Coral Reefs (2007) 26:1035–1045
DOI 10.1007/s00338-007-0213-2

REPORT

Designing marine reserves to reflect local socioeconomic conditions: lessons from long-enduring customary management systems

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Received: 11 July 2006 / Accepted: 27 February 2007 / Published online: 21 March 2007

Abstract Coral reef conservation strategies such as marine protected areas have met limited success in many developing countries. Some researchers attribute part of these shortcomings to inadequate attention to the social context of conserving marine resources. To gain insights into applying Western conservation theory more successfully in the socioeconomic context of developing countries, this study examines how long-enduring, customary reef closures appear to reflect local socioeconomic conditions in two Papua New Guinean communities. Attributes of the customary management (including size, shape, permanence, and gear restrictions) are examined in relation to prevailing socioeconomic conditions (including resource users' ability to switch gears, fishing grounds, and occupations). Customary closures in the two communities appear to reflect local socioeconomic circumstances in three ways. First, in situations where people can readily switch between occupations, full closures are acceptable with periodic harvests to benefit from the closure. In comparison, communities with high dependence on the marine resources are more conducive to employing strategies that restrict certain gear types while still allowing others. Second, where there is multiple clan and family spatial ownership of resources, the communities have one closure per clan/family; one large no-take area would have disproportionate affect on those compared to the rest of the community. In contrast, communities that have joint ownership can establish one large closure as long as there are other areas available to harvest. Third, historical and trade relationships with neighboring communities can influence regulations by creating the need for occasional harvests to provide fish for feasts. This study further demonstrates the importance of understanding the socioeconomic context of factors such as community governance and levels of dependence for the conservation of marine resources.

Keywords Coral reef · Socioeconomic · Customary management · Marine protected areas · Marine tenure

Communicated by Guest Editor R. Pollnac.

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Introduction

Coral reefs are experiencing multiple anthropogenic disturbances that are reducing their capacity to provide critical ecosystem goods and services (McClanahan 2002; Hughes et al. 2003). Marine protected areas (MPAs), which restrict or prohibit extractive activities from a delineated area, are thought to be a useful tool for coral reef conservation because they attempt to protect the entire ecosystem in a localized area (Agardy 1997; Pearce 2002). Support for MPAs is generally high among scientists, conservation groups, and development agencies, although their track record of actually improving ecological conditions is questionable (Willis et al. 2003). Some studies suggest that MPAs are frequently unsuccessful as a reef conservation strategy, particularly in developing countries, where socioeconomic factors such as poverty can drive resource abuse, and capacity for enforcement is often lacking (McClanahan 1999; Christie et al. 2003; Christie 2004). For example, McClanahan et al. (2006) found that out of eight designated MPAs in Papua New Guinea and Indonesia, only one was successful at protecting fish and one was successful at protecting coral. One of the pressing questions for resource

managers is "why are some MPAs effective while others are not?"

Although considerable gaps exist in the marine science pertaining to MPAs (Sale et al. 2005), one of the primary reasons many MPAs fail in developing countries may be because the socioeconomic context within which they can effectively operate is inadequately incorporated in planning and management (McClanahan 1999; Christie et al. 2003; Christie 2004). Socioeconomic factors are critical to the success of common-property institutions such as MPAs because they can influence whether and how people adopt restraints on resource use (Berkes 1989; Ostrom 1990; Becker and Ostrom 1995; Agrawal 2001; Pretty 2003). When common property institutions are designed to reflect socioeconomic conditions, they can produce strategies with appropriate rules, monitoring, and sanctions, which create incentives for joint cooperation that are higher than those for poaching (Ostrom 1990). In these situations, compliance with resource use restrictions can be high resulting in potential societal and conservation benefits (McClanahan et al. 2006). Alternatively, in situations where socioeconomic conditions are poorly reflected by common property institutions, incentives for compliance may be poor and outcomes such as free riding and overexploitation are likely (Ostrom 1990).

Despite the widespread use of MPAs for coral reef conservation, there is only a limited body of empirical studies focused on identifying the socioeconomic factors that enable communities to employ successful management (Fiske 1992; Pollnac et al. 2001; White et al. 2002; Crawford et al. 2004; McClanahan et al. 2006). These studies suggest that socioeconomic factors such as local resource use patterns, de facto governance institutions (e.g., customary marine tenure), market forces, and poverty need to be considered in MPA planning and management (see Pollnac 1998; Bunce et al. 2000; Pollnac and Crawford 2000 for detailed descriptions of a range of socioeconomic factors to be considered specifically for MPA management). However, there are few examples of how these socioeconomic factors can be practically reflected in MPA location, design, and management (Crawford et al. 2004).

Learning from long-enduring management systems

Insight into how MPAs may better reflect local socioeconomic conditions may be gained by examining the social context in which long-enduring sociocultural institutions, such as taboos and customary marine tenure systems, limit marine resource use in coastal communities (Johannes 2002; Becker and Ghimire 2003). A wide range of these "customary management" regimes have been documented, including temporary closures, fallow rotation, gear restricted areas, and permanently closed areas (Neitschmann 1985; Ruddle 1995; Hviding 1996; Colding and Folke 2001; Cinner et al. 2005a, 2006). Customary management systems can be dynamic and adaptive to changes in both social and ecological conditions (Berkes et al. 2000; Cinner et al. 2006). In some instances, customary management systems have been effective at meeting both conservation goals (i.e., increasing fish catch in adjacent fisheries, increasing abundance of target species, and/or increasing biomass of target species) and community goals (i.e., by increasing harvests or providing fish for feasts), while achieving high levels of compliance without active enforcement patrols (Evans et al. 1997; McClanahan et al. 1997; Ruttan 1998; Aswani and Hamilton 2004; Aswani and Weiant 2004; Cinner et al. 2005a, 2006; McClanahan et al. 2006). Customary management regimes frequently possess design principles of effective governance institutions that induce compliance, including the demarcation of boundaries of resources and user groups, mechanisms for conflict resolution, sanctions for violators, adaptability to social and ecological conditions, and mechanisms to induce compliance (through perceived legitimacy of authorities and regular reminders of rules) (Berkes 1989; Sutinen and Kuperan 1999; Dietz et al. 2003; Cinner et al. 2006).

Human behavioral ecologists suggest that practices such as customary management are adapted and refined over time in situations where the benefits of conservation outweigh the short-term costs of limiting harvests (i.e., making conservers less likely to suffer extinction or more likely to spread and prosper compared to non-conservers) (Ruttan and Borgerhoff Mulder 1999; Smith and Wishnie 2000). Thus, one would expect that where these systems have persevered for generations, potentially complex designs may emerge that are well adapted to providing benefits to the communities and minimising costs under their specific socioeconomic conditions (Smith and Wishnie 2000). One approach to examining conditions under which a particular harvesting restraint strategy provides costs or benefits to resource users is by conducting detailed studies of the daily activities of resource users. For example, foraging behaviour studies of hunters and fishers have examined whether the benefits of short-term harvesting restraints outweigh the costs to individuals (Alvard 1995, 1998; Aswani 1998). However, it is also important to examine these processes at a larger spatial scale to determine how broader socioeconomic forces such as dependence on resources and governance institutions can influence the costs of a particular harvesting restraint strategy. This study attempts to build on previous studies by taking a different approach: examining whether design characteristics of customary management practices (size, shape, and duration) may reflect broader socioeconomic

issues (such as resource use and marine tenure arrangements) in ways that appear to minimize social costs.

Recent comparative studies suggest that there may be linkages between specific socioeconomic factors (e.g., dependence on marine resources) and whether a community employs customary management institutions to govern marine resources (Cinner 2005a) or even the types of strategies that may be appropriate for a community (Cinner 2005b). For example, Cinner (2005b) quantitatively compared the socioeconomic conditions in 15 Papua New Guinean communities with different customary management arrangements. Results showed that communities that employed periodic closures to manage marine resources had similar socioeconomic characteristics (i.e., low dependence on marine resources). Alternatively, the only community to employ a different management strategy (a restricted gear area) had very high dependence on marine resources. To further explore the potential relationship between socioeconomic characteristics and the type of management strategy appropriate for a community, two of these cases, examined in Cinner (2005b) are discussed in detail here: Muluk village on Karkar Island (Madang Province) and Ahus village in the Manus Province (Fig. 1). The objectives of this study are: (1) to document traditional tenure-based governance systems that incorporate closures as a management tool; (2) quantify the benefits communities claimed to receive from these closures (3) examine socioeconomic conditions in the communities; (4) explore how limitations in peoples' ability to switch occupations, gear and fishing grounds may influence the costs of a particular closure strategy to individuals and groups; and (5) examine the ways in which local tenure institutions may influence the design of closures systems (including size, shape, and duration).

Background of coastal governance in Papua New Guinea

In Papua New Guinea (PNG), coastal resources are, in theory, governed by polycentric institutions (i.e., governance operating at multiple levels with a degree of autonomy at each level) operating at the national, provincial, and local scales. At the national and provincial scale, government fisheries departments attempt to regulate and manage marine resources. However, a lack of funding and enforcement has made the execution of policy at these scales difficult (Cinner and McClanahan 2006). National and provincial governments recognize the rights of coastal communities to own inshore marine resources under a system known as Customary Marine Tenure (CMT) (Asafu-Adjaye 2000). This provides traditional owners with the ability to exclude outsiders from accessing inshore marine resources and forms the foundation for additional customary restrictions on marine resource use. Ownership of resources is defined by social groups typically at the individual, family, clan, and/or community level, and different groups may have overlapping rights with differing levels of autonomy. For example, at Ahus, clans may own the rights to a particular reef area (i.e., the right to exclude or permit access), but a family within that clan may own the exclusive rights to harvest a particular species and an individual within that family may own the rights to allow people to use a specific gear type, such as a net. The size of tenure areas can vary considerably, and are not necessarily static. In a study of 15 tenure institutions in PNG, Cinner (2005a)

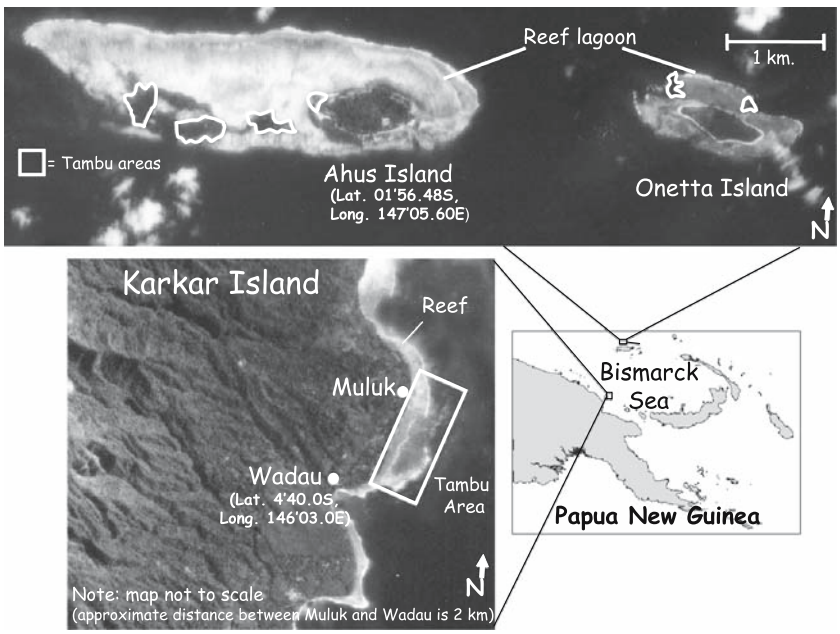

Fig. 1 Comparison of Muluk and Ahus reef closure systems. Ahus' system is comprised of six small reef closures, while Muluk's is a single larger closure (both indicated by *white outlined areas*)

found that the size of tenure grounds ranged from 0.25 to 15 km^2. Depending on kinship ties to other villages and the exclusivity of the tenure model (see Aswani 1999), the seascape for an individual fisher may be limited to the area of fishing grounds owned by his/her clan or village, or it may encompass those of neighbouring villages.

Materials and methods

Study sites

At Ahus, approximately 600 residents live on a small (28 ha), densely populated, low-lying island with few terrestrial resources (e.g., timber, firewood, farmland, etc.) (Fig. 1). The Muluk community, situated on the sparsely populated eastern side of Karkar Island, has a population of 330 people in 50 households (Cinner et al. 2006). Karkar is a volcanic island with a high elevation (1,839 m) and substantial terrestrial resources (e.g., timber, coconut and cocoa plantations, farmland, etc.).

The two communities in this study share national recognition of CMT and share many local-level similarities that are considered important in the emergence and successful functioning of common property institutions (Agrawal 2002). In particular, both villages are remote, island communities with a low population base (<600 people), low migration (<8% of the population), a single religious institution, the use of exclusive CMT to prohibit outsiders from accessing marine resources, nucleated settlements on the coast, a lack of direct access to national or global markets for marine products, and the presence of conflicts with outsiders over marine resources (Cinner 2005b; Cinner et al. 2005a, 2006; McClanahan et al. 2006). However, the communities differ considerably in regards to one aspect that may influence common property systems: dependence on and use of resources (Lise 2000; Agrawal 2001; Zanetell and Knuth 2004; Cinner 2005b). For example, 77% of households in Ahus ranked fishing as a primary occupation, compared to just 5% in Muluk (Cinner et al. 2005a, 2006). While a number of socioeconomic and historical processes could influence management in these communities, the scope of this study is limited to examining how contrasting elements of resource use may influence the type of closure in place for each community.

Research

Field research was conducted in Muluk between November–December 2001 and May–June 2002 in Ahus. A combination of household surveys, key informant interviews, oral histories, and participant observation in resource use activities was used to gather information.

Information about customary management institutions was obtained through interviews with resource users, traditional leaders, and elected officials. Key informants were selected opportunistically and through "snowball sampling" (i.e., having informants recommend other informants). Seasonal calendars were developed to examine the seasonality of fishing and other resource use activities. Key informants were questioned about the exclusivity of customary marine tenure institutions, the scale at which tenure institutions are controlled (i.e., individual, family, clan, community, etc.), resource use rights within and outside these tenure areas, the size of fishing grounds, and the size, shape, and duration of customary closures within these tenure areas. To determine the size of tenure and closure areas, resource users showed the approximate boundaries using obvious landmarks or reef features as guides. These boundaries were then drawn on aerial photographs (1:100,000 scale) and digitally traced with the UTHSCSA Image Tool 2000 (University of Texas Health and Science Centre, San Antonio, USA). The aerial photographs showed reef, sand, and seagrass areas to approximately the 10 m depth mark.

The methods described in Henry (1990) were used to systematically sample 51 out of the 105 households in Ahus and 41 of the 50 households in Muluk (Cinner et al. 2005a, 2006). Questions in household surveys were directed towards the head of the household. Respondents were asked about the number and type of occupations their household was involved in. The relative importance of each occupation was determined by having respondents rank the occupations their household engaged in, from most important to least important to their household's well being (Pollnac and Crawford 2000). Respondents were also asked their household's typical fortnightly expenditures.

Fishers in each village were asked about which gear types they used and then asked to rank each gear in order of perceived importance. For example, if a fisher used nets and spear guns, the fisher was asked to rank which was more important to the household's well being (which could include contributions to the household's catch or prestige). Fishing effort was estimated by asking household respondents the average number of days per week that each member of the household was engaged in specific fishing activities (i.e., the number of fishing trips per gear type) in each fishing season. The author participated in fishing trips at each village to observe different fishing techniques and verify information obtained from surveys. The margin of error surrounding participation in select occupations, gears, and fishing effort was calculated using a finite population correction factor, which corrects error based on the proportion of the population surveyed (Scheaffer et al. 1996).

Results

Customary management in Ahus village

Marine resources at Ahus and other island communities on the North coast of Manus are governed by a complicated system of customary rights that determine whether and how specific individuals, families, clans, and villages can access particular reef areas, target specific species and engage in specific harvesting methods (Carrier 1982, 1987; Carrier and Carrier 1989a, b; Cinner et al. 2005a, b). Each village owns specific fishing grounds from which other villagers are excluded from fishing. Fishing grounds are mainly situated in the reef lagoon surrounding the island and the inshore coral reefs on the shoreline of the main Manus Island adjacent to the village. The fishing grounds under Ahus' customary tenure encompass 550 ha of reef lagoon (including uninhabited Onetta Island) (Fig. 1). Ahus also claims resource rights on the narrow reef lagoon on the main Manus Island (approximately 2.5 km away) and excludes villagers from the main island from accessing marine resources. However, there is very little fishing activity in this area: no fishing trips were observed during the study period, and no fishers within Ahus village discussed fishing there. Pelagic fishing within this area is limited by the seasonality of pelagic species and weather conditions. Thus, most fishing activities are targeted in and around the lagoon.

Fishers' ability to switch to alternate fishing grounds is limited by tenure rights governing where villagers can fish (both inside the lagoon and in the lagoon of neighbouring villages). Within the reef lagoon, each villager is restricted to fishing in the area controlled by his or her clan. Fines of up to US $29 were levied for fishing in another clan's area. Two such fines had been imposed in the year preceding the research. These fines are considerable relative to the average household fortnightly expenditures in the village (US $44). There are five main clans on Ahus, with 24 different sub clans recorded. Clan and village boundaries are dynamic and often under dispute. Depending on their individual kinship ties to other clans and villages, which can provide use-rights or privileges to additional resources, fishers may or may not be able to fish beyond their clan's section of the lagoon.

Tenure institutions also restrict the type of fishing gear villagers could use, the way they can use it, and the type of fish species they can target. Certain families and individuals own the rights to use specific gears (e.g., nets) and require others to seek their permission before using this gear. Thus, although specific fishing gear (e.g., nets) is available for purchase in the provincial market, Ahus residents that purchase this gear are not necessarily free to use them, even in their own traditional fishing area. Furthermore, other resource owners may own the traditional rights to use the gear with a specific technique (e.g., driving the fish into the net). Key informants explained that if someone wanted to go fishing for a specific species, using a certain gear, with a specific technique, in a specific location, they might need permission from up to four resource owners. In general, though, there are no owners for line fishing or using a spear gun.

At Ahus, customary taboos (*tambu)* restrict fishing in six small areas totalling 33.2 ha or 6% of Ahus' reef area (Fig. 1). There are three additional *tambu* areas on the northern reef edge, but seas were too rough to access these areas and their size could not be determined. Spear and net fishing are prohibited in the *tambu* areas, however, line fishing is permitted. Decisions to implement restrictions or harvest each *tambu* area at Ahus are the responsibility of the kinship group with control over that specific reef area. Key informants suggested that decisions about resource use could be made by an individual in one area and by a small council in another area. These *tambu* areas have been operating for as long as living memory in the village.

Several times per year the community harvests fish from within the *tambu* areas to provide for feasts. Villagers benefit from these traditional restrictions because the biomass of fish in the *tambu* areas is higher than outside, and large numbers of fish are easily caught (Cinner et al. 2005b). The community not only benefits from the direct consumption of fish harvested within the *tambu* area, but these feasts also play important roles in maintaining trade relations with neighbouring villages, which are critical for Ahus to acquire terrestrial resources such as firewood, timber and vegetables (Cinner et al. 2005b). The main goal of the fishing restrictions is to maintain a dependable supply of fish stocks within the closure. However, Ahus islanders implement the *tambu* because of the benefits they gain through meeting their social and economic need to have feasts, rather than any intrinsic notion of resource conservation.

Using underwater visual census, Cinner et al. (2005a) found that the biomass of fish and the size of targeted fish species were more than 60 and 20% higher, respectively, inside the tambu area compared to areas outside. Since fishing is often size selective (i.e., larger individuals are captured first) (Roberts and Polunin 1991), the larger average size of fish within the *tambu* area is potentially a result of reduced fishing pressure on species not targeted by line fishing, which is permitted in these areas. Cinner et al. (2005b) found a lower abundance of discarded fishing gear inside, compared to outside the *tambu* area, suggesting that compliance with reserve rules was high. Since there are no active enforcement patrols, internal motivations to comply with the fish restrictions may have come from factors such as regular reminders of the closures during feasts and the perceived legitimacy of the clans to restrict harvesting

within their tenure (Sutinen and Kuperan 1999; Berkes et al. 2000; Cinner et al. 2005a). At Ahus, there are also restrictions on harvesting commercial invertebrate species such as beche de mer (*Holothuria* spp.) and trochus (*Trochus niloticus*). Clan leaders ban the harvesting of these species when prices are low to allow stocks to recover.

Customary management in Muluk Village

Muluk has customary ownership over the reef adjacent to their village and the neighbouring village, Wadau. The people of Wadau were granted use privileges to the reefs in front of their village when they relocated to the coast from the interior. Wadau residents can use marine resources adjacent to their village for subsistence, but cannot exclude outsiders and have to abide by decisions Muluk villagers make to open or close reefs.

At Muluk, access to marine resources is more centralised than in Ahus. Decisions to allow or restrict access to reef resources are made by a council of three chiefs (one from each clan) and decisions cannot be made in the absence of any of these chiefs. Key informants claimed that all Muluk villagers have equal access to reef-related resources throughout the 92 ha of shallow-water fishing grounds Muluk controls. However, there are taboos that restrict some fishing practices. For example, fishing effort is restricted by initiation rights for particular fisheries, such as fishing for flying fish (called "bom bom" fishing), where fish are speared with hand spears from a canoe at night. Muluk also periodically close 58 ha of reef adjacent to their village for 1–2 years (Fig. 1).

The decision to close the reefs at Muluk is reached through a consensus between the three-clan chiefs and is usually initiated when declines in fish catch are observed. Resource users and elders in Muluk explained that when the reefs are intensively harvested, fish change their behaviour, remaining farther away from fishers and becoming difficult to catch (Cinner et al. 2006). They noted that by temporarily banning fishing (up to 1 year), reef fish "allow" fishers to get closer and are easier to catch. Thus, Muluk residents benefited from the closure because it made fishing easier. During periods when the *tambu* is instated, fishers from Muluk can fish in sections of their reef that are not *tambu*, including the reef in front of neighbouring Wadau. As with Ahus, the *tambu* system has been in place for generations and the purpose of the *tambu* does not appear to be intrinsic conservation, but rather to meet community goals of improving fish harvests.

Cinner et al. (2006) found that the percentage of damaged coral was lower inside the *tambu* area compared to outside, and the average size of targeted fish, biomass of these fishes, average trophic level of fish, density of giant clams (a target species), and the density of coral recruits were higher inside the managed area compared to outside the area. Inside the closure there was a higher biomass of long, intermediate, and short-lived fish families from various functional groups (i.e., carnivores, herbivores, etc.) (Cinner et al. 2006). A lower abundance of discarded fishing gear inside the managed area, compared to outside, suggests that poaching within the *tambu* area was low. The closure appears to reduce overall fishing pressure inside the area and fishing mortality even in slow-growing and long-lived species (Cinner et al. 2006). As with Ahus, there are no active enforcement patrols; thus, motivations to comply likely come from internal factors such as perceived legitimacy of the rules and authorities, and peer pressure (Sutinen and Kuperan 1999). Villagers receive regular reminders of the closures during special occasions such as initiation ceremonies and celebrations.

Resource use

Fishing is the most important occupation at Ahus; 96% of the community engage in fishing and 77% rank it as their primary occupation (Fig. 2). Only two households surveyed did not engage in fishing: one headed by an 82-year old man and the other by a woman. Tourism (which consisted mainly of making handicrafts for Papua New Guinean visitors to the main Manus island and looking after a guest house on Ahus island) and informal economic activities (e.g., occasionally operating a small trade store out of a spare room in the house) are the main supplementary occupations on Ahus (Fig. 2). At Ahus, the lack of terrestrial resources and the presence of historical trade monopolies

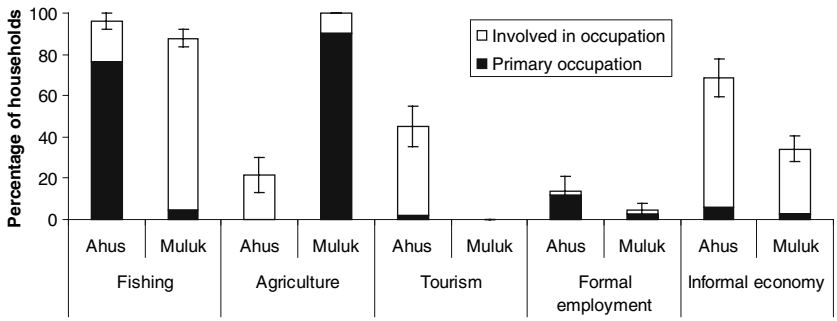

Fig. 2 Percentage of households on Ahus and Muluk involved in different occupational categories, highlighting the proportion that rank each occupation as the primary occupation for the household (error bars ± 95% CI)

limit the ability of residents to readily switch between fishing and other productive activities (Carrier and Carrier 1989b; Cinner et al. 2005a).

In contrast, fishing is largely a secondary activity at Muluk and few residents rank it as a primary occupation (Fig. 2). Agriculture is the most important occupation in Muluk. There is no involvement in tourism and minimal involvement in salaried employment (i.e., government work or teaching). Informal economic activities, such as owning a small shop, carpentry and transportation play an important secondary role in livelihood strategies. There is a mean of 2.7 ± 0.25 ($\pm$95% CI) occupations per household in Ahus, compared to 3.3 ± 0.1 in Muluk (Cinner et al. 2005a, 2006). The high number of occupations per household and low relative importance of fishing suggests that people in Muluk are more readily able to switch between fishing and other livelihood activities compared to people in Ahus.

A variety of fishing gear is used in both communities: 84% of fishers in Ahus use more than one fishing gear compared to 65% in Muluk. At Ahus, the ability to acquire or use certain fishing gear is restricted by tenure institutions. Most fishers use hand lines and spear guns (80% used both), both of which are unregulated by tenure institutions (Fig. 3). Line fishing and spear fishing each account for close to half of Ahus' fishing effort (Fig. 4). However, fishers are restricted in switching to other gear by tenure rights that restrict the gears people can use, and by poverty, which limit their ability to acquire highly capitalized gear (e.g., larger boats) to target the pelagic fishery which is not regulated by tenure institutions. At Muluk, spear guns, spears (hand spears), and line fishing comprise the majority of fishing activity (Fig. 3). Line fishing and spear fishing (with spear guns) each account for more than one third of Muluk's total fishing effort (Fig. 4). At Muluk, more than 50% of households engage in both line fishing and spear fishing (both of which are potentially affected by the *tambu*). However, 51% of villagers also engage in using hand spears, generally to target flying fish in deeper water, which do not form part of the restricted *tambu* areas (Fig. 3). The socioeconomic conditions and management characteristics at the two villages are summarized and contrasted in Table 1.

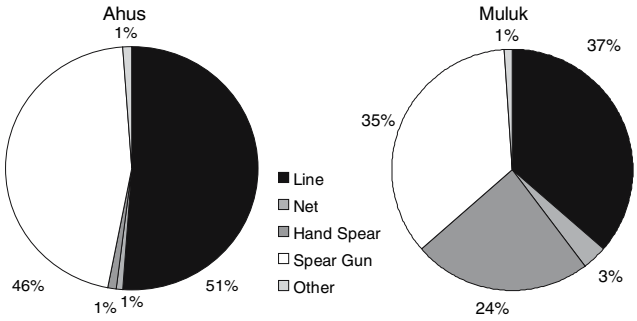

Fig. 4 Proportion of community fishing effort devoted to different gear types

Discussion

Both the specific *tambu* strategies and the goals of the communities are quite different. At Muluk a larger, temporary no take area is used to "tame" the fish so they are easier to catch. At Ahus, several smaller, permanent restricted gear areas are used to provide a "bank account" of fish that can be harvested during a feast. One commonality between strategies is that resources are managed for the social welfare of the community rather than for intrinsic conservation goals (Alvard 1995; Ruttan and Borgerhoff Mulder 1999; Smith and Wishnie 2000). A possible explanation for the use of different strategies in each community is that they are required to meet these differing goals. However, numerous studies describe how temporary closures (as used in Muluk) can be used to stockpile fish in preparation for a feast (as is the goal in Ahus) (Ravuvu 1983; Polunin 1984; Neitschmann 1985; Wright 1985). Thus, a more likely explanation for the use of these different strategies is that they have been adapted to meet each community's goals in ways that minimize social costs (e.g., displacement, sacrificed effort, inequity) under the local socioeconomic context. The costs of a particular strategy to resource users will be determined in part by factors such as the location, duration, and size of resource restrictions, and also by socioeconomic factors, which may limit alternative options for those displaced by the restrictions.

One way to examine socioeconomic conditions in a management context is to use the concept of different types of mobility. When faced with displacement by harvesting

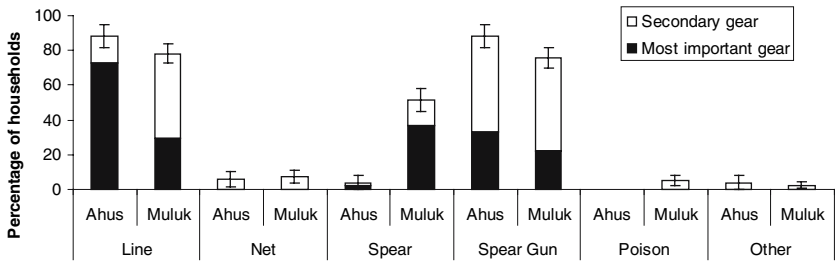

Fig. 3 Percentage of households that use different fishing gear, highlighting the proportion that rank each gear as the most important gear for the household (error bars $\pm$ 95% CI)

Table 1 Summary of management characteristics and socioeconomic conditions at Muluk and Ahus

	Muluk	Ahus
Closure characteristics		
Closure size (deep water parts not included)	58 ha (63% of total reef area)	33.2 ha (5.8% of total reef area)
Closure configuration	Single large area in front of village	Six small areas owned by different clans
Restrictions	All extractive activities	Net fishing and spear fishing
Duration	6–12 months	Permanent
Periodicity	Put in place every 6–24 months	Harvested 1–3 times per year
Socioeconomic conditions		
Marine tenure system	Controlled by a council of chiefs, highly exclusive to outsiders	Very decentralized controlled by kinship group (individuals, families, cans), highly exclusive to outsiders
Dependence on marine resources	Low: abundant terrestrial resources	High: very limited access to terrestrial resources
Ability to switch to alternate occupations	High: high number of alternate occupations	Low: few alternate occupations
Ability to switch between gear types	High—initiation rights limit use of hand spears	Moderate—tenure institutions restrict access to nets and other gear, but spear and line fishing are unregulated
Ability to change fishing grounds	High: fishers can fish anywhere in their villages' control and in neighbouring village's reefs	Low: individuals' fishing grounds are highly restricted by kinship group's fishing grounds

restrictions (e.g., customary closures or MPAs), four general options are available to fishers so they do not suffer a loss of productivity: poaching, switching effort to an alternative occupation, switching to alternate fishing locations, or switching to an alternate fishing gear (i.e., to a non-restricted gear or a gear that enables fishers to target alternate marine resources such as pelagic fishes). Switching effort from fishing to an alternative livelihood requires occupational mobility (i.e., the ability to switch between occupations). Switching fishing grounds requires spatial mobility (i.e., the ability to fish in other locations). Switching gear requires gear mobility (i.e., the ability to acquire or use alternative harvesting technologies). Each type of mobility may be limited or facilitated by socioeconomic factors such as tenure rights and dependence on marine resources.

In general, there is little evidence that poaching occurs within the *tambu* areas in either community (Cinner et al. 2005a, 2006). Thus, fishers at each village may rely on elements of occupational, spatial, and/or gear mobility to minimize the potential loss of productivity incurred by the *tambu* areas. The particular *tambu* strategies and designs at each village may reflect differing elements of mobility (Table 1; Fig. 5).

Muluk's strategy of periodically closing a large portion of their reef appears feasible for the community because of villagers' high occupational, gear, and spatial mobility (Table 1; Fig. 5). At Muluk, where fishing is a supplemental activity and residents practise multiple livelihood strategies, switching to other occupations when the closure is in place does not affect villager's primary livelihood strategies. Furthermore, 51% of Muluk households use hand

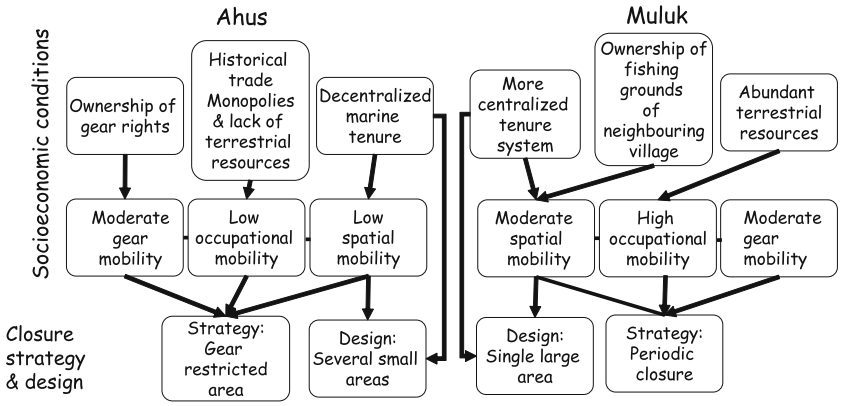

Fig. 5 Conceptual model of how mobility and tenure may influence the design and strategy of different socioeconomic conditions

spears to catch flying fish in the deeper water, which means that almost a third of the community's fishing effort is not affected by the closure. In addition, Muluk owns rights to fishing grounds in front of the neighbouring community of Wadau, and utilises these areas frequently. Therefore, periodic closures within the shallow lagoon waters adjacent to Muluk village may inconvenience fishers, but does not prevent them from accessing marine resources.

Alternatively, at Ahus, there are few options for residents to switch fishing grounds or occupations. However, residents do have a moderate ability to switch between fishing gear, and their *tambu* regulations allow for certain forms of fishing. These socioeconomic conditions and management practices may be linked in two important ways (Table 1; Fig. 5). First, the strategy appears to minimize displacement from the closure under conditions of high dependence on marine resources, low occupational mobility and low spatial mobility. By allowing limited fishing in the *tambu* areas, fishing effort is reduced enough to provide a reliable stock of natural resources, but does not completely displace fishers. If strategies such as a no-take closure (permanent or temporary) were implemented at Ahus, fishers affected by the closure would be displaced because they could not switch occupations and could not fish in alternative locations. Secondly, Ahus' strategy appears equitable to resource users (a concept deemed critical in compliance with fisheries regulations, Sutinen and Kuperan 1999) because it reflects the local gear mobility situation. In particular, everyone shares a portion of the burden and the benefit of the *tambu* areas despite complicated marine tenure arrangements that limit the use of certain gears. The *tambu* regulations not only restrict gears that certain individuals have ownership of (e.g., nets and weirs) but also restrict gears that everyone has access to (e.g., spear guns). Likewise, the *tambu* restrictions also appear to create equitable benefits by allowing line fishing, a gear that everyone has access to. Alternative strategies such as island-wide gear restrictions (e.g., banning nets) would completely disenfranchise the traditional owners of the rights to use those gears, causing disproportional costs to accrue to one particular user group.

The spatial design of the closures (i.e., having one large closure versus several small closures) also appears to reflect the local socioeconomic conditions within each community (Table 1; Fig. 5). In particular, the designs of the closures reflect the scale of decision-making (i.e., local tenure institutions), a concept deemed crucial to the success of common property institutions (Dietz et al. 2003). In Muluk, the three clans make a collective decision to close a large contiguous patch of reef, reflecting the highly communal nature of the existing marine tenure regime. Closing off a large contiguous area appears equitable in Muluk because the community can either switch to alternative occupations or fish outside the closure. Alternatively, at Ahus, each major clan has at least one closure that they are responsible for administering. Because of the highly decentralized nature of these arrangements, closure of a large contiguous area encompassing the cumulative area of the small dispersed closures, would likely create a source of inequity and internal conflict within the community. Depending on where it was placed, a large contiguous closure within this social system would lead to specific families or clans bearing the entire burden of sacrificed production and associated income from their area, while other families or clans would continue to harvest unabated. The design of several small closures spreads out the burden, so that each clan can decide whether and how much reef area and production they wish to sacrifice.

By reflecting the different mobility situations at Ahus and Muluk, long-enduring customary closures meet community goals and conserve resources in ways that appear to distribute benefits and costs equitably among resource users. Debates exist about whether contemporary MPAs should be periodic or permanent in nature, particularly in temperate climates (Agardy 2000). There is also considerable debate about whether marine protected areas (MPAs) should be large or partitioned into several smaller reserves (known as the SLOSS, single large or several small debate) (Sladek Nowlis and Roberts 1999; Dahlgren and Sobel 2000; Halpern 2003; Roberts et al. 2003). To date both of these have been largely ecological debates, but this study has shown that these issues also appear to have important social determinants that are virtually absent in the literature (e.g., Agardy 2000; Roberts et al. 2003). For example, in a review of criteria for selecting marine reserves, Roberts et al. (2003) assert that biological criteria should precede social criteria and that social input should not compromise biological integrity. The present study reinforces the idea that questions of reserve size, and permanence should not be largely ecological debates, but must also incorporate socioeconomic aspects of resource use and governance. Inference from this study is limited because it is based on two case studies. However, results suggest that contemporary MPAs may be able to achieve high compliance and consequently, conservation benefits by using strategies that reflect local socioeconomic conditions. The framework of examining resource users' spatial, occupational, and gear mobility used in this paper may contextualize local socioeconomic conditions in ways that are helpful to conservation managers and planners.

Acknowledgments I thank the people of Ahus and Muluk Villages, John Ben, the Manus and Madang Provincial Governments, the PNG

Department of Environment and Conservation, the National Fisheries Authority, the University of PNG, T. Poluma, H. Malai, Francis. Thanks to D. Feary and T. Hughes for providing comments on drafts of this manuscript. This work was supported by the David and Lucile Packard Foundation through a grant to the Wildlife Conservation Society.

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