinsic factors (Gneezy et al., 2011), and these findings suggest that intrinsic motivations are likely to be strongly associated with culture. The important policy implication of this finding is that policy makers need to be careful that extrinsic incentives designed to alter hunting behaviours do not negatively affect these intrinsic (cultural) motivations.

The valuation of such services (formally, indigenous cultural services, as defined in the Common International Classification of Ecosystem Services; BISE, 2016) is particularly challenging for three reasons. Not only is the idea of 'valuing' indigenous cultural services contentious and probably inappropriate in many contexts (Venn & Quiggin, 2007), but many of these services are inherently inseparable from each other and from other ecosystem services. Consequently, one cannot simply estimate the value of individual services and sum them (de Groot et al., 2002; Carbone & Kerry Smith, 2013). There are also tenuous or non-existent links between most indigenous cultural

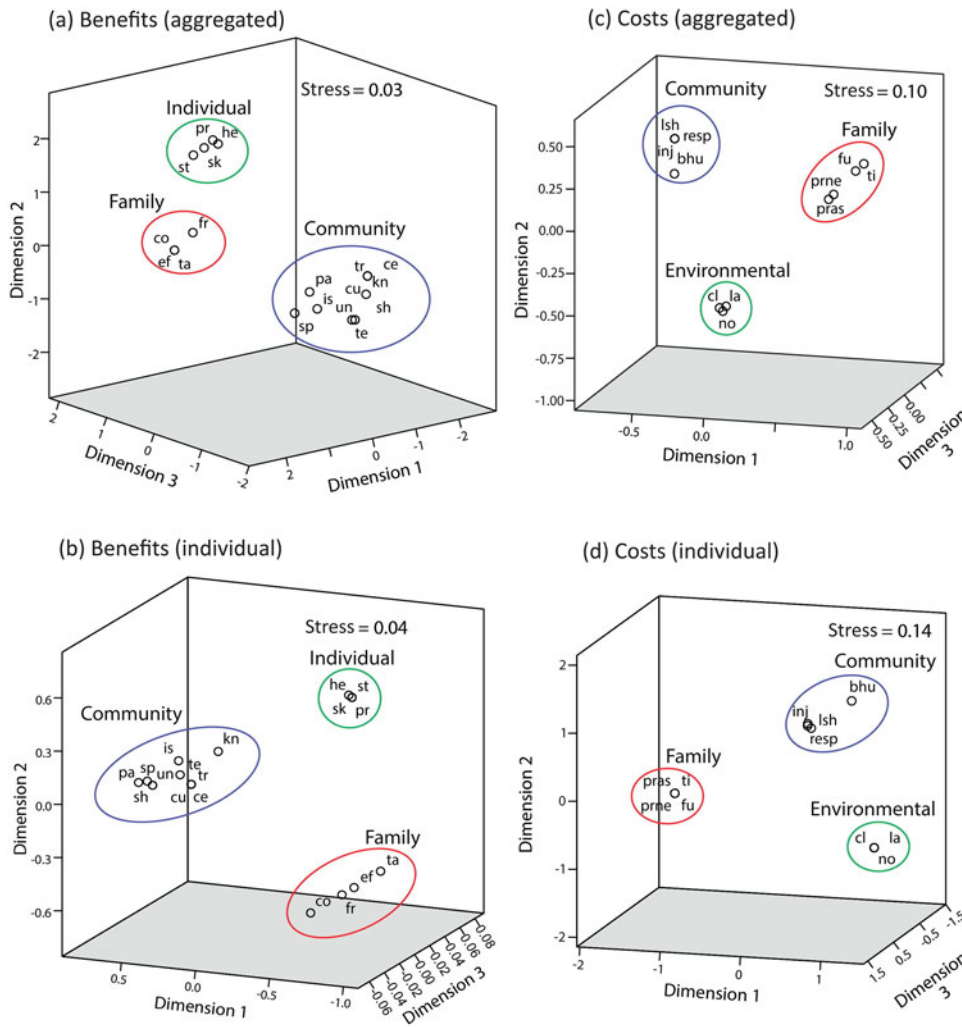


FIG. 2 Multidimensional scaling representations of the clusters of benefits (a & b) and costs (c & d) of hunting, at the aggregated and individual levels, for the respondents of Mabuiag and St Paul’s (Fig. 1) combined (N = 78). The clusters of benefits include community benefits (tr, keeps tradition; cu, keeps culture; un, unity of the community; sh, sharing; pa, Islan Pasin; te, teaching the children; sp, spiritual connection to the sea; ce, food for ceremonies; kn, shows knowledge of the hunter; is, essence of being an Islander), family benefits (co, food for home consumption; fr, fresh food; ta, tasty food; ef, cost-effective), and individual benefits (sk, shows skills of the hunter; st, shows strength of the hunter; pr, prestige; he, health). The clusters of costs include community costs (resp, no respect for cultural protocols; bhu, bad hunting; lsh, less sharing; inj, injuries), family costs (fu, fuel; ti, time; prne, pressure for results when in need of food; pras, pressure for results when asked to go hunting), and environmental costs (la, few animals; cl, cleaning animal waste on the beach; no, disturbance of animals from noise).

services and market prices (Daniel et al., 2012), requiring the use of sophisticated valuation approaches by which inferences may be drawn about those values. There is a substantive and rapidly growing body of literature on methods for doing so (Bateman & Great Britain Department for Transport, 2002; Day et al., 2012) but not all of these methods can be validly applied in all settings. Although simpler than more accepted approaches to cost–benefit analysis such as contingent valuation, our methodological approach facilitates quantification of the cost-effectiveness of various management approaches (Supplementary Material 1), using culturally appropriate participatory methods to address the problems outlined above.

Further developments

Our research group continues to work with the communities and agencies involved and we are confident that the

population status of dugongs and turtles and the hunting patterns and values of Torres Strait Islanders have not changed (Fuentes et al., 2015; Marsh et al., 2015; Cleguer et al., 2016; Hagihara et al., 2016; Urwin et al., 2016; Watkin Lui et al., 2016a,b). We have also conducted research on the values of hunting with the Torres Strait Islander diaspora (Watkin Lui et al., 2016a,b) with whom c. 12% of the meat is shared, an important cultural practice (Supplementary Material 1).

Nonetheless, the debate over traditional hunting of dugongs and turtles has intensified (Watkin Lui et al., 2016b). The Australian government is under increasing pressure to ban the practice and to offer monetary compensation to the Islanders based on the replacement value of the meat. Yielding to these demands would reflect a limited understanding of the multidimensional benefits gained by the Torres Strait communities involved in traditional hunting. Not considering the full spectrum of values as assessed by an affected community group can have negative

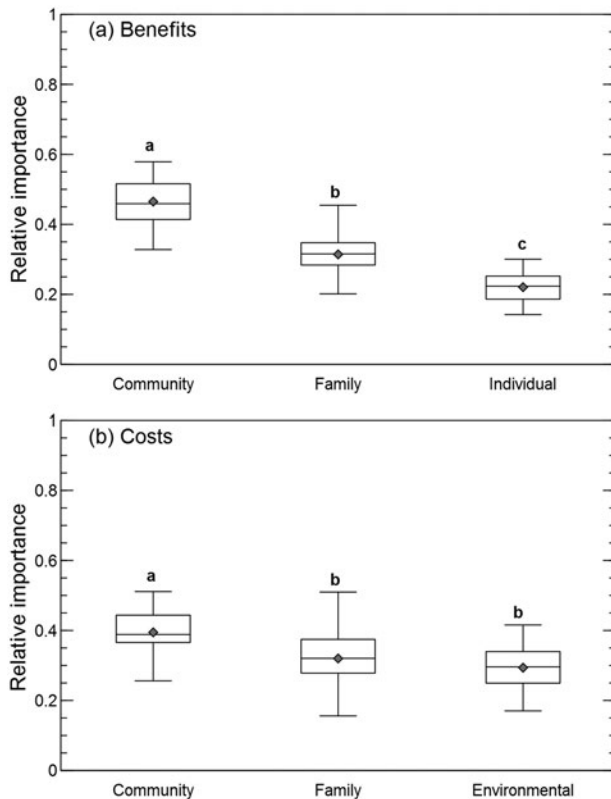


FIG. 3 Relative importance scores for clusters of (a) benefits and (b) costs of hunting as perceived by respondents from Mabuiag and St Paul's in Torres Strait, Australia (Fig. 1). The median is represented by a horizontal line, the box represents the inter-quartile range, and the whiskers represent the data range. Box plots that do not share the same letter are derived from distributions that are significantly different from each other at $P < 0.001$ (Wilcoxon test).

consequences for resource users (invisible losses; Turner et al., 2008) as well as decision makers, who risk angering people with whom they want to work (Voyer et al., 2014), which can lead to regulatory non-compliance, especially in remote areas such as Torres Strait.

The recognition and integration of cultural values of indigenous hunting into the environmental decision making and political discourse is politically difficult but could help foster co-management processes based on institutional fit, from local to global (Robards & Lovcraft, 2010). However, a more open dialogue about indigenous hunting risks making way for interest groups that disagree with indigenous perspectives (Robards & Lovcraft, 2010). Indigenous groups must prepare for possible conflicts with non-indigenous attitudes about wildlife conservation, sustainability and environmental management, while being ready to confront decisions made at the global or national level by global political environment groups ignorant of the cultural impacts of their decisions (Wenzel, 2009).

Banning the hunting of dugongs and green turtles in Torres Strait would also contravene the hunting rights

established by Australian Native Title and environmental laws, and the Torres Strait Treaty between Australia and Papua New Guinea (Havemann & Smith, 2007). Thus our results contribute to the debate by providing policy makers and interested stakeholder groups with a comprehensive understanding of the hunting values of Torres Strait Islanders, which could be used as a foundation for co-management processes for the management of dugong and turtle hunting. We have made an initial attempt at estimating a lower bound for the monetary value of these values in Supplementary Material 1.

Conclusion

The methodology we developed provides insights into types of benefits and costs associated with traditional hunting, and their relative importance from a community perspective. Our approach could be used to develop a typology of costs and benefits of related activities in other communities that hunt for terrestrial and marine wild meats. The technique also made it possible to make various kinds of benefits and costs more visible, and to use a quantitative assessment. Our findings reinforce the call of previous researchers (e.g. Gregory et al., 2007; Turner et al., 2008) to consider socio-cultural issues when devising natural resource management strategies. Various groups interested in the sustainable management of wildlife inevitably hold diverse images, values and worldviews. A comprehensive understanding of the values held by those primarily affected by a management decision can assist stakeholders to work together to achieve a common goal, and fulfil the requirements of co-management promoted by management agencies. The approach outlined here is relatively straightforward to implement in remote communities and cross-cultural situations, and could have wide application with indigenous communities.

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Author contributions

The study was conceived and conducted as a PhD project by AD under the supervision of NS and HM. FWL provided

cultural advice from the perspective of an Australian Indigenous researcher. MKK recast the research into an appropriate theoretical background for an *Oryx* special issue on cultural values in the context of her work with the other members of the research team on associated projects.

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Biographical sketches

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