The economic importance of freshwater crayfish harvesting in Madagascar and the potential of community-based conservation to improve management

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Abstract Madagascar's endemic freshwater crayfish (Parastacidae: *Astacoides*) are harvested by local people for both subsistence use and small-scale trade. There has been concern that populations, and even species, are threatened by overexploitation but little is known about the harvest or its economic importance. We studied crayfish exploitation in eastern Madagascar over 3 years. The existence of local taboos (*fady*) preventing commercial crayfish harvesting, as well as access to markets and forest, influenced involvement in the harvest. All four crayfish species found in the region were harvested, but *A. granulimanus* provided the majority of the catch. In one harvesting village more than 50% of the 47 households were directly involved in the harvest, which contributed USD 2,382 to the village economy in 2003/2004, an important sum in the context of local incomes. Subsistence use was widespread, particularly by children to whom it may provide an important protein source. Community-based conservation (through transfer of harvesting rights and responsibilities for forest management to local communities) is central to a new conservation paradigm in Madagascar. This recognizes communities' long term interest in their natural resources and offers an ideal opportunity for those concerned with the sustainability of the harvest to implement management tools (such as avoiding reproductive females, size limits and no-take zones). We discuss each tool with respect to biological implications and practical constraints. We note that community-based approaches may not be sufficient to conserve rarer species, which make up a small proportion of the value of the harvest.

Keywords Community-based natural resource management, crayfish, economic value, harvesting, Madagascar, non-timber forest product, sustainable exploitation, taboo.

Introduction

In the last 10–20 years the importance of non-timber forest products in sustaining rural livelihoods in many developing countries has been increasingly recognized (Pimentel *et al*., 1997; Byron & Arnold, 1999). Forest products are often not the primary source of income for the entire community but may be particularly important to poorer households and in buffering incomes during difficult times (Pattanayak & Sills, 2001). Despite encouraging early estimates (Peters *et al*., 1989), revenues from forest products alone seldom outweigh the value from timber or conversion to agriculture (Godoy *et al*., 2000), both because of the dispersed nature of forest products, and poorly developed markets (Arnold & Perez, 2001). However, where local communities bear opportunity costs as a result of forest protection (Ferraro, 2002; Balmford & Whitten, 2003), permitting the sustainable harvest of forest products by communities can help reduce these costs. Many rural people in Madagascar rely, at least partly, on harvesting forest products (Shyamsundar & Kramer, 1997; Kremen *et al*., 1998; Ferraro, 2002). As conservation decision makers in Madagascar look beyond conservation within the limits of traditional protected areas, potential revenues from sustainable harvesting of forest products, such as freshwater crayfish, are seen as important in persuading villagers that sustainable forest use is preferable to slash-and-burn agriculture (Erdmann, 2003).

Madagascar's freshwater crayfish belong to an endemic genus (Parastacidae: *Astacoides*) currently containing six species (Hobbs, 1987). Crayfish have been

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Table 1 Scientific and vernacular names recorded in this study for the *Astacoides* crayfish species mentioned in the text.

Scientific name	Vernacular names
A. betsileoensis	*Orantsatria, Oramena*
A. caldwelli	*Oramena*
A. crosnieri	*Orampotaka, Orambory, Oramalemy, Oranjena*
A. granulimanus	*Orambato, Oramaintso, Oran'ala, Peopeoka*

harvested at least since early colonial times (Sibree, 1915) and remain important in both subsistence use and trade. Regulations from Madagascar's Département des Eaux et Forêts state that only crayfish larger than 100 mm total length should be harvested but this is not widely enforced. There is little available information on the ecology or conservation status of the crayfish but there is concern that populations, and even species, may be threatened by overharvesting. Crandall (2003) recommended that all six described species should be listed as threatened under the IUCN Red List criteria, and currently *A. crosnieri* and *A. petiti* are categorized as Endangered and *A. betsileoensis*, *A. caldwelli*, *A. granulimanus* and *A. madagascariensis* as Data Deficient (IUCN, 2004). Although nothing is known about the sustainability of the harvest in most areas or for most species, recent research (Jones *et al*., 2005) has shown that commercial exploitation of *A. granulimanus* (for vernacular names see Table 1) can be sustainable. Here we investigate the crayfish harvest in and around a national park in eastern Madagascar, looking at its economic importance, who is involved, the species targeted and methods used. We discuss the potential of community-based conservation, through the transfer of forest management to local people, to promote improved management practices.

Study area and human context

This research was carried out in villages at the periphery of Ranomafana National Park, Fianarantsoa Province (Fig. 1). The natural vegetation is humid evergreen forest at 500–1,500 m altitude intersected by numerous streams and rivers in which four of the six described species of *Astacoides* crayfish are found (Jones, 2004). The human population of the area are mostly poor and rely on a mixture of small-scale agriculture and harvesting forest products for subsistence use or sale (Ferraro, 2002). During the so-called hungry season, when rice stocks run out, more families are pushed below the poverty line (Dostie *et al*., 2002). The majority of people living around Ranomafana self-identify with one of the ethnic divisions

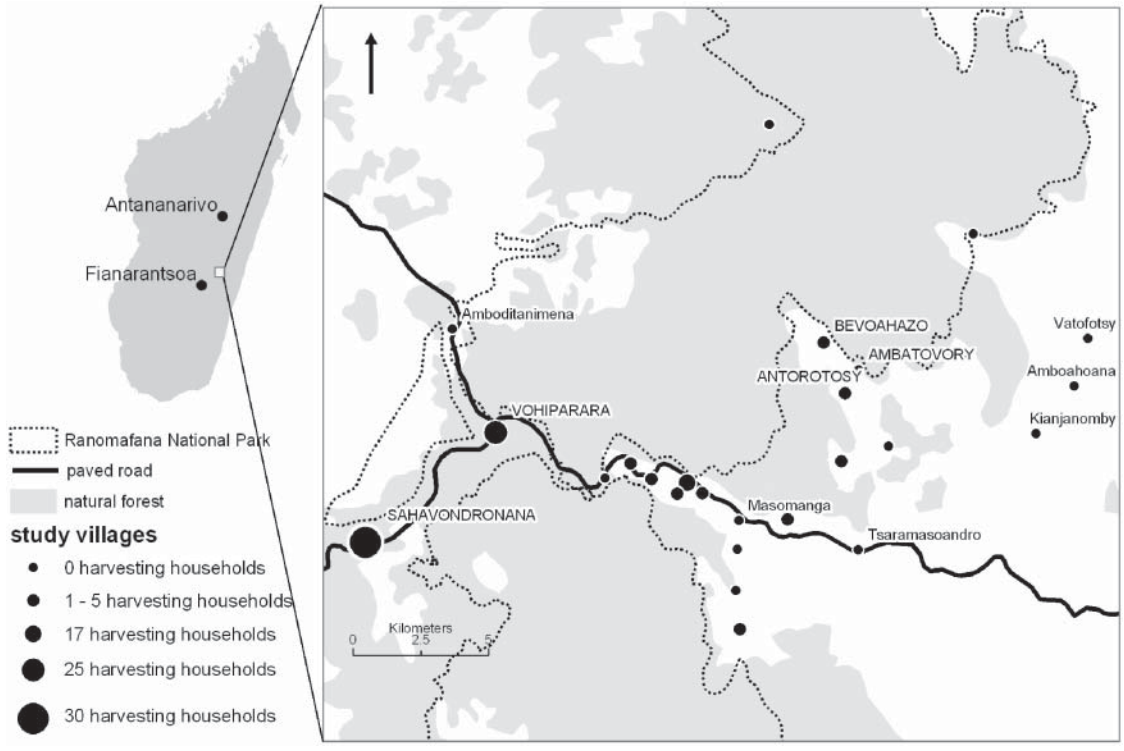

Fig. 1 The location of Ranomafana National Park within Madagascar and the 27 villages visited during this study. The size of the spot reflects the approximate number of commercial crayfish harvesting households in each village. Only villages mentioned by name in the text are labelled and villages where detailed work was carried out are labelled in uppercase.

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of Betsileo and Tanala. These classifications refer more to flexible cultural and economically adapted groups than to ethnic tribes (Harper, 2002). The Malagasy are well known for their extensive system of taboos (*fady*), many of which have resource management implications (e.g. O'Brien *et al*., 2003).

Methods

Field work was carried out between February 2001 and May 2004. Interviews were carried out in Malagasy and both non-Malagasy authors were sufficiently fluent in the language to be fully involved. We used three methods with increasing level of detail to investigate the crayfish harvest in the area. We had opportunities to confirm our findings and expand on interview results in numerous informal discussions over the 2 years that we (JPGJ, FBA and NJH) lived in two of the villages (Bevoahazo and Vohiparara). Statistical analysis was carried out using *Genstat* 4.2.

Village interviews

We carried out focus group interviews in 27 villages (Fig. 1) with the aim of obtaining a broad understanding of the importance of crayfish harvesting across the area. The villages visited ranged in size from 10 to 60 households, and included communities with varying access to markets and forested land. We conducted interviews with self-selected groups including village elders and traditional leaders, and emphasized informal discussion rather than a strict question-answer format (Mitchell & Slim, 1991). We asked informants to list the top economic activities of the village in order of importance and to estimate the number of households that harvested crayfish commercially. Open-ended discussions were used to identify reasons why villages relied on crayfish harvesting to different extents.

Household interviews (Rapid Rural Appraisal)

In two villages where commercial collection of forest products was important (Sahavondronana and Vohiparara) and three villages that did little commercial harvesting (Ambatovory, Antorotosy and Bevoahazo), we carried out more detailed interviews using tools developed for Rapid Rural Appraisal (Chambers, 1990). During preliminary interviews with community leaders we mapped the households in the village, recording the gender of the head of household, and classified these according to the main economic activities of the householders (forest product harvester including or not including crayfish, farmer, labourer or salaried worker). We used these maps as a sampling frame to select households for interview, focusing our effort on harvesting households. In total we interviewed 85 households (23–67% of the households in each village). We used semi-structured interviews and calendars describing the agricultural year to look at the importance of commercial or subsistence crayfish harvesting to the household economy and to discuss crayfish management practices.

Household interviews (daily)

In the commercial harvesting village of Vohiparara we carried out an intensive interview schedule with nearly 90% (22/25) of the crayfish harvesting households. Between January 2003 and January 2004 we interviewed the head of household for 8 consecutive days every 3 weeks. Informants were asked about the main activities of the day. If they had been crayfish harvesting, crayfish were brought to the interview and the species and carapace length (CL) of each crayfish was recorded. The following day we asked whether they had been sold, to whom and for how much. To investigate factors influencing the price of crayfish we used the price for a batch of crayfish as the response variable in a General Linear Model (GLM) with normal error structure. Explanatory factors tested were the species of crayfish, the number of individuals in the batch, the total mass of the batch, state in which the batch was sold (cooked or raw), the season in which it was sold (hot or cold) and the buyer (villager or passer-by).

We estimated the total earnings (E) per household from crayfish harvesting using $E = \sum_{i=1}^{n}\left[\left(\frac{H_i}{I_i}\right) \pm (\mu_{Ei} + \mu_{Si})\right]365$, where H_i is the number of days a harvester spent crayfish harvesting during the I_i interview days, μ_{Ei} is the mean price obtained for a batch of crayfish sold by harvester i and μ_{Si} the subsistence value obtained from a day's harvesting and n is the number of household members.

Crayfish eaten by the household were assigned a subsistence value equivalent to the price of raw crayfish sold in the village. Three harvesting households did not take part in the daily interviews but based on focus group interviews we assumed they earned equivalent to the mean of the lower earning 50% of harvesters. To estimate the value of crayfish to stall holders in Vohiparara we estimated the mean difference in the price of a batch of crayfish of mean size if it was sold raw to another villager or was sold cooked and direct to a passer-by. We assumed that stallholders obtain a similar mark-up and that they always bought crayfish raw from the harvesters, sold them cooked to consumers, and sold 100% of the crayfish they bought. The exchange rate fluctuated over the study period; we used a mean exchange rate for the year 2003/2004 of MGF 5,830 to USD 1.

Results

The importance of crayfish harvesting

Of the 27 villages visited in the Ranomafana area, one or more households were involved in commercial harvesting in nearly 50% of villages (Fig. 1). However, only three villages (Ambalavao, Sahavondronana and Vohiparara) reported that crayfish harvesting was very important to the village economy. In these villages, which were all on the road with good market access and lacked widespread *fady* preventing commercial crayfish harvesting, 50–60% of households harvested crayfish commercially. Harvesting households varied in how reliant they were on crayfish; for some it was their only income but for others crayfish were only seasonally important with most harvesting occurring from September to December; the period of food scarcity.

A GLM looking at the factors affecting the value of a batch of crayfish explained 59% of the variance (Table 2). Both the number of crayfish in a batch and its total mass positively affected price, suggesting that larger crayfish were of higher value. Cooked crayfish had a higher sale value than raw and the price for a batch of crayfish was higher in the cold than in the hot season. The price of crayfish sold to passers-by was higher than that to other villagers. The species of crayfish had no significant effect on its price.

The mean annual earnings per harvesting household from crayfish harvesting in Vohiparara was USD 83. There was a lot of variation and the most heavily harvesting household earned USD 267 and the least USD 23; this variation was mostly due to the number of days per year spent harvesting (linear regression of annual earnings and annual number of days spent harvesting; $F = 93.2$, $P < 0.001$, $R^2 = 0.83$). Extrapolating for all 25 harvesting households in Vohiparara, the estimated gross annual revenue from crayfish to harvesters from Vohiparara for the year 2003/2004 was USD 2,074. If earnings by stall holders are included, this increased to USD 2,382. A higher proportion of female-headed (10/13) than male-headed (16/34) households relied on harvesting, but this trend was not significant ($\chi^2 = 3.39$, $P = 0.071$). Respondents said crayfish harvesting was an unpopular activity as the forest is cold and full of leeches but the lack of opportunities for waged labour and the high investment costs and deferred benefits of agriculture were the main reasons given for harvesting crayfish.

In villages where commercial crayfish harvesting was not important, two main reasons were given. In many of these villages, particularly those of the Tanala but also in the Betsileo village of Amboditanimena, there were strong traditional *fady* (taboo) preventing commercial crayfish harvesting. Other villages (Amboahoanana, Kianjomby, Masomanga, Tsaramasoandro and Vatofotsy) reported that they are too far from the forest to make crayfish harvesting a viable economic activity. Two of these communities (Amboahoanana and Vatofotsy) reported that more crayfish harvesting occurred in the past before the conversion of forest resulted in the local extirpation of crayfish. Elders in these villages expressed regret at the loss of crayfish, saying they were valued both as a food source and for the recreational opportunities provided by crayfish harvesting. All villages with access to the forest reported harvesting for subsistence use; 93% percent of households interviewed in three villages where commercial exploitation was *fady* to most households reported subsistence crayfish harvesting. Most reported harvesting as an occasional activity (10–15 times a year).

Table 2 GLM of the factors predicting the price (USD) of a batch of crayfish (n = 358). The minimal model comprised only significant terms and explained 59.1% of the variance.

Model term		*F* statistic	df	P
Full model				
Number of crayfish		57.71	1	<0.001
Total mass of batch		356.28	1	<0.001
State (cooked or raw)		36.38	1	<0.001
Season (hot or cold)		10.66	1	0.001
Buyer (villager or passer-by)		8.47	1	0.004
Species		0.15	2	0.86
Minimal model		Average effect	SE	
Constant		0.247	0.041	
Number of crayfish		0.018	0.002	
Total mass of the catch (g)		$1.204 * 10^{-4}$	$5.121 * 10^{-5}$	
State	cooked	0.000	0.000	
	raw	−0.210	0.035	
Season	hot	0.000	0.000	
	cold	0.075	0.023	
Buyer	villager	0.000	0.000	
	passer-by	0.075	0.026	

The crayfish harvest

More than 95% of the crayfish harvested in Vohiparara were *A. granulimanus* (n = 13,256). *A. betsileoensis* and *A. crosnieri* were much less commonly caught and made up only 4 and 1% of the catch, respectively. *A. granulimanus* also dominated the crayfish harvest in other villages visited. However, villagers in Sahavondronana reported that *A. betsileoensis* made up a significant proportion of the catch during the warm months when they readily enter eel traps. *A. crosnieri* were seldom targeted by harvesters because of their muddy taste, small size and the difficulty of harvesting this species in its swampy habitat. *A. caldwellii* were rare in the areas visited in this survey, but were harvested opportunistically where present.

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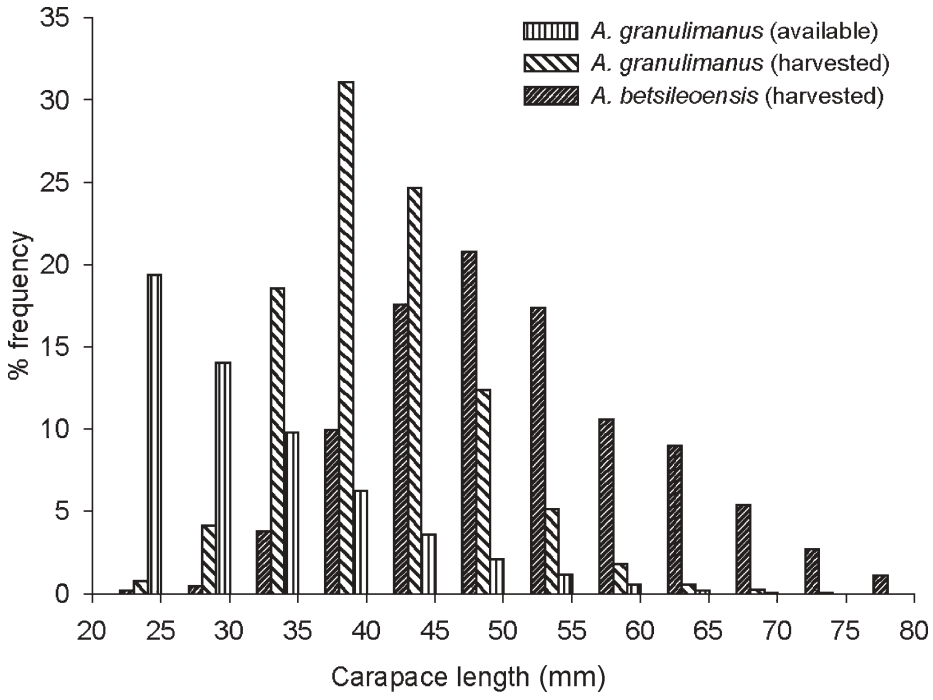

Fig. 2 The size frequency distribution of *A. granulimanus* (n = 12,068) and *A. betsileoensis* (n = 443) harvested in Vohiparara compared with the size frequency distribution of *A. granulimanus* (n = 26,096) found in the river during an ecological study (Jones *et al.*, 2005).

Harvesters were selective for larger crayfish (Fig. 2) but 79% of *A. granulimanus* and 32% of *A. betsileoensis* caught in Vohiparara were smaller than the legal limit under Malagasy regulations (equivalent to 45 mm CL). *A. betsileoensis* tended to be caught at a larger size than *A. granulimanus*, probably because *A. betsileoensis* live in deep rivers and therefore harvesters fish from the bank with baited sticks; this method appears to be more selective than entering the river to turn rocks. In some areas, but not close to any of the villages visited in this study, we saw occasional evidence of harvesters digging the crayfish out of their burrows. This practice was widely condemned by interviewees.

All crayfish harvesters (whether for commercial or subsistence use) admitted they collect crayfish bearing eggs. Many villagers expressed a strong preference for crayfish with eggs saying they are fatter and tastier. In addition the crayfish reproductive period (July–December) overlaps with the hungry season of food scarcity. Some interviewees stated they release crayfish carrying young (crayfish incubate their young under the tail for some weeks post-hatching). Anecdotal evidence suggests that this is true; when we asked a harvester where we might find crayfish still bearing young to photograph, she offered to lead us to a rock under which she had seen a female with young the day before. On lifting the rock we found a large female bearing many young.

Discussion

The importance of crayfish harvesting

Commercial crayfish harvesting was important in relatively few villages in the Ranomafana area. However, in these commercial harvesting villages >50% of households were directly involved in the harvest. Although low in absolute terms, the revenue earned from crayfish harvesting is significant in the context of local incomes. More that 88% of rural households in Fianarantsoa Province live on <USD 153 per year (INSTAT, 2002) and harvesters in Vohiparara earned 14–161% of this amount from crayfish harvesting. The vast majority of the catch was *A. granulimanus*, the most common species in the area. However other species, particularly the much rarer (Jones, 2004) *A. betsileoensis*, were also harvested. Villagers distinguish species, giving them different vernacular names (Table 1) but the value obtained for a crayfish depends on an individual's size and not on the species.

Subsistence use was widespread. Although most households interviewed mentioned it as an occasional activity its importance may have been underreported. We often observed children collecting and consuming crayfish close to the village but this was not mentioned during interviews. This opportunistic crayfish collecting may provide a significant source of protein as children in the area have a protein-poor diet (Hardenbergh, 1993).

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The households that relied most heavily on crayfish harvesting appeared to be disproportionately poorer. Female-headed households in Vohiparara tended to depend more on crayfish harvesting than male-headed households. Female-headed households are often poorer, due to a number of factors including a high dependency ratio (Quisumbing *et al*., 2001) and a lack of opportunities for wage labour, and are known to be poorer in Madagascar as a whole (INSTAT, 2002). Male-headed households involved in crayfish harvesting tended to be less well off than average and claimed they harvested crayfish because of the lack of alternatives. Agriculture requires investment in seeds and labour and the benefits are deferred; a barrier to entry for poorer members of the community. It is difficult to separate use and dependency (Bennett, 2002) but due to limited alternatives it seems likely that many people are dependent on crayfish harvesting under the current economic conditions.

Potential tools for community-management of crayfish

Recent work (Jones *et al*., 2005) suggests that the harvest of *A. granulimanus* in the Ranomafana area could be sustainable under current conditions. However, this is not a cause for complacency as the findings refer to one species, in one locality, under the specific conditions at the time of the study. Crayfish harvesting levels are high in many parts of the eastern rainforests (S. Goodman, pers. comm.) and no information is available on the sustainability of this harvest. Under the terms of the agreements being set up in Madagascar that transfer responsibility for forest management to communities, the communities are expected to establish rules to ensure forest resources are exploited sustainably (MEF, 2001). This policy framework formalizes communities' long-term interests in their natural resources and offers an ideal opportunity for those concerned with the sustainability of their crayfish harvest to implement improved management. A number of management tools may be useful to protect crayfish stocks from overexploitation and could be introduced and enforced at the local level. Suitable tools need to be selected by the communities concerned but technical support and collaboration with conservationists may be necessary.

The simplest method of protecting brood stock and thus reducing the risk of overexploitation is to leave crayfish with eggs or young. Unfortunately, despite awareness of the potential effect on future harvests, people in all villages visited harvested crayfish with eggs. The preference for the taste of crayfish with eggs and the coincidence of the period when people suffer food scarcity with the period of crayfish reproduction are challenges for this management strategy. However it has the potential to offer the greatest protection to the brood stock with the least cost in terms of forfeited catch and could therefore be popular with communities. Unfortunately, enforcement of this regulation would be difficult as harvesters could scrape off eggs before bringing crayfish to market. One solution could be for communities to ban the harvest of all females during the breeding period.

Setting minimum size limits to ensure that females have spawned at least once before they are harvested is a common management tool for crayfish populations in Europe (Skurdal & Taugbol, 1994). The existing law regarding minimum harvest size in Madagascar is not widely known and is not enforced. Size limits are relatively easy to enforce as enforcement can take place at the point of sale (in a market). *Astacoides* species become reproductive at different sizes (Jones 2004), however, and therefore the current law, even if properly applied, may not be suitable for protecting the brood stock of all species. Further research is needed to identify appropriate size limits.

No-take zones have become an important tool in the management of marine resources and recent empirical work suggests that they can improve marine fish catches (Gell & Roberts, 2003). It has been suggested that fully protected core areas of forests may act in a similar way by providing a source to resupply animal populations in nearby harvested areas (Bennett & Robinson, 2000). Management transfer agreements in Madagascar usually require zoning of a community's forest into use and non-use zones. Unfortunately, basic information on dispersal and metapopulation dynamics is not available for crayfish in Madagascar, making it difficult to assess the potential of this tool to improve harvests. However, the strong relationship between size and fecundity (Jones & Coulson, 2006) suggests that no-take zones may be a useful way of increasing recruitment in heavily fished areas. Unfortunately, enforcing no-take zones for crayfish harvesting in forest may be impractical. Visibility in forest is much lower than on the open sea, harvesting causes little noise, leaves little trace and could easily be carried out in secret. It would be impossible to identify the origin of catches once they enter the market. The practical disadvantages of enforcing no-take zones may outweigh any advantages.

Crayfish carrying eggs or young may be less likely to respond to baited sticks (J.P.G. Jones & F.B. Andriahajaina, unpubl. data) and therefore such traditional harvesting practices offer some protection to the brood stock. Using spades to dig for crayfish offers no protection to the brood stock and, in addition, destroys habitat. Banning such destructive harvesting practices,

although difficult to enforce, may aid the sustainability of the harvest.

Conclusions and caveats

Where rural people depend on natural resources they have shared interests with conservationists and therefore, in the appropriate policy environment, the two are natural allies (Hutton & Leader-Williams, 2003). There are a number of successful examples where communities and conservationists in Madagascar have worked together to develop local laws to manage access to important natural resources, resulting in improved management (Rakotoniaina & Randriamanampisoa, 1999; Durbin *et al*., 2003). Crayfish are a valued resource and there is potential for improved management under community-enforced and implemented management agreements. However, the natural resource needs of communities may be supplied by a relatively narrow range of species, and thus people may have little incentive to conserve the full range of biodiversity (Adams & Hulme, 2001). Rarer crayfish species such as *A. betsileoensis*, which make up only a small percentage of the harvest, may require additional protection or monitoring. However, communities may be unable to provide this because of the small contribution of rarer species to the harvest and consequent low value (Hockley *et al*., 2005). To establish whether changes in tenure are resulting in positive outcomes in terms of the resource, monitoring is important. Monitoring with sufficient power to detect declines is costly in terms of effort (Sheil, 2001) but simple monitoring of the number and size of individuals caught per day at a given site could give useful information both to the community managers of the resource and to external bodies interested in the success of community-based conservation as a policy (Hockley *et al*., 2005). We believe that transferring forest to communities has the potential to improve the management of economically important resources but we stress that conservationists must be realistic about the degree to which community management can ensure the conservation of the full range of biodiversity.

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Julia Jones is interested in exploitation of wildlife resources by local people and institutional mechanisms that promote sustainable exploitation. She has spent much of the last 5 years in Madagascar where, with Neal Hockley, she established the project Vokatry ny Ala.

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