Conservation Biology

Contributed Paper

Effectiveness of Community Forestry in Prey Long Forest, Cambodia

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Abstract: *Cambodia has 57% forest cover, the second highest in the Greater Mekong region, and a high deforestation rate (1.2%/year, 2005–2010). Community forestry (CF) has been proposed as a way to reduce deforestation and support livelihoods through local management of forests. CF is expanding rapidly in Cambodia. The National Forests Program aims to designate one million hectares of forest to CF by 2030. However, the effectiveness of CF in conservation is not clear due to a global lack of controlled comparisons, multiple meanings of CF, and the context-specific nature of CF implementation. We assessed the effectiveness of CF by comparing 9 CF sites with paired controls in state production forest in the area of Prey Long forest, Cambodia. We assessed forest condition in 18–20 randomly placed variable-radius plots and fixed-area regeneration plots. We surveyed 10% of households in each of the 9 CF villages to determine the proportion that used forest products, as a measure of household dependence on the forest. CF sites had fewer signs of anthropogenic damage (cut stems, stumps, and burned trees), higher aboveground biomass, more regenerating stems, and reduced canopy openness than control areas. Abundance of economically valuable species, however, was higher in control sites. We used survey results and geographic parameters to model factors affecting CF outcomes. Interaction between management type, CF or control, and forest dependence indicated that CF was more effective in cases where the community relied on forest products for subsistence use and income.*

Keywords: biomass, deforestation, degradation, forest management, participatory forestry

Efectividad de la Silvicultura Comunal en el Bosque Prey Long, Camboya

Resumen: *Camboya tiene una cobertura forestal de 57%, la segunda más grande en la región Mayor del Mekong, y una tasa de deforestación alta (1.2% y^{-1}, 2005–2010). La silvicultura comunal (SC) se ha propuesto como una forma de reducir la deforestación y apoyar los medios de vida a través del manejo local de los bosques. La silvicultura forestal está expandiéndose rápidamente en Camboya. El Programa Nacional de Bosques busca designar un millón de hectáreas de bosque para la SC para 2030. Sin embargo, la efectividad de la SC en la conservación no está clara debido a la falta global de comparaciones controladas, los significados múltiples de SC y la naturaleza de contexto específico de la implementación de SC. Estudiamos la efectividad de la SC al comparar nueve sitios de SC con controles pareados en bosques de producción estatal en el área del bosque Prey Long, Camboya. Estudiamos las condiciones forestales en 18-20 parcelas colocadas al azar y con radios variables y en parcelas con un área fija de regeneración. Encuestamos el 10% de las casas en cada una de las nueve aldeas de SC para determinar la proporción que usa productos forestales como medida de casas con dependencia del bosque. Los sitios de bosque comunal tuvieron menos indicadores de daño antropogénico (tallos cortados, tocones de árboles, árboles quemados), una biomasa superficial mayor, más tallos regenerativos y una abertura reducida del dosel que en las áreas de control. Usamos los resultados de las encuestas y parámetros geográficos para modelar los factores que afectan los resultados de la SC. La interacción entre el tipo de manejo, SC o control, y la dependencia del bosque indicó que la SC es más efectiva en casos donde la comunidad depende de productos forestales para subsistir y generar ingresos.*

Palabras Clave: Biomasa, deforestación, degradación, manejo de bosques, silvicultura participativa

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Paper submitted November 28, 2012; revised manuscript accepted July 7, 2013.

Conservation Biology, Volume 00, No. 0, 1–10

DOI: 10.1111/cobi.12217

Introduction

Tackling tropical forest loss demands well-crafted policy interventions that engage with direct and indirect socioeconomic drivers, including major industries, subsistence use, and management regime (Geist 2002; Butler & Laurance 2008). Unabated tropical deforestation (Wright 2005) and the failure of some state-protected areas to take local people's needs and traditional practices into account (Colchester 2004; Hayes & Ostrom 2005) has led some to favor a local, rights-based approach to conservation (Campese et al. 2009). Community forestry (CF) is an initiative that has been rapidly expanding since the 1980s (White & Martin 2002; Agrawal et al. 2008; Sunderlin et al. 2008); it aims to protect forests and benefit local livelihoods (Lawrence et al. 2006; Charnley & Poe 2007).

Community forestry is a broad term, and due to the variation in CF aims and practices, it is difficult to make generalizations about its effectiveness. There is an expanding body of research on community management of natural resources and on the factors affecting success (e.g., Gibson et al. 2005; Agrawal & Chhatre 2006; Ostrom 2007). Evidence of the success of CF and the conditions of successful CF is limited (Pagdee et al. 2006; Bowler et al. 2010). The effect of CF on forest condition is particularly important as an indicator of success because it has ecological and social significance. We used signs of anthropogenic damage, plant biomass, canopy openness, tree regeneration, abundance of economically valuable species, tree basal area, and tree species diversity as measures of forest condition. Globally, there have been 34 controlled studies that report data on forest condition (Bowler et al. 2010). Most studies report on only a few ecological indicators. Given the long history of CF in South Asia, studies of CF are highly skewed; approximately 60% are from India and Nepal. There is a need for studies on the ecological impact of CF in countries in other regions of the world, where CF has developed more recently. Cambodia is one such country.

In addition, there is a need to better understand what conditions facilitate CF, including management practices, governance, and dependence of the community on the forest (hereafter forest dependence) (Ostrom 2007). Assessment of forest dependence and a contextualized understanding of what this means in practice would greatly enhance our understanding of why we see variation in the success of CF (Lise 2000).

We defined CF as a scheme that vests responsibility of management of local forests in local communities, aims to produce social and economic benefits to local forest communities through forest management, and aims to maintain or improve forest cover and condition.

We sought to assess the impact of CF management on forest condition in Prey Long forest, Cambodia, and examined whether CF and state management have significantly different impacts on forest condition.

Methods

Study Site

Cambodia is an excellent case study for assessing tropical forest conservation in the context of weak institutions (Clements et al. 2010). Management of forests in Cambodia is divided between the Ministry of Environment, which holds jurisdiction over protected areas, and the Forestry Administration (FA), which manages areas of production forest. The greater Prey Long region falls under the FA and is classified as production forest.

CF spread to Cambodia in the 1990s (Blomley et al. 2010). At first CF only secured small patches of degraded forest for local communities (Chandet et al. 2010). CF sites are formally registered by the Ministry of Agriculture Forestry and Fisheries (MAFF), following election of a committee and mapping of the proposed area by FA officials. Communities are under obligation to protect the forest by maintaining forest cover and limiting degradation for 5 years before harvesting timber. Communities regularly patrol the CF areas to deter illegal logging.

The Prey Long landscape covers 520,000 ha (Ashwell et al. 2004); however, 80,000 ha was identified as the most biologically important (McDonald 2004). Prey Long is a lowland evergreen forest, home to 80% of Cambodia's economically valuable and endangered endemic tree species; thus it is a priority for floral conservation (Olsson & Emmett 2007; Strange et al. 2007).

In areas where high-quality forests persist, Cambodian rural populations are dependent on forest products as a major source of income. Approximately 250,000 people live in 340 villages in and around Prey Long (Olsson & Emmett 2007). Oleoresins from *Dipterocarpus* trees and rattans (*Calamus* sp.) are the most significant nonwood forest products. Firewood and timber for building are also significant subsistence forest products. Revenue from resin trees and timber to build homes are often reported as the motivation to engage in CF (Biddulph 2010; Blomley et al. 2010).

Prey Long also contains valuable hardwoods—including *Lagerstroemia* and *Dipterocarpus*—and luxury timber trees—*Dalbergia* and *Afzelia* (*Febaceae*), which have dark, dense wood and are almost extinct in Prey Long (Schmidt & Theilade 2010). The capacity of local communities to manage Prey Long forest is of interest to national and international policy makers and local people because of the potential contribution of CF to reducing carbon emissions from deforestation and degradation (REDD+) (Agrawal & Chhatre 2006; Hayes & Persha 2010).

Natural resource management efforts in Cambodia are encumbered by political conditions that include lack of judicial independence and hierarchical bureaucracy (De Lopez 2004). Deforestation in Cambodia is often driven by the armed forces (Le Billon 2000; Fox 2009) and more recently economic land concessions (De Lopez 2001) and small-scale agricultural expansion.

In general, CF sites have been located in areas of degraded forest (Blomley et al. 2010). However, in the area of Prey Long, CF sites contain relatively valuable forest. Prey Long is a suitable area to test the interaction between forest dependence and CF success because in this area local people still rely on forest products.

Site Selection

Forests across the Prey Long area are primarily moist, lowland, evergreen forest. The areas in this study cover 3 of the 7 forest types identified by Theilade et al. (see Olsson & Emmett 2007), mainly evergreen forest, with some areas of deciduous forest and a few plots in stands of *Lagerstroemia.*

Nine CF sites were selected around the area of Prey Long forest in Kampong Thom province. Each CF site was paired with a nearby control area of state forest (Fig. 1). We used Geographic Information System (GIS) maps to select paired sites with matching length of roads within the forest area, distance to the nearest settlement, forest type, and forest cover. Site information came from the most recent Forest Administration Survey (2006). Sites were also discussed with local guides, who in some cases alerted us when the FA maps did not yet show certain areas proposed to become CF sites or where the map showed a CF border in a slightly different location to the actual CF area patrolled (such as Ou La community forest). In one case, a CF area that had been mapped by the FA was rejected by the community (Sam Aong community forest, removed from Fig. 1). Pairing was performed with the aim of controlling for baseline differences. In some cases, no appropriate areas of unmanaged forest could be found near the CF site, in which case the best available options were chosen with preference given to matching forest type.

Indicators of Forest Condition

We assessed indicators of forest condition—forest density and regeneration, logging evidence, and other factors expected to contribute to deforestation. The latter included both biophysical factors and patterns of forest use that might affect CF implementation.

Forest condition indicators were measured by stratified random sampling. In each of the 18 sites (9 CF and 9 controls), indicators were measured at 18–20 randomly placed plots. Canopy openness was sampled at random locations around plots.

To test the effectiveness of CF management, we looked at 7 measures of forest condition: recent signs of anthropogenic damage, aboveground biomass (AGB), forest regeneration, canopy openness, tree basal area, abundance of economically valuable species, and tree species diversity. Of these, anthropogenic damage is likely to be the most sensitive indicator of management effectiveness, whereas the others are more likely to be biased toward baseline differences. Signs of anthropogenic damage were assessed by counting the number of trees >10 cm diameter at breast height (DBH) cut down or burned since CF implementation (Persha & Blomley 2009). Estimation of time since damage occurred was necessarily subjective and was based on freshness of cut, signs of regrowth, and local knowledge of when particular clearings were made. If damage appeared to have occurred several years ago but the date was doubtful, we erred on the side of caution and did not record it as recent.

Trees >10 cm DBH were sampled proportional to size in variable-radius plots (relascope plots), the most efficient for measuring basal area and biomass (Philip 1994). Stems <10 cm DBH and >0 cm DBH (stems that reached requisite height) were sampled in 1.5-m fixed-radius plots to measure regeneration sampling proportional to frequency. Fixed- and variable-radius plots were combined to utilize their respective efficiencies (Radtke & Packard 2007).

Canopy openness was sampled at random points with a canopy scope, which is suitable for simple and rapid assessment of understory light environments, even where light levels are low, as in mature tropical forest (Brown et al. 2000). A local guide identified tree species by common names, and we took leaf samples. An expert compared the leaves we collected with herbarium specimens and a Cambodian tree species list (CTSP/FA 2003). The same guide helped us to identify trees at both paired CF sites and control site where possible so that variation in common names would have minimal effect on the data.

The abundance of valuable timber tree species was measured. This indicator was designed to be sensitive to logging pressure; therefore, species were chosen that were highly valued by communities and locally known to be targeted by loggers (F.H.L., unpublished data): *Dipterocarpus alatus*, *Sindora cochinchinensis*, *Anisoptera costata*, *Dialium cochinchinense*, *Crypteronia paniculata*, *Dalbergia cochinchinensis* and *Lagerstroemia* sp.

Factors Affecting Deforestation

Factors expected to contribute to deforestation were chosen based on the literature (Geist 2002; FAO 2010) and measured using GIS software and household survey data. Baseline land cover had 3 levels: evergreen forest, deciduous forest, or nonforest and data were derived from the 2006 Forest Administration Survey. The more recent 2010 Forest Administration Survey was not used because we wanted to use the land cover data as a baseline—the 2006 data were collected when most CF sites were established between 2005 and 2009.

We measured distance to nearest village with ArcGIS. (All ArcGIS software was ESRI ArcMap version 10.0.)

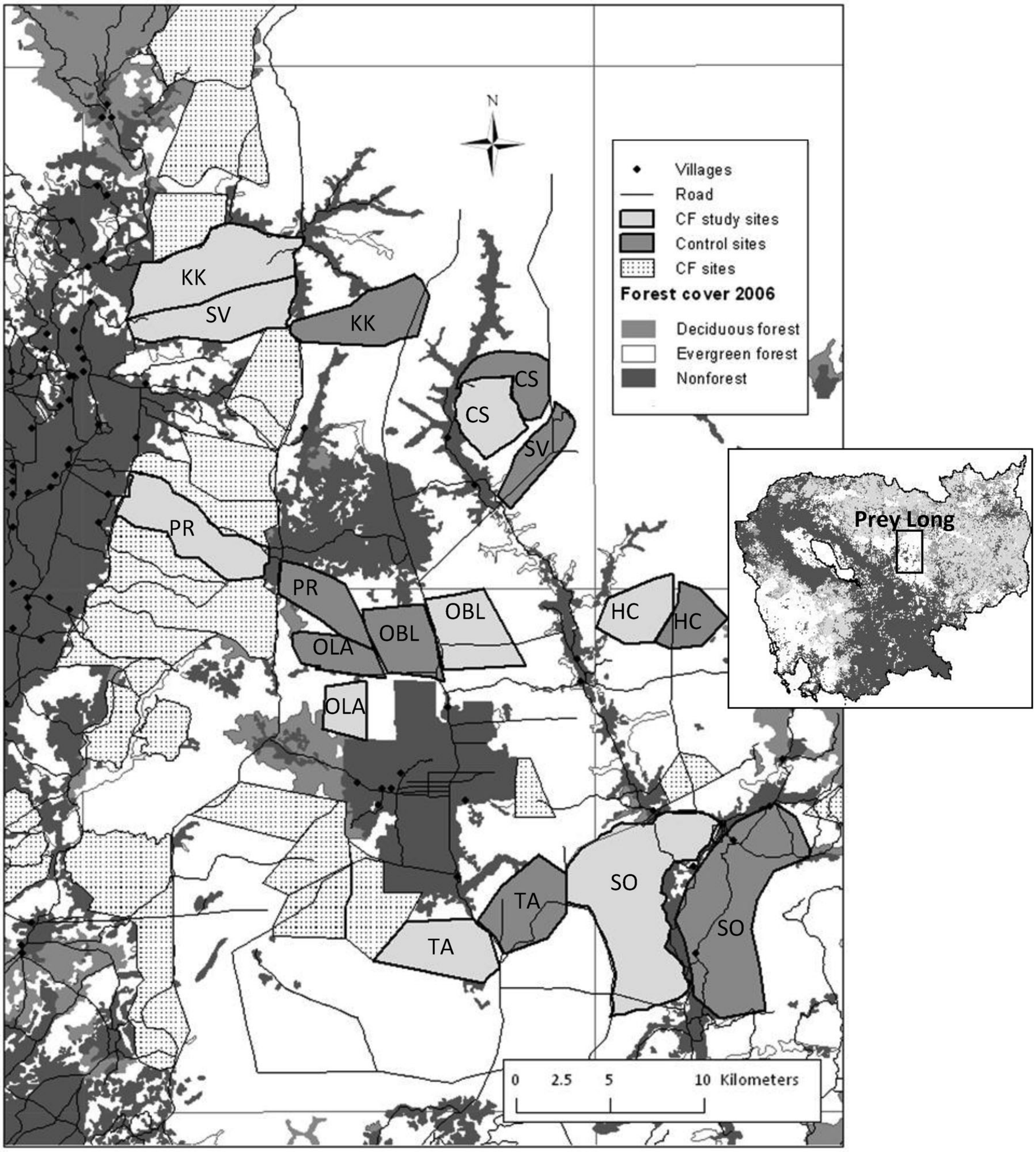

Figure 1. Study sites, Prey Long Forest, Cambodia (community forest [CF] study sites, CFs included in this study; CF sites, CFs not included in the study; CF and control sites are labeled with the same 2 letter codes for each pair; OLA CF outline is an approximation (see text); SV control site could not be placed closer to SV because a rubber concession and established agricultural lands were nearby). Inset map shows forest cover in Cambodia and location of Prey Long forest.

We expected a shorter distance to reduce forest condition; however, a short distance might also enable easier patrolling. We measured distance to nearest commercial center with ArcGIS. We expected proximity to commercial centers to particularly affect illegal logging due to demand for timber and wood processing facilities.

We measured population pressure as kernel of population of nearest 25 villages weighted by distance, that is, summed local population with distance individuals would have to travel to access the forest taken into account. We measured distances with ArcGIS. We measured proportion of household survey respondents native to that village as mean score ranging from 0 to 1, where 1 represents all respondents born in the village and 0 represents no respondents born in the village. We measured distance to nearest road, which would affect access and ease of timber transportation with ArcGIS. We calculated forest dependence, measured as proportion of households who derive income from forest products, using household survey data.

To test the effect of forest dependence on CF success, we developed an indicator of forest dependence based on household survey data taken at each of the 9 CF villages. Household surveys were conducted with at least 10% of households, randomly selected. Forest dependence was measured as proportion of households who derived income from forest products excluding timber but including hard resin from *Shorea guiso*, oleoresin from *D. alatus*, rattans, such as *Calamus tetradactylus*, and vines and other forest products. The numerical average ranged from 0 to 1, depending on the proportion of survey respondents who depended on forest products for monetary income. We also used an indicator of migration, which can affect forest condition because it is often associated with low forest dependence and pressure for new agricultural land. Levels of migration were measured simply as the proportion of respondents native to the village. Respondents born in the village were assigned a score of 1 and those born elsewhere were assigned a score of 0. The overall score for each village was the mean response.

Data Analyses

The difference between CF and controls was examined using a mixed model (fixed and random effects) to take into account all factors that might affect deforestation and forest condition. Mixed effects models are a powerful tool for the analysis of grouped data (Pinheiro & Bates 2000)—in this case plots located within sites.

Indicators of forest condition (AGB) (canopy openness, etc.) were modeled using a selection of the factors shown below (derived from our assessment of factors affecting deforestation):

$$\begin{aligned}\mathrm{AGB} = {} & \mathrm{For.Type} + \mathrm{Dist.Rd} + \mathrm{Dist.Vill} + \mathrm{Dist.CC} \\ & + \mathrm{Dist.P} + \mathrm{Native} + \mathrm{For.Dep} \times \mathrm{CF} + \varepsilon_{\mathrm{SITE}} \\ & + \varepsilon_{\mathrm{SITEPAIR}}, \end{aligned} \quad (1)$$

where For.Type is the baseline forest type (evergreen, deciduous, or open), Dist.Rd is distance to road, Dist.Vill is distance to village, Dist.CC is distance to commercial center, Dist.P is total population pressure weighted by distance, Native is proportion of survey respondents born in the village, For.Dep is proportion of respondents earning income from forest products, CF is CF treatment or control (fixed effects), $\varepsilon_{\mathrm{SITE}}$ is the error associated with random selection of sites from a normally distributed population, and $\varepsilon_{\mathrm{SITE\ PAIR}}$ is the error associated with random selection of the paired sites (random effects).

The effect of different predictors in the model was tested in R, version 2.13.1, package nlme. Predictors for each response variable were chosen for inclusion in the model with the function stepAIC (R, version 2.13.1, MASS package), which performs stepwise regression and selects variables that minimize the Akaike information criterion (AIC). The predictors selected for each response variable are shown in Supporting Information. Data were tested for spatial autocorrelation, which was found not to affect the response variables.

We calculated AGB of living stems with the following equation because it was the best predictive model for moist evergreen forest stands (Chave et al. 2005):

$$\begin{aligned}\mathrm{AGB}_{\mathrm{est}} = {} & p \times \exp(-1.449 + 2.148 log(D) \\ & + 0.207(log(D))^2 - 0.0281(log(D))^3), \end{aligned} \quad (2)$$

where $\mathrm{AGB}_{\mathrm{est}}$ is estimated aboveground biomass, D is diameter at breast height (cm), and p is wood density derived from the Global Wood Density database (Zanne et al. 2009). When the species of a tree was unknown, the average wood density for the genus was used. If we did not know the genus, we used the average wood density across all known species in the data set.

For dead stems and logs, the height (or length) was measured and the following equation (Chave et al. 2005) was used to calculate biomass:

$$\mathrm{AGB}_{\mathrm{est}} = \exp(-2.187 + 0.916 \times \log(pD^2H)), \quad (3)$$

where H is height (m).

Biodiversity was calculated using Fisher's (log series) alpha:

$$\alpha = (N(1 - x))/x, \quad (4)$$

where α is Fisher's alpha, N is number of individuals sampled, and x is estimated from the iterative solution of

$$S/N = ((1 - x)/x) - (-\ln 1 - x), \quad (5)$$

where S is the number of taxa. This indicator was calculated based on local names, checked for consistency by asking all villagers for information on local synonyms. For example, a tree locally called *pes* and *prub tru* was always recorded as *pes*. Fisher's alpha as an indicator was chosen because it is derived from ecological principles, has low sample size sensitivity, and good discrimination (Magurran 2004).

Results

Forest condition between CF and control sites differed significantly. CF sites had a mean of 4.00 m^2/ha (SE 1.32) fewer damaged trees than control sites ($p = 0.0195$) (Fig. 2). Baseline forest type also had a significant effect on signs of anthropogenic damage. There were a mean of 1.15 (SE 0.54) more damaged trees in deciduous forest than in evergreen forest, $p = 0.035$ (Supporting Information). AGB showed 434 Mg/ha (SE 180) more biomass in CF sites compared with controls ($p = 0.0423$) (Fig. 3).

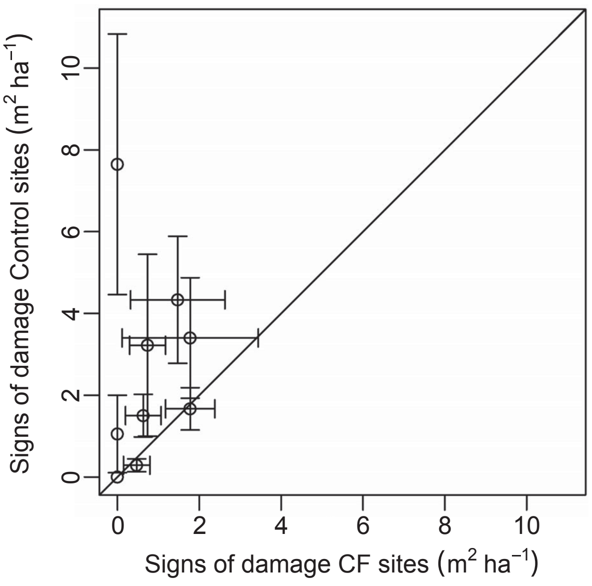

Figure 2. Signs of damage at community forest (CF) sites plotted against damage at control sites. Each point is a paired site. Diagonal line is 1:1 relationship (i.e., equal damage for CF and paired controls). Error bars show standard error of the mean.

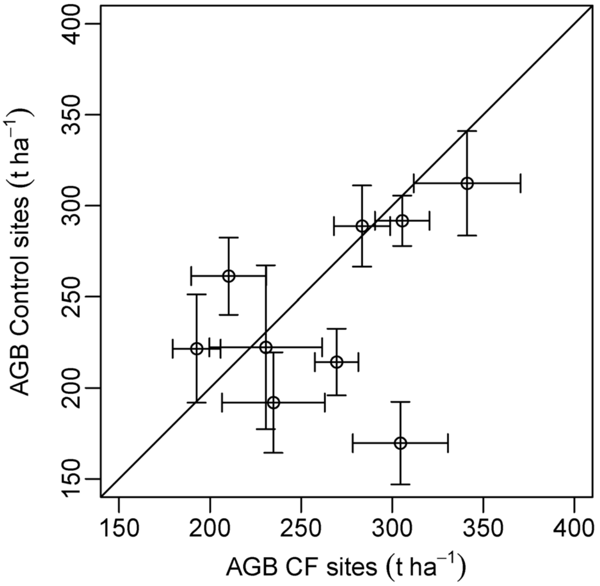

Figure 3. Aboveground biomass (AGB) at community forest (CF) sites plotted against AGB at control sites. Each point represents a paired site. Diagonal line is 1:1 relationship (i.e., equal AGB for CF and paired controls). Error bars show standard error of the mean.

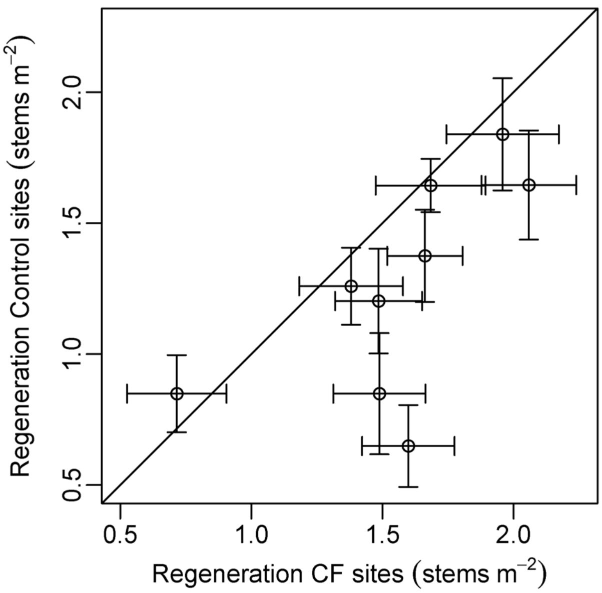

Figure 4. Regeneration at community forest (CF) sites plotted against regeneration at control sites. Each point represents a paired site. Diagonal line is 1:1 relationship (i.e., equal regeneration for CF and paired controls). Error bars show standard error of the mean.

Mean canopy openness, was significantly greater in control sites than in CF sites, 5.7 more points on a 0–20 scale (SE 1.3), ($p = 0.0005$) (Supporting Information). There were 0.3 (SE 0.11) more regenerating stems per meter in CF sites, ($p = 0.015$) (Fig. 4). Baseline forest cover also had a significant effect on regeneration; there were 1.04 (SE 0.16) fewer regenerating stems per meter in deciduous forest compared with evergreen forest ($p = 0.00$). Basal area did not differ significantly (-10.83 m^2/ha [SE 5.78]) between CF sites and controls when forest dependence was the interaction term ($p = 0.10$) (Fig. 5; Supporting Information).

Across all sites, 533 morphotypes were identified to local names, of which 90 could be identified to species. The endangered species *Diospyros crumenata* and *D. cochinchinensis* were found. Several species identified had not yet been assessed by the International Union for Conservation of Nature Red List but are locally considered rare, such as *Heritiera javanica*. There was a significant difference in the abundance of valuable species. There were 3.14 m^2/ha (SE 1.01) more valuable trees in control sites ($p = 0.017$) (Fig. 6), suggesting that more high-value trees were logged from CF sites. However, CF sites with high forest dependence had significantly more valuable species ($p = 0.015$) (Supporting Information). A nonsignificant difference of 0.7 (Fisher's alpha, unitless index) was found in the level of biodiversity between CF and control sites (Supporting Information). As distance to commercial centers increased biodiversity decreased significantly, -0.00039 (SE 0.00013; $p = 0.0071$).

The predictor variables identified through stepwise AIC comparisons were CF/control sites, baseline forest

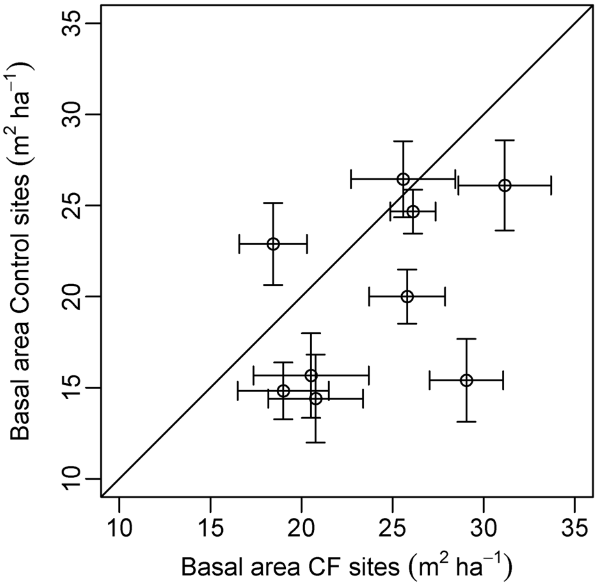

Figure 5. Basal area at community forest (CF) sites plotted against basal area at control sites. Each point represents a paired site. Line indicates 1:1 relationship (i.e., equal aboveground biomass for CF and paired controls). Error bars show standard error of the mean.

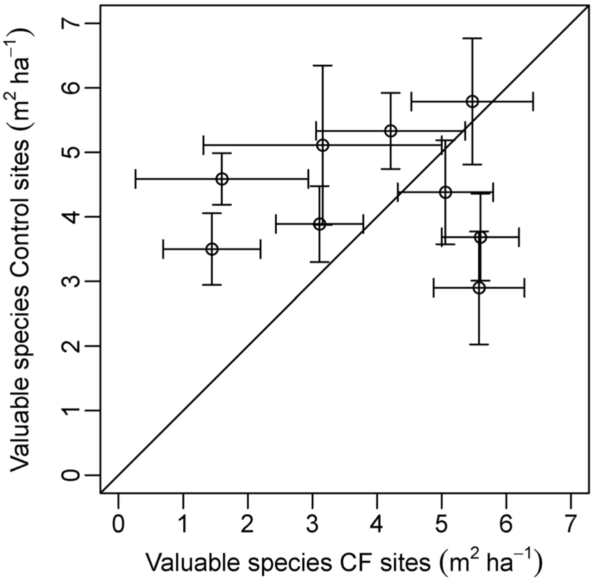

Figure 6. Economically valuable species at community forest (CF) sites plotted against valuable species at control sites. Each point represents a paired site. Line indicates 1:1 relationship (i.e., equal valuable species abundance for CF and paired controls). Error bars show standard error of the mean.

type, distance to commercial center, distance to nearest village, distance to road, and the interaction term, forest dependence × CF. Baseline forest type was significant for the response variables signs of anthropogenic damage, basal area, and regeneration (Supporting Information). Distance to commercial center was significant for the response variables basal area ($p = 0.017$), canopy openness ($p = 0.0015$), and biodiversity ($p = 0.0071$). The indicator of migration, native was not significant for AGB ($p = 0.18$) but was chosen by stepAIC.

The interaction term forest dependence × CF was chosen by stepAIC for basal area ($p = 0.1$), valuable species ($p = 0.015$), and signs of damage ($p = 0.094$) (Supporting Information).

Discussion

Our results indicated that CF successfully maintained or improved forest condition. This result is important in the context of the limited ecological evidence to support CF implementation (Charnley & Poe 2007; Bowler et al. 2010). Signs of damage, canopy openness, regeneration, and AGB all showed that CF management was successful at maintaining forest condition compared with state management in control sites.

CF management did not affect basal area or biodiversity to a significant degree, and abundance of valuable species was higher in control sites. This may be because most CF sites were established 2–5 years prior to sampling, so basal area and biodiversity may not have been affected yet. Valuable species may be more abundant in controls because these areas were located closer to the core area of Prey Long, and although now disturbed, these sites may retain rare species not found closer to villages in CF sites. Alternatively it could be that CF sites, although generally less disturbed, are being selectively logged illegally.

The nonsignificant difference in species biodiversity may be explained by the fact that although logging tends to reduce the richness of late-successional trees, it often increases the richness of early-successional tree species. In forests, such as those in this study, that are naturally dominated by a small number of late-successional tree species, low-level logging may increase biodiversity due to a rise in number and richness of early-successional species (Sheil 2001). This hypothesis is consistent with the fact that species diversity increased closer to commercial centers—suggesting that more degraded areas has higher biodiversity. Alternatively variations in local naming, particularly local synonyms, may have affected this result.

Seven other quantitative studies on CF management that addressed effects on biodiversity, and 5 that assessed species richness, comparing CF with state or no management, showed no consistent effect (Bowler et al. 2010). Four studies that assessed the effects of CF on SD indicated fewer cut stems in community managed areas; however, others showed the opposite result (Bowler et al. 2010). Bray et al. (2008) showed that a majority of *ejidos,* CF sites in Mexico, were effective in reducing deforestation compared with protected areas. Somanathan et al. (2006) and Gautam et al. (2004) used remote sensing methods to show that CFs in the Himalaya had greater forest cover than state managed forest. Persha and Blomley (2009) found that in the West Usambara Mountains, Tanzania, communal management showed better forest condition and fewer signs of damage within the previous 12 months, than either joint forest management or centralized management.

Baseline forest type was an important predictor of signs of anthropogenic damage, regeneration, and basal area. Distance to road was not a significant predictor for any of the indicators, which confounds much of the literature on causes of deforestation (Geist 2002). This may be because the area is a lowland forest and therefore relatively accessible throughout. Distance to nearest village predicted valuable species abundance, and distance to commercial center predicted regeneration, basal area, biodiversity, and canopy openness. By controlling for physical forest attributes at the plot level, we created a more sensitive assessment of the impact of CF management.

Forest dependence affected 3 forest condition metrics: basal area, SD, and valuable species. Because it was expected that signs of anthropogenic damage would be the most reliable indicator of recent management impact, this result indicates forest dependence did affect the ecological success of CF. We suggest that this might be because there was a greater incentive to engage in forest management. In Cambodia, as elsewhere, CF has been criticized as a means to make communities a cheap workforce to patrol forests, which officials would otherwise be responsible to maintain (Gibson et al. 2000; Biddulph 2010). Our result gives support to these arguments, showing that attempts to establish CF sites in areas of forest that are of little or no use to communities are arguably exploitative and likely to be ineffective.

Prey Long includes areas of valuable forest, used by local communities, allocated to CF. Therefore, if CF can be expected to work at all in Cambodia, it should show a significant result in this area. Thus the results cannot be generalized to all CF sites in Cambodia, many of which are less than 500 ha and located in degraded forest. However, this result can be generalized to other areas of valuable forest where local communities derive significant benefits from the forest, including internationally to countries with similar levels of development, weak state law enforcement, and medium- to high-value lowland tropical forest.

A previous study of floral composition in Prey Long with a limited sample size found only 63 species (Olsson & Emmett 2007). We found 90 known species—almost a 50% increase—that confirms the importance of Prey Long for biodiversity conservation, as recognized in early calls for the protection of Prey Long as a UNESCO World Heritage site (Ashwell 1997). Our results suggest that thorough botanical surveys in the area are needed to assess the biological value of Prey Long forest.

In Prey Long forest, CF appears to be effective at reducing degradation. CF was affected by dependence on forests. This suggests that forest dependence, rather than causing forest degradation, creates motivation to put effort into protecting forests.

For CF to be most effective, sites should be located in areas of high-quality forest, far from commercial centers, where local communities depend on forest products. On the other hand, CF sites close to population centers and deforestation threats, but with high forest dependence, may be the most important for reducing deforestation.

CF sites should be established rapidly in order to prevent delays, during which time sites may be degraded by illegal logging, reducing the abundance of locally valuable species.

Reducing deforestation and improving forest condition is being pushed as a measure of CF success by those developing REDD+ schemes. It has been suggested that CF is a significant means of conserving carbon, particularly under conditions of community ownership of forests (Chhatre & Agrawal 2009). Our results show that in Prey Long AGB is significantly higher in CF sites.

One of the major trade-offs in CF management is that community extraction leads to a collective action problem—how to limit short-term use for maximal long-term gain. In Prey Long, forest dependence primarily means income from resins, a nonwood forest product collected sustainably from species of *Dipterocarpus*. Therefore, forest dependence does not imply pressure to exceed the maximum sustainable timber yield. In areas where communities primarily use forests for wood products, forest dependence may both incentivize CF protection and at the same time make it more difficult to achieve.

Cambodia's National Forest Program aim of expanding CF to one million hectares should be implemented in areas of high-value forest such as Prey Long, where communities derive significant subsistence and monetary benefit from the forest through sustainable use. Their way of life and motivation to engage in forest management will not be easily replaced, once lost.

Acknowledgments

F.H.L. was supported by St. Peter's College Foundation, 2011 field trip supported by RGS Slawson Award. D.P.B. was supported by HSBC Climate Partnership. Conservation International Cambodia and Pact International Cambodia provided logistical support. Many thanks to research assistants, T. Ng, Y. Hy, V. Ouern, L. Hong, P. Sras, J. E. Norrie, and W. Gray. Southeast Asia teams at Kew and Edinburgh herbaria are gratefully acknowledged for help with specimen identification.

Supporting Information

Forest metrics results for community forest and control sites (Appendix S1) and factors affecting forest condition derived from the mixed effects model (Appendix S2) are available on-line. The authors are solely responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

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