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Factors influencing the sustainability of customary dugong hunting by a remote indigenous community

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SUMMARY

The sustainability of indigenous customary hunting and fishing in remote areas can be influenced by human factors operating at global as well as regional and local scales because of the hybrid nature and sectoral interactions of the local economic environment. The internationally significant population of dugongs (*Dugong dugon* or seacow) in Torres Strait between Australia and Papua New Guinea supports an important indigenous fishery. The economic, socio-cultural and environmental factors that influenced hunting activity in 1998 and 1999 by the members of the community of Mabuiag Island were investigated to inform the sustainable management of the fishery. The landed catch during the eight months March to October of 145 dugongs in 1998 and 170 dugongs in 1999 potentially provided the community with an average of 290 g of dugong meat per person per day. Fifty-seven per cent of adult males on the island participated in dugong hunting, but more than half the catch in each year was caught by only two hunters. The probability of at least one person from the community going dugong hunting in 1998 and 1999 was 0.59 ± 0.02 per day. This probability was influenced by local environmental factors, including the abundance of dugongs in the traditional hunting grounds (affected by wind speed, year, season and lunar day) and the size of the commercial crayfish catch (which is influenced by the global market price, as well as local conditions). Although dugong hunting remains a very important part of the islanders' contemporary culture and customary economy, the capacity to hunt dugongs is facilitated by the ease with which some hunters move between the state, commercial and customary sectors of their local economy. The complexities of the economic, social and cultural environments need to be considered in planning for the sustainable harvesting of threatened species by remote indigenous communities.

Keywords: dugong, hybrid economy, indigenous hunting, marine mammal, sustainability, threatened species

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INTRODUCTION

Increasing recognition that effective management of natural resources for sustainable use requires an understanding of both human and biological systems (Berkes & Folke 2000) has led to cross-disciplinary studies to improve understanding of the interactions between human behaviour and exploited resources. This approach has been used in commercial fisheries research (see Holland & Sutinen 1999; Hilborn & Walters 2001) and anthropological studies of subsistence practices such as hunting (see Winterhaulder & Lu 1997; Fitzgibbon 1998) and fishing (Aswani 1998; Bird *et al.* 2001).

For subsistence fisheries to be sustainable, it is important to understand which conditions cause people to conserve resources and which conditions favour overexploitation (Schmink *et al.* 1992). These influences are complex and may operate at global as well as regional and local scales, even in remote areas. This complexity results from the sectoral interactions between the components of the contemporary local economy.

The predominantly Melanesian peoples of the remote region of Torres Strait between Queensland (Australia) and the Western Province of Papua New Guinea (Beckett 1987) are renowned as some of the highest consumers of seafood in the world. They practise customary specialized marine subsistence involving hundreds of species, including fish, shellfish, sea birds, marine turtles and dugongs (sea cows).

About 200 people live on Mabuiag Island, one of the major dugong hunting islands in Torres Strait (Fig. 1). The community operates in a hybrid economy (*sensu* Altman 2001, 2005) with three sectors: (1) customary (subsistence), (2) market (commercial fishing) and (3) state, rather than the usual two (market and state). The average incomes of Mabuiag Islanders are very low relative to Australian norms (*c.* US$ 7000–9000 per annum; see McLennan & Madden 1999; Arthur 2003), but this value ignores the contribution of the customary sector, which is not monetized and therefore not quantified or recognized in mainstream terms (Altman 2005).

The fishery for the crayfish or tropical rock lobster (*Panulirus ornatus*) is the most important commercial activity for the men living at Mabuiag. Crayfishing occurs all year round with peak catches during March–August. Most fishing activity occurs during neap tides when the currents are slower

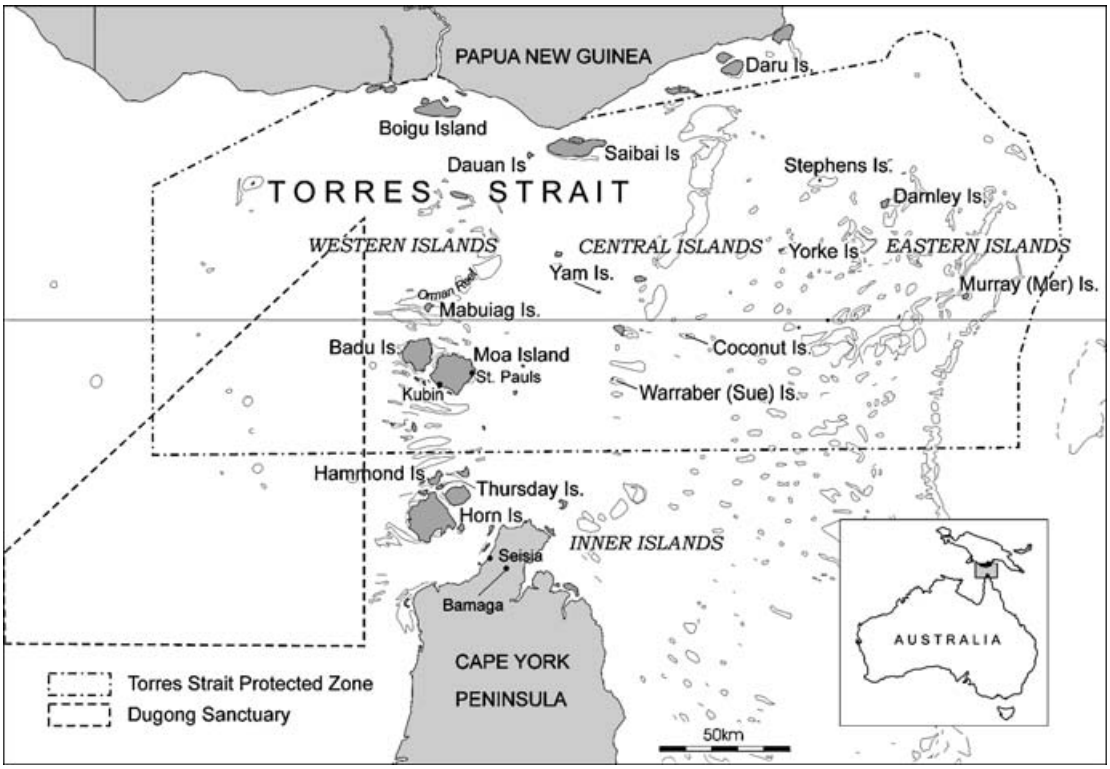

Figure 1 The Torres Strait region showing the location of Mabuiag Island and other communities in Torres Strait, the Torres Strait Protected Zone (established in 1984 by the Torres Strait Treaty between Australia and Papua New Guinea) and the dugong sanctuary where hunting is technically banned, even though this ban has not been enforced.

and the water is clearer (Pitcher *et al.* 1997). Fishing is conducted from small outboard-powered aluminium dinghies with limited range (Arthur 1991; Altman *et al.* 1994). The products of this fishery are largely oriented to export markets and the price structure fluctuates markedly over time (Altman *et al.* 1994).

The dominant component of the state economy is the Community Development Employment Program (CDEP), a publicly-funded work-for-welfare programme aimed at improving the employment and income status of indigenous Australians. Indigenous community associations, in this case the Mabuiag Island Community Council, receive a non-discretionary grant similar to the collective unemployment payment and pension entitlements of all local participants, plus the option of discretionary payments (Altman *et al.* 2005). Scheme participants generally work part-time for wages on community-orientated jobs (Arthur 1991). CDEP participants can combine this work with other activities, such as fishing for crayfish and/or customary hunting and fishing as they see fit.

The customary sector of communities such as Mabuiag should not be confused with the pre-European contact hunter-gatherer economy (Altman 2004). It uses modern, as well as traditional technology and knowledge. Along with fishing for local consumption, dugong hunting is a major component of the customary economy. The right to hunt the dugong (Marsh 1996; Marsh *et al.* 1997; Kwan *et al.* 2001; Kwan 2002, 2005) is protected by the Torres Strait Treaty between Australia and Papua New Guinea. Management initiatives such as the dugong sanctuary in Western Torres Strait (Fig. 1) have not been enforced.

Two different modelling techniques suggest that current dugong harvest levels are unsustainable (Heinsohn *et al.* 2004; Marsh *et al.* 2004) providing pressure for increased regulation of the fishery to conserve the dugong, which is listed as vulnerable to extinction by the IUCN (Hilton-Taylor 2000) and under Queensland legislation. This study aimed to contribute to the sustainable management of the dugong fishery in Torres Strait by proving empirical information to guide Islanders and fishery managers in their response to current concerns. To achieve this aim, we described and quantified the major influences on the hunting pattern, hunting effort and harvest levels of dugongs at Mabuiag Island, a major dugong hunting community. The qualitative literature on dugong hunting in Torres Strait (Nietschmann & Nietschmann 1981; Eley 1988; Nietschmann 1984, 1989; Johannes & MacFarlane 1991) suggests that hunting activity varies with season and tidal regime. We investigated the relative importance of these and other environmental and social factors that might influence the harvest, through a census of the harvest at Mabuiag over almost two years.

METHODS

Collection of data

We attempted to obtain data from all hunts conducted by Islanders living at Mabuiag during the study period. Accordingly, Donna Kwan lived on Mabuiag Island for almost two years and attended virtually all landings of dugongs between November 1997 and October 1999 inclusive, to interview hunters and to collect specimens for biological examination. Dugongs are butchered at specific landing sites belonging to individual families, making this approach logistically feasible.

Informal semi-structured interviews (Kuale 1996) were conducted with the hunters at the landing sites during the butchering of each dugong. Our interview questions were informed by previous studies (Nietschmann & Nietschmann 1981; Eley 1988; Nietschmann 1984, 1989; Johannes & MacFarlane 1991) and our cumulative personal experience of dugong hunting practices which dates from the early 1970s. When it was not possible or culturally appropriate to interview a member of the hunting party at the butchering event (for example when a dugong was caught for a funeral feast), the hunter, a member of his crew or a knowledgeable community member was interviewed as soon as possible after the butchering, usually the next day.

A member of each hunting party was asked to provide information on: the timing and duration of the hunting trip; the hunting technology used; the location of hunting; the composition of the hunting party; the number and sex of dugongs caught; and how the catch was to be used or distributed. Details of the sea state at the time of the hunt were also recorded. Information on the commercial cray fish landings at Mabuiag were obtained from records of landings at the local seafood factory. Data on wind velocity and tidal cycle were obtained from relevant meteorological records and tide tables.

Statistical analysis

The data obtained from the interviews with dugong hunters on 755 days and especially during the eight months from March to October for both 1998 and 1999 (598 days), were used to explore the relationships between the major determinants of daily dugong hunting by hunters based at Mabuiag Island during 1997–1999. The relationships between the following responses were examined in terms of the independent variables and covariates listed in Table 1: (1) the daily probability that hunting occurred; (2) the total number of dugongs caught per trip, given that hunting occurred; and (3) catch per hunting hour.

After exploratory data analysis to determine the most appropriate model structure, the data were modelled using generalized linear models (GLMs) and generalized additive models (GAMs). GLMs allow the specification of the link function, which determines the relationship between the mean and the linear predictor, and the variance function, which defines the relationship between the mean and the variance. The link function used for the binary response 'daily probability of hunting occurring' was the logit (i.e. log $(p/(1-p))$, and the variance function was the binomial distribution (i.e. logistic regression model). The link function used for the count response 'total number of individuals caught per trip' and the rate response 'catch per hunting hour' was the log (i.e. log (μ)), and the variance function was the Poisson distribution (i.e. Poisson regression).

The exploratory data analysis revealed that the relationships with some explanatory variables were non-linear. Accordingly, GAMs were used to examine non-linear relationships between the continuous independent variables and each response by including smoothing terms in the models. Model selection was based on Akaike's Information Criterion (AIC), and the model selected for inference was the one that minimized this Criterion. This method selects a 'best approximating' model from a candidate set of considered models.

All means are presented ± 1 standard error unless otherwise stated, and *df* represents degrees of freedom for the various tests. The sample sizes on which the various analyses are based are provided in the results.

Table 1 Summary of the results of the generalized additive models (GAMs) used to examine the main variable affecting: (1) the probability of hunting for dugongs by hunters, (2) the mean total dugong catch per trip based in Mabuiag in 1998–1999 (the final models minimize the AIC). Covariates: month (8 levels, May–October), year (two levels, 1998 and 1999), month in year (21 levels January–December 1998 and January, March–October 1999); season (3 levels, south-east, north-west, doldrums and variable; see Fig. 3*a*); minimum tidal height (4 levels); maximum tidal height (4 levels); and mean tide difference (5 levels). Continuous independent variables: lunar day (day 1 = new moon, etc.); wind direction; tide difference between maximum and minimum tidal height; and log daily crayfish catch in kg landed at Mabuiag Island. *Smooth terms in models.

Model description	*AIC*	*df*
(1) Probability of hunting for dugongs		
Full model		
Month + year + (month × year) + season + (season × year) + min. tide + max. tide + mean tide difference + lunar day* + wind velocity* + mean tide difference* + log crayfish catch*	709.31	56
Final model		
Month + year + (month × year) + season + lunar day* + wind velocity* + log crayfish catch*	685.6	22
(2) Mean total dugong catch per trip given hunting occurred		
Full model		
Month + year + (month × year) + season + (season × year) + min. tide + max. tide + mean tide difference + lunar day* + wind velocity* + tide difference* + log crayfish catch*	206.5	56
Final model		
Year + season	157.5	5

RESULTS

Dugong catch and hunting techniques

One hundred and forty-five dugongs were caught over eight months (March–October) in 1998 and 170 dugongs during March–October 1999. The landed catch potentially provided the community of Mabuiag with an average of 290 g of dugong meat per person per day in both 1998 and 1999. (This estimate assumes a total dugong catch of 161 for all months in 1998 and 170 in 1999, Neitschmann's 1984 calculation of 115 kg of useable meat per dugong and the census estimate of the Mabuiag human population in 1996 [$n = 179$]). The meat from most dugongs (92% in 1998 and 91% in 1999) was reportedly used for home consumption. Most of the remainder was used for funeral feasts. Our interviewees reported that only 1–2% of dugong meat landed at Mabuiag was exported to relatives or friends outside Mabuiag Island.

As required by one of the few regulations applying to indigenous hunting in Torres Strait, dugongs were generally caught using a *wap* (harpoon with a detachable head). The hunting platforms were the motor-powered dinghies that were also used for commercial crayfishing and inter-island transport.

During 1998–1999, 29 men based at Mabuiag Island acted as hunters (harpooners), 20 in 1998 and 22 in 1999. Twenty hunters (69%) were from Mabuiag Island, representing 57% of adult males on the island (35 males > 25 years old, Australian Bureau of Statistics 1997).

Two hunters based at Mabuiag Island caught between 56% ($n = 88/156$) and 59% ($n = 85/144$) of the catch for which the identity of the hunter was known in 1998 and 1999, respectively. Only three other hunters in 1998 and two others in 1999 caught more than 10 dugongs each, with hunting effort ranging from 0.92 to 1.25 dugongs per trip. The remaining hunters caught between one and seven dugongs, with the range of their hunting catch per unit effort (CPUE) being 0–2.33 dugongs trip^{-1} in 1998 and 1999. The hunting CPUE of the most active hunters was lower than that of some less avid hunters because the latter hunted opportunistically, waiting until the more experienced hunters returned with news of dugongs close to the community. The less active hunters were able to maximize their returns in this manner because of the flexibility of their employment (Table 2).

Table 2 Three examples of the employment options in Mabuiag Island illustrate the flexible way in which workers can move between the commercial, state and customary components of the local economy to optimize their returns of dugongs and crayfish during the lunar cycle. Yes = usual activity; ? = potential activity if conditions are right; CDEP = Community Development Employment Programme.

Phase of the moon	*Commercial: crayfishing*	*State: CDEP*	*Customary: hunting*
CDEP worker			
First quarter		Yes	
Full moon			?
Last quarter		Yes	
New moon			?
CDEP worker/casual crayfisher			
First quarter	Yes		?
Full moon		Yes	
Last quarter	Yes		?
New moon		Yes	
Commercial crayfisher			
First quarter	Yes		?
Full moon			Yes
Last quarter	Yes		?
New moon			Yes

Hunting locations

Knowledge of the spatial distribution and abundance of dugongs was an important factor in the choice of specific hunting locations even though all hunting was carried out on the traditional maritime estate of the Mabuiag community and within 35 km of that community. Islanders actively sought information on dugong locations from people travelling by aircraft or boat around Torres Strait.

Probability of dugong hunting

Based on 553 days of data, the mean probability of at least one person from the community going dugong hunting in 1998 and 1999 was 0.59 ± 0.02 per day. The most parsimonious model indicated that the probability of hunting was influenced by month, year, the interaction between month and year, season, lunar day, wind velocity and the size of the catch of crayfish (Table 1).

Hunting was most likely on spring tides immediately after new moon (and to a lesser extent at full moon; Fig. 2*a*). There was considerable temporal variability in the hunting patterns in 1998–1999 (Fig. 3*a*). Although the probability of hunting was higher in 1999 than in 1998, the mean total catch per trip during March to October was higher in 1998 (1.1 ± 0.06 dugongs) than in 1999 (0.93 ± 0.06 dugongs). The higher hunting effort in 1999 is also reflected in the higher total catch during March–October in 1999 ($n = 170$) compared with 1998 ($n = 145$). This variability was also apparent in hunting activity in terms of number of hunters, total trips and total catch in various months in 1998 and 1999. For example, hunting activity was concentrated in the second half of the year in 1998, but in the first half of the year in 1999 (Fig. 3*a*). In 1998, most hunting trips were undertaken during the mornings or afternoons (85.2%, $n = 75/88$). However in 1999, only 36% of trips were undertaken at these times.

The probability of hunting was greatest during the south-east season (May–October) (Fig. 3*b*). The hunters explained

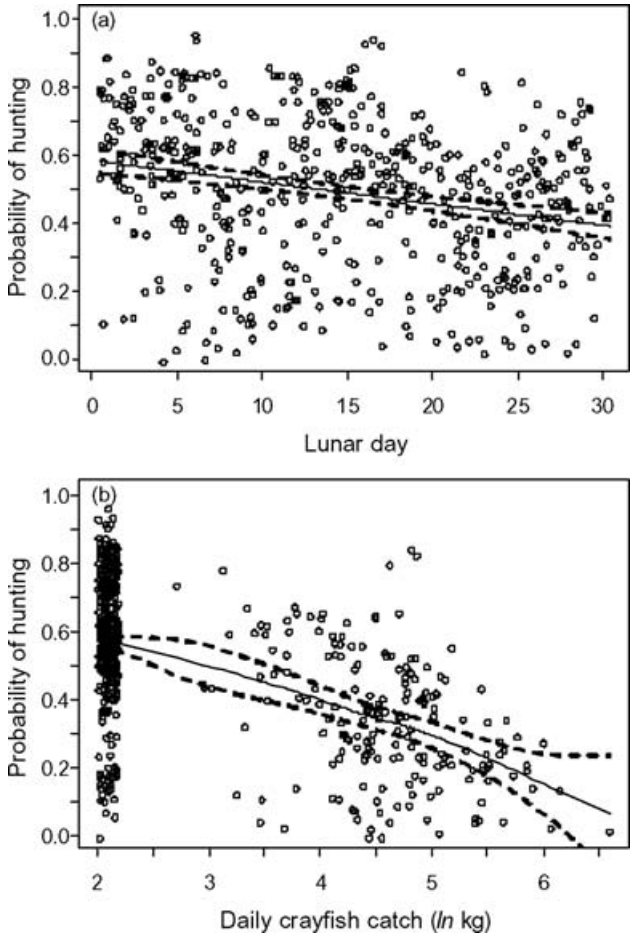

Figure 2 Relationships between the probability of dugong hunting by hunters based at Mabuiag Island in 1998–1999 evident from the generalized additive models and (*a*) lunar day and (*b*) daily crayfish catch. The solid line represents a smoothing spline, dashed lines represent approximate 95% confidence intervals.

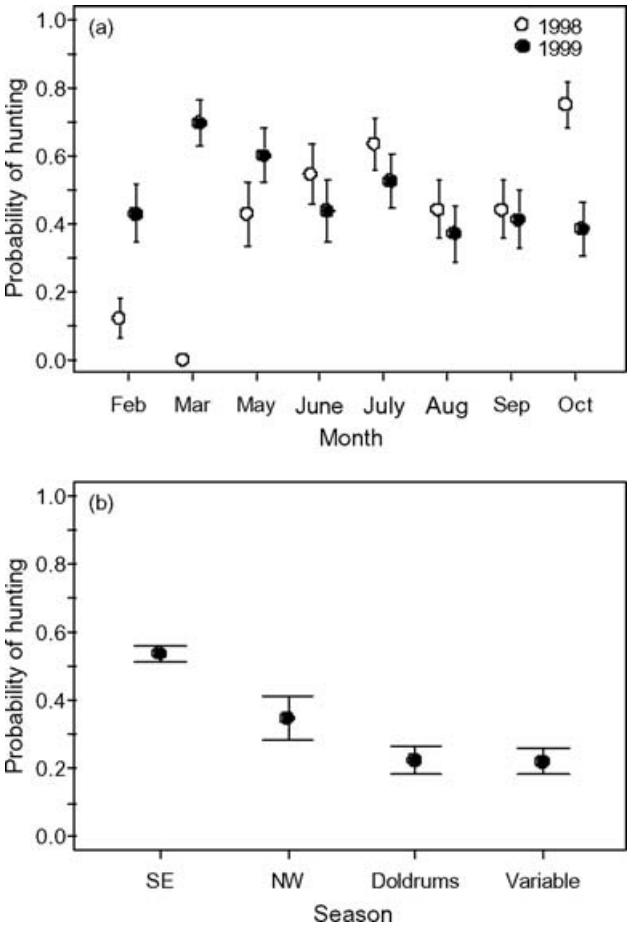

Figure 3 The relative probability (± SE) of dugong hunting in 1998 and 1999 from Mabuiag Island (*a*) during March–October each year and (*b*) by season for both years combined. SE = south-east season (May–October); NW = north-west season (November–April); doldrums = October–December; variable = at any time.

that the noise from the windy conditions on waves masked the noise of dinghies and their engines.

In 1999, over 50% of hunting trips were at night compared with only 7% in 1998. The hunters attributed these differences to patterns of local abundance of dugongs, however the catch data suggest that the influences were more complex.

Interactions between customary dugong hunting and the commercial crayfish fishery

There was a negative relationship between the probability of dugong hunting and crayfish landings at Mabuiag Island (Fig. 2*b*). In 1998, the abundance of crayfish, combined with favourable diving conditions, resulted in very high (9978 kg) catches of crayfish between March and June. During the same period in 1999, only 3171 kg of crayfish were landed at Mabuiag. The price of crayfish also varied over the two years of the study yielding US$ 25 kg^{-1} for crayfish tails in 1998 and US$ 20 kg^{-1} in 1999.

Factors affecting dugong hunting effort

Based on dugong catches during 259 days, the mean dugong catch per trip was 1.01 ± 0.05. The most parsimonious model consisted of the main effects of year and season (Table 1, AIC = 157.55, $df = 5$). The mean dugong catch per trip was significantly higher in 1998 than in 1999, and higher during the doldrums (1.57 ± 0.15) than in the south-east (0.9 ± 0.05) and variable (1 ± 0.08) seasons.

Based on the 197 days for which the necessary information was available, the factors influencing dugong catch per hunting hour were investigated. Model selection supported the null model over any combination of the covariates, i.e. there were no significant systematic differences detected using the AIC criterion between months, seasons, years or any continuous variables in the rate of dugong catch per hunting hour.

DISCUSSION

The customary fishery for dugongs is an important source of fresh meat and has great cultural significance for Mabuiag

Islanders. It is integral to their customary way of life or *Ailan Kastom* (Kwan 2005). The social and cultural importance of the dugong makes its management particularly challenging because the decision to hunt depends on a complex interaction of local and global environmental, social, cultural and economic factors. In addition, the capacity for an individual to take advantage of good conditions is facilitated by his ease of movement between the customary, state and commercial sectors of the economy (Table 2), the use of infrastructure (vessels imported from outside the region) common to commercial crayfishing and customary hunting, and the fact that the optimum times for cray fishing and dugong hunting are in opposite phases of the lunar cycle (Table 2).

Socioeconomic factors are important in several aspects of the dugong hunting effort of the Mabuiag Island community. The decision to hunt is dependent on factors such as disposable cash to purchase fuel or the opportunity to earn additional income from other fishing activities such as diving for crayfish (Pitcher *et al.* 1997). However, the opportunity to earn such income was limited in 1999 because of very low crayfish numbers in the Torres Strait region and low prices for the product. As most of the crayfish are exported, the price is determined by global markets and fluctuations in currency rates.

The negative correlation between dugong and crayfish catches (Fig. 2*b*) is a significant challenge for dugong management in Torres Strait. Periods of low crayfish abundance apparently coincide with episodes of seagrass dieback, which also reduce the fecundity of dugongs (Boyd *et al.* 1999; Kwan 2002). Conversely, in times of crayfish abundance and/or high prices, the Islanders use the resultant income to buy better or additional dinghies that can also be used for dugong hunting.

According to hunters, the high number of dugongs landed ($n = 101$) at Mabuiag during the period March–June 1999 was the result of the favourable weather conditions for hunting and the need to 'feed their families'. The reduction in their income from the commercial component of the economy (crayfishing) forced them to rely more on the state component of the economy (CDEP) and the customary component (hunting to supply their households with dugong meat) because of the limited disposable income available to purchase store goods.

Hunters also reported that the high levels of crayfishing activity in the Mabuiag and Badu areas drive dugongs away from reefs. Increased participation of Islanders diving for crayfish and the presence of freezer mother boats anchored at Orman Reef during periods of crayfish abundance were reputed to cause dugongs to avoid nearby feeding areas during the day and to restrict their feeding to the hours of darkness or when boats have gone. This situation encouraged reef hunting at night despite the associated dangers.

Most families on Mabuiag Island supplement their food supply from the customary economy by fishing or hunting. Fresh dugong meat is a favoured source of protein. Thus despite their cultural importance at weddings and funerals (see Fitzpatrick-Nietschmann 1980), dugongs are caught for subsistence as well as for ceremonies by members of the Mabuiag community. Successful hunting also continues to provide social capital because successful hunters have high social status in their community.

The principles of reciprocity and sharing of traditional resources such as dugong meat still underpin the customary economy (Nietschmann 1984, 1989; Kwan 2002). As monetary exchange for dugongs is illegal under Queensland and Australian laws (see Marsh *et al.* 2002), hunters are required to outlay the expensive costs of hunting, but are expected to share their catch freely with their community including their relatives living in cities on the mainland. Only about 15.5% of Torres Strait Islanders now live in Torres Strait (Arthur 2003) and meat is exported from communities via commuter aircraft to the diaspora living on the mainland. Despite our evidence that only 1–2% of the dugong meat landed is exported, we consider that it is likely that the very important obligations of Islanders to their families, including this diaspora, explains at least part of the extraordinarily high dugong catch (which averaged 290 g per Mabuiag resident per day; see also Marsh *et al.* 1997). The tension between a family's social obligations to their local community and to their scattered family may substantially increase hunting effort because individual hunters now store dugong meat in freezers.

According to Nietschmann (1989), hunting pressure in Torres Strait during the late 1970s was correlated with: (1) the size of resident island communities, (2) the food needs and social obligations within these communities, (3) the environmental conditions affecting dugong distribution and abundance, and (4) the environmental conditions influencing hunting success. Since then, socioeconomic factors, such as the competing opportunities offered by the commercial sector of the economy and the disposable income required to pay for dinghies, motors and fuel, have increased in importance. We believe that all these factors contribute to the high interannual variability in catch records reported by Marsh *et al.* (2004). Other factors contributing to this variability include inconsistency in catch monitoring methods, and the movement of large numbers of dugongs into and out of the region in response to seagrass dieback and recovery (Marsh *et al.* 1997, 2002, 2004; Marsh 1998). Two different population modelling techniques suggest that the indigenous harvest of dugongs in Torres Strait is unsustainable (Heinsohn *et al.* 2004; Marsh *et al.* 2004) but overharvest is difficult to prove empirically with the data available, and with so many other confounding influences on the population, especially the tendency of dugongs to undertake large-scale movements for reasons that are not well understood (Marsh *et al.* 2004).

The Islanders attribute some of the variability in hunting success to their degree of observance of their indigenous rules and practices. The 1970s and early 1980s were periods of overharvesting in central Torres Strait, resulting in the expansion and collapse of the artisanal dugong fishery in Daru (Hudson 1986). Boigu Islanders in Western Torres Strait attributed their low hunting success at this time (see

Raven 1990; Johannes & MacFarlane 1991) to their disregard for practices such as sharing dugong meat and returning dugong skulls to the sea, as well as to unfavourable weather conditions, pollution and disturbance from boat motors. The Boigu people resolved to follow the cultural rules more closely and to wait until conditions improved (Raven 1990), believing that, although populations of dugongs vary at local scales, they always return. The aerial surveys provide indirect evidence for extensive dugong movements (Marsh *et al.* 2004) providing empirical support for some of the Islanders' beliefs.

CONCLUSIONS

Understanding the impacts of human hunting or fishing behaviour on prey populations is basic to the development of sustainable harvest strategies. Most approaches to understanding human behaviour and its impact on populations of prey species are based on assumptions that it is imperative for the hunter to maximize his economic returns (see Aswani 1998; Hilborn & Walters 2001) and/or nutritional status, or to minimize the time needed to acquire the nutritional requirements necessary for fitness (see Winterhaulder & Lu 1997; Fitzgibbon 1998; Bird *et al.* 2001).

Although dugong hunting remains an important part of the Torres Strait Islanders' contemporary culture, harvesting decisions are increasingly informed by other factors, in particular the commercial sector of the economy. As mentioned above, modelling suggests that the current harvest is not sustainable (Heinsohn *et al.* 2004; Marsh *et al.* 2004). Ensuring the sustainability of this fishery and the cray fishery are now a major imperative for both the Islanders and the Australian government.

In 2003, the Australian Minister of Environment instructed that the sustainability of the dugong fishery be addressed with high priority; management agency staff are working with traditional owners to develop a mutually-acceptable framework for sustainable dugong hunting. It will be important to involve the master hunters who take most of the dugong catch in such negotiations. In addition, government funding has recently been allocated for community-based management and catch monitoring initiatives. Thus the state sector of the economy is set to assist the customary sector to become ecologically sustainable. The Torres Strait Protected Zone Joint Authority is also introducing measures to improve the sustainability of the cray fishery. It will be important to coordinate these management initiatives given that dugong and crayfish landings are highly interdependent (Fig. 2*b*).

The relative importance of the three sectors of the hybrid economy illustrated here is peculiar to indigenous communities in developed countries because the state welfare sector is typically much weaker in developing countries. Nonetheless, the harvest rates of threatened species hunted by remote indigenous communities in other parts of the world are also likely to be affected by a mix of local, regional and global economic, socio-cultural and environmental influences. To be effective, management strategies will need to identify, understand and acknowledge the relevant influences on harvest rates on a case–by-case basis.

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