Is poverty more acute near parks? An assessment of infant mortality rates around protected areas in developing countries

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Abstract The relationship between conservation and poverty has received extensive attention recently, and the impacts of protected areas on the welfare of communities surrounding them has been debated. I seek to contribute to this debate by using a unique sub-national database of infant mortality rates for an analysis of such mortality surrounding protected areas in developing countries. The paper tests the hypotheses that poverty rates in regions surrounding protected areas in developing countries are higher than national averages and that poverty rates are highest around large and strictly protected areas. Preliminary evidence suggests that infant mortality rates surrounding protected areas, and even those surrounding the most strictly protected areas, are not very different from national rates. Infant mortality rates are significantly higher among populations surrounding larger protected areas but the causal relationship is uncertain. Data limitations and other problems related to this kind of global analysis are discussed. Information of the kind presented in this paper can assist management authorities to assess the relative poverty surrounding protected areas in their countries so as to set priorities for poverty alleviation interventions, and may serve as a useful sampling frame for local case studies and long-term monitoring.

Keywords Biodiversity conservation, conservation and development, parks, protected areas, poverty.

Introduction

Many of the poorest countries are located in tropical regions that are also biologically diverse, containing many of the world's rare and threatened species. Attention is increasingly being drawn to the benefits of biodiversity for the global community versus the real costs incurred by poor communities in rural areas of the developing world, where large areas have been dedicated to nature conservation in the form of protected areas (Amend & Amend, 1995; WCMC, 2007). Local communities may suffer from displacement or dispossession at the time of establishment of a protected area, or restricted access to resources within protected areas (Ghimire & Pimbert, 1997). On the other hand, it has been argued that protected areas can benefit local communities by providing ecosystem services or opportunities for income-generating ecotourism activities (Scherl *et al.*, 2004).

The relationship between conservation and poverty has received extensive attention recently (Sanderson & Redford, 2003, 2004; Adams *et al.*, 2004; Roe & Elliott, 2004; Fisher *et al.*, 2005), and the specific relationship between protected areas and their impacts on local poverty levels or their potential to contribute to poverty alleviation has been contested (Scherl *et al.*, 2004; Wilkie *et al.*, 2006). Much of the evidence to date on the impacts of protected areas on local poverty has been based on a limited number of case studies (Cernea & Schmidt-Soltau, 2006; Upton *et al.*, 2008). Until recently there has been no comparative data on the levels of poverty surrounding protected areas worldwide and this has hampered broad-scale analyses of any interrelationships.

If protected areas exacerbate local poverty one could expect poverty rates in areas surrounding protected areas to be higher than national levels, and even higher surrounding those protected areas in the most restrictive categories of protection, where human consumptive uses are most limited. Similarly, larger protected areas would be expected to deprive communities of more resources than smaller protected areas, and hence one would expect poverty rates to be higher around such protected areas. This paper combines a global map of sub-national infant mortality rates with areas included in the 2006 World Database of Protected Areas (WCMC, 2006a) to test these hypotheses.

The IUCN system defines six categories of protected areas (IUCN, 1994) ranging in approximate order of strictness from strict nature reserves and wilderness areas (categories Ia and Ib, respectively), to national parks and national monuments (II and III, respectively),

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habitat management areas (IV), protected landscapes (V), and managed resource areas focusing largely on the sustainable use of biotic resources (VI). The categories associated with the strictest conservation status have been variously identified as I and II (Scherl *et al.*, 2004; Naughton-Treves *et al.*, 2005) and I-III (Zimmerer *et al.*, 2004; CEESP, undated). Here I assume categories I-III are the most restrictive in terms of human consumptive uses, and that IV-VI (and particularly V and VI) are more flexible in terms of human interventions and the sustainable use of resources within them. Although awareness of the need to reconcile conservation with human needs is growing (Fisher *et al.*, 2005), between 1985 and 1997 the area of protected areas established under the most restrictive categories grew at approximately the same rate as those in less restrictive categories (Zimmerer *et al.*, 2004). CEESP (undated) provides one possible reason for this continued growth in the size of the protected area estate in these categories: 'more prestige seems to have been attached to those [protected areas] designed to exclude [human communities] both as residents and decision-makers (usually corresponding to IUCN categories I, II and III)'.

Here I address the rates of poverty surrounding protected areas, not the numbers of people in poverty. Although poverty rates may be high surrounding protected areas, particularly in remote biodiverse regions such as the Amazon, the actual numbers of poor people are relatively small compared to the numbers in urban areas and densely settled agricultural regions (Chomitz *et al.*, 2007; K. Redford *et al.*, unpubl. data). I will return to this in the Discussion.

Methods

Infant mortality rates serve as a useful proxy for overall poverty levels because they are highly correlated with many poverty-related metrics such as income, education levels and health status (Dasgupta, 1993; Balk *et al.*, 2006). Infant mortality rates measure the number of deaths of infants under age 1 per 1,000 live births in a given year. Globally, national infant mortality rates range from a low of 3 to highs of >150 in countries suffering chronic food deficits or conflict. This metric is particularly good for distinguishing poverty levels at the lower end of the income ladder but because infant mortality rates tend to reach a lower asymptote and vary less at higher income levels they are less useful for distinguishing levels of wealth or well being at the higher end. When compared with other metrics of poverty, such as sub-national GDP estimates or small-area poverty estimates, infant mortality rates have the advantage that they are less likely to be influenced by the kind of skewed wealth distribution that may make otherwise poor areas appear well off because a few billionaires live there, and the data are available for 90% of the population in medium and low income countries (Balk *et al.*, 2006). Measurement of infant mortality rate is standardized and straightforward for statistical services in even the poorest countries, and the data are relatively robust.

A global gridded infant mortality rate map at 2.5 minute resolution, base-lined to the year 2000 and containing 10,370 sub-national units, was compiled by CIESIN (2005; see Storeygard *et al.*, 2007, for details). Sub-national infant mortality rate data were compiled from national and international sources (UNICEF, 2004) and matched to geographical information system (GIS) boundary files using *ArcMap* (ESRI, Redlands, USA). Most data were derived from vital registration systems but three developing countries (Brazil, China and Mexico) have high resolution data based on indirect measures. Because the year and source of the infant mortality rate data varied by country, an adjustment was applied to convert all estimates to a common year (2000), using a single source of year 2000 national infant mortality estimates (UNICEF, 2004).

For purposes of comparison, I consider areas with infant mortality rates <15 to be not poor, in the range of 15-32 to be moderately poor, 32-65 to be poor, 65-100 to be very poor, and >100 to be extremely poor. The global map of infant mortality rates depicts large swaths of sub-Saharan Africa, the Gangetic plain of India, all of Iraq and Afghanistan, and the western-most parts of China as falling in the extremely poor category (CIESIN, 2006). Much of the rest of South Asia is very poor, as well as rural portions of China and Mongolia, and all of Papua New Guinea. In Latin America, north-eastern Brazil and parts of Bolivia are very poor, and much of the Amazon, Peru, Ecuador and Central America are poor.

In this analysis I used the national IUCN category I-VI points database of the 2006 World Database of Protected Areas (WDPA), which contains records for 70,585 designated protected areas (WCMC, 2006a). I overlaid the protected areas' centroids (points representing the centre of each protected area) on the poverty map, removed selected protected areas that could not be clearly associated with a country-infant mortality rate polygon, and then added the infant mortality rate information to the protected areas data (for further details, see Appendix). The final cleaned points database included 61,065 protected areas with infant mortality rate values assigned, i.e. 86.5% of the original number of protected areas. The data were exported from the GIS to the statistical software package *SPSS* (SPSS, Chicago, USA) to carry out the analyses. Marine protected areas and protected areas without area information were excluded from analyses of infant mortality rate by size of protected areas, in the first case because the size of marine protected areas are not directly comparable to terrestrial protected areas (on average marine protected areas are four times larger), and in the latter because the data were simply missing. Marine areas were not excluded, however, from other analyses because, in principle, they may impact the livelihoods of coastal residents (through restricted access to fishing, through improved fisheries, or ecotourism benefits) just as much as terrestrial protected areas, and because many marine protected areas contain substantial terrestrial areas within their boundaries.

It is important to recognize that the infant mortality rate data are at a relatively coarse scale, with some countries having no sub-national reporting units, and many having only 2-5 sub-national units. The finest resolution infant mortality rate data are available for Brazil, Mexico and China, with 4,407, 2,409 and 2,367 sub-national units, respectively. Of the 199 countries included, the average number of sub-national units for all countries is 52.5 but 119 countries have only one unit, although most of these are countries with small populations: only nine non-Organization for Economic Development (OECD) countries with only one unit had populations >10 million. Spatially, however, several large countries such as the two Congos, Cote D'Ivoire, Chad, Iraq and Malaysia only had national data. Thus, this analysis is limited by the spatial resolution of the available infant mortality rate data. To account for this, in most analyses I only include countries with more than four sub-national units, and I undertook a separate analysis for Latin America, a region with particularly high resolution data.

Another issue is that the protected areas' centroids may not always properly represent the overall poverty levels or the number of biomes in and around the area. Given the relatively coarse spatial resolution of the infant mortality rate and biome data and the fact that many protected areas in the WDPA lack area and accurate boundary data, I judged it sufficient to utilize the centroids rather than attempt the more computationally demanding spatial analysis implied by overlaying grids. Had the full protected area extent been used, however, some of the larger protected areas would probably span areas with varying infant mortality rates, and the dominant infant mortality rate for the protected area would probably be different from the one obtained at the centroid. Strengths and weaknesses of the 2004 WDPA are discussed in Chape *et al.* (2005). The 2006 version is considerably improved but issues that persist include a mix of expert judgement and official encoding of IUCN category for some protected areas, missing area data for 7,730 protected areas of my sample (8.7% of the total), and missing establishment date information for 20,734 protected areas (34% of the total). In addition, the area data reported in the points database do not always conform to the area figures obtained through GIS analysis using the polygon representations of protected areas; however, using the polygon version of WDPA for IUCN category I-VI protected areas would have meant excluding an unacceptably large number of protected areas from this analysis because of missing boundaries.

For analyses by country income group, data from World Bank (2007b) were utilized. I grouped together high income OECD and high income non-OECD countries (since OECD status was not relevant to this analysis) but otherwise left the categories of low, lower middle, and upper middle income unaltered.

My null hypotheses are that there are no major differences in infant mortality rates by IUCN protected area or size category, and that infant mortality rates in areas surrounding protected areas are not significantly different from national rates.

Results

For the 10,490 protected areas in low and lower middle income countries the mean infant mortality rate is 32.5 ± SD 28 (range 1.9–330), i.e. in the poor category. In the low income countries only (n = 1,639), upon which much of this analysis rests, the mean infant mortality rate is 78 ± SD 30 (range 12.4–203), i.e. in the very poor category, and the distribution of infant mortality rates for these countries approximates a normal distribution (Fig. 1).

Upton *et al.* (2008) found that low income countries tend to have a larger area under the strictest forms of protection than richer countries, suggesting that the level of restriction on local resource access (particularly for countries with large protected area estates) may be exacerbating national poverty rates. If protected areas do contribute to higher poverty rates, one may expect infant mortality rates to be higher than national average in the vicinity of protected areas, and even higher surrounding the most restrictive protected areas. To test this, I utilize a subset of low, lower middle, and upper middle income countries with more than four sub-national infant mortality rate units and compare the average infant mortality rate for all protected areas, the average infant mortality rate for the most restrictive categories of protected areas (IUCN category I-III), and the national infant mortality rate (Table 1). There is no clear pattern discernible in the results. Sudan, Botswana, Mauritania, Iran, Senegal and Uganda have protected area infant mortality rates that are 10 or more deaths per 1,000 higher than the national average, and Namibia, Tanzania, South Africa, Kazakhstan, Pakistan, Niger and

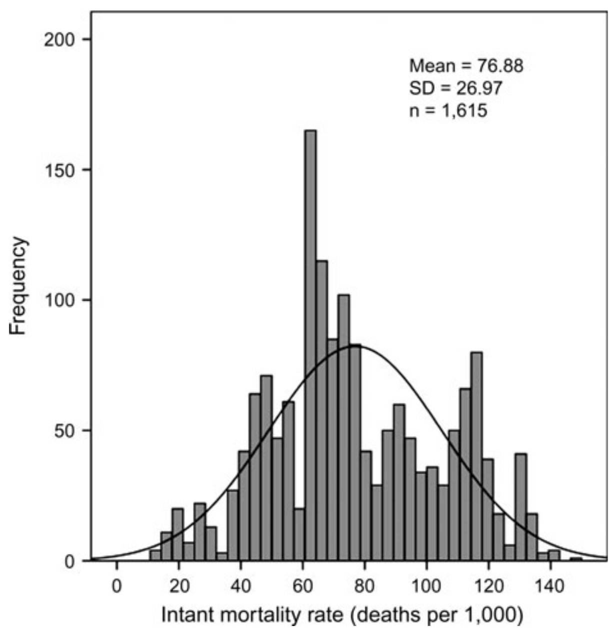

Fig. 1 Histogram of infant mortality rates for protected areas in low income countries (24 protected areas with infant mortality rates >150 excluded).

Mozambique have protected area infant mortality rates that are 8 or more deaths per 1,000 lower than the national average. Approximately the same number of countries fall above equality (zero difference) as fall below. Table 2 is constructed using the national average infant mortality rates for protected areas, the most restrictive protected areas, and the country as a whole. It shows that across the range of country income groups infant mortality rates are all within 1-2 deaths per 1,000 of each other, suggesting that there is little difference among poverty levels surrounding protected areas of different types and those at the national level (although the differences are statistically significant at P <0.001, two-tailed). This conclusion is confirmed by an analysis of protected areas in all low income countries with greater than four sub-national units. Overall there is not a statistically significant difference (P >0.10, two-tailed) between the average infant mortality rates for the most restrictive protected areas (mean = 78) and those in categories IV-VI (mean = 75.7), suggesting that poverty levels in areas surrounding both types of protected areas are comparable.

Upton *et al.* (2008) suggest that larger protected areas are more likely to have an impact on local poverty rates as measured by the infant mortality rate. I test this by analysing infant mortality rates for different size categories of protected areas in low income countries. For the reasons stated above I removed marine protected areas from consideration. Fig. 2 shows that infant mortality rates for all protected areas are lowest around the smaller protected areas, rising from *c.* 70 for protected areas <10,000 ha to 103 for protected areas ≥1 million ha. For the most restrictive protected areas the pattern is somewhat less clear, although infant mortality rates are still <80 in the 100,000 ha and below categories, and >85 for protected areas >100,000 ha. Differences by size category are statistically significant at P <0.001 (two-tailed). For low and lower middle income countries the infant mortality rate is highly correlated with the natural log of area (R^2 = 0.27, P <0.001). If only the most restrictive categories of protected areas are considered, R^2 increases to 0.47 (P <0.001). The same analysis carried out for all protected areas and the most restrictive protected areas in upper and upper-middle income countries gives an R^2 of 0.03 and 0.001 respectively (P <0.001), indicating there is virtually no relationship between protected area size and infant mortality rates in richer countries.

It is conceivable that longer established protected areas could have a higher impact on infant mortality rates because they may have denied residents access to resources over a longer time period. Testing this for the low-income countries, the correlation between infant mortality rate and the date of establishment is positive (R^2 = 0.05, P <0.001), suggesting that poverty rates are higher surrounding protected areas established more recently. Results are the same for the most restrictive protected areas. Using an earlier version of the WDPA, Zimmerer *et al.* (2004) found that restrictive and less restrictive protected area estates grew at approximately the same rate from 1985-1997. Using only the protected areas in low income countries with area and date of establishment data, in the 11 years 1980-1990 out a total of 378 newly designated areas the area under restrictive protected areas grew by 10.8 million ha, whereas the area under categories IV-VI grew by 18.2 million ha. In the 11 years 1991-2001 this pattern was reversed. Out of 270 newly designated areas, the cumulative area established under the most restrictive protected areas more than doubled to 25.3 million ha, whereas the area established under categories IV-VI declined by 60% to only 10.9 million ha. Fig. 3 shows the area added in the strictest categories by year. The average infant mortality rate surrounding restrictive protected areas established during the two periods declined from 77 to 70, suggesting that the newer strict protected areas are being established in less poor regions than in the earlier period.

Finally, it is possible that some patterns hidden in a global analysis of developing countries can be revealed by studying one region. Latin America has the advantage of relatively high resolution infant mortality rate data and a large number of protected areas representing

Table 1 Mean infant mortality rates near all protected areas (PA) and near the strictest protected areas, and national infant mortality rates (see text for data sources), with percentage differences compared to national infant mortality rates, ordered by percentage difference between all protected areas and national rates. Latin American countries are in bold. Empty cells indicate missing data.

Country	Mean (all)	Mean (strictest)	National	% difference between all PA and national	% difference between strictest PA and national
Sudan	90.7	81.9	65	25.7	16.9
Botswana	93.5	102.1	74	19.5	28.1
Mauritania	134.4	134.4	120	14.4	14.4
Iran	47.2	46.0	36	11.2	10.0
Senegal	90.3	87.5	80	10.3	7.5
Uganda	95.2	95.8	85	10.2	10.8
Ecuador	36.8	37.4	27	9.8	10.4
Benin	101.9	99.7	95	6.9	4.7
Guinea	118.2	118.2	112	6.2	6.2
China	37.9		32	5.9	
Viet Nam	28.8	33.3	23	5.8	10.3
Cambodia	100.3	98.5	95	5.3	3.5
Ethiopia	120.0	121.1	116	4.0	5.1
Togo	84.0	86.1	80	4.0	6.1
Peru	35.8	36.6	32	3.8	4.6
Ghana	65.6	70.6	62	3.6	8.6
Madagascar	89.3	86.0	86	3.3	0.0
Gambia	95.3	99.8	92	3.3	7.8
Mexico	28.0	27.5	25	3.0	2.5
Eritrea	55.8		53	2.8	
Nicaragua	36.7	40.1	34	2.7	6.1
Dominican Rep.	37.6	37.5	35	2.6	2.5
Paraguay	28.1	26.6	26	2.1	0.6
India	70.0	70.6	68	2.0	2.6
Gabon	62.0		60	2.0	
Nepal	70.9	71.5	69	1.9	2.5
Colombia	21.7	22.1	20	1.7	2.1
Armenia	33.5	32.1	32	1.5	0.1
Argentina	18.3	18.6	17	1.3	1.6
Mali	125.2	122.6	124	1.2	−1.4
Chile	12.1	12.1	11	1.1	1.1
Uruguay	16.1	18.6	15	1.1	3.6
Philippines	31.1	31.6	30	1.1	1.6
Venezuela	20.8	20.6	20	0.8	0.6
Costa Rica	10.8	10.9	10	0.8	0.9
Indonesia	35.7	35.0	35	0.7	0.0
Thailand	25.4	26.2	25	0.4	1.2
Cuba	6.8	7.0	7	−0.2	0.0
Uzbekistan	50.7	51.8	51	−0.3	0.8
Algeria	39.6	38.8	40	−0.4	−1.2
Haiti	80.5	83.0	81	−0.5	2.0
Lebanon	27.5	20.5	28	−0.5	−7.5
Brazil	34.4	32.3	35	−0.6	−2.7
Morocco	40.1	41.2	41	−0.9	0.2
Burkina Faso	106.1	107.2	107	−0.9	0.2
Bolivia	58.1	56.2	59	−0.9	−2.8
El Salvador	32.8	36.2	34	−1.2	2.2
Angola	152.5	138.6	154	−1.5	−15.4
Zimbabwe	71.2	62.6	73	−1.8	−10.4
Turkey	36.0	36.6	38	−2.0	−1.4
Guatemala	37.0	35.3	39	−2.0	−3.7
Cameroon	92.9	106.5	95	−2.1	11.5
Bangladesh	51.8		54	−2.2	
Nigeria	98.4	102.7	102	−3.6	0.7

Table 1 (Continued)

Country	Mean (all)	Mean (strictest)	National	% difference between all PA and national	% difference between strictest PA and national
Sri Lanka	13.3	13.6	17	−3.7	−3.4
Egypt	34.1	34.7	38	−3.9	−3.3
Zambia	97.2	98.5	102	−4.8	−3.5
Mongolia	54.6	54.6	60	−5.4	−5.4
Rwanda	112.2	122.9	118	−5.8	4.8
Kenya	70.3	68.8	77	−6.7	−8.2
Turkmenistan	68.3	65.2	75	−6.7	−9.8
Central African Rep.	107.1	102.1	115	−7.9	−12.9
Namibia	47.9	46.9	56	−8.1	−9.1
Tanzania	95.9	94.9	104	−8.1	−9.1
South Africa	41.7	35.1	50	−8.3	−14.9
Kazakhstan	50.4	54.4	60	−9.6	−5.6
Pakistan	75.1	74.0	85	−9.9	−11.0
Niger	148.7	141.9	159	−10.3	−17.1
Mozambique	110.4	105.8	130	−19.6	−24.2

all categories and sizes. I selected 18 countries in Latin America and the Caribbean (Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Mexico, Nicaragua, Paraguay, Peru, Uruguay, Venezuela) with 4-4,447 sub-national units (mean = 395, median = 15.5) that collectively hold 82% of the protected areas in the region. Fig. 4 shows that infant mortality rates vary significantly ($P < 0.001$, two-tailed) across the IUCN categories but not in any clearly discernible pattern. The mean infant mortality rate for the strictest categories of protected area is 26.8, and for the remaining protected areas it is 25.4, and although significant ($P < 0.05$, two-tailed) it is a barely noticeable difference and well within the margin of error of the data sets employed. Re-examining Table 1 and looking at the Latin American countries only, it appears that these countries tend to have slightly higher than national-level infant mortality rates in areas surrounding protected areas, particularly in Ecuador and Peru where many protected areas are located in the less developed highland and Amazonian regions. Mexico and Brazil, the two countries with the highest resolution infant mortality rate data, have a barely discernible difference between protected area and national average infant mortality rates. Fig. 5 shows that infant mortality rates tend to be slightly higher surrounding larger protected areas but once again the rates are virtually indistinguishable from one another.

Discussion

I have tested the hypotheses that poverty rates in regions surrounding protected areas in developing countries are higher than national averages, and that poverty rates surrounding more restrictive and larger protected areas are even higher. There are a number of limitations in the data sets, particularly their relatively coarse spatial resolution. Bearing these limitations in mind, the data suggest that infant mortality rates surrounding protected areas, and even those surrounding the most restrictive areas, are not particularly different from national rates. Obviously, if they affect infant mortality rates at all protected areas are just one among a number of potential factors, but the fact that there is not a clearer pattern suggests that protected areas are not major contributors to poverty at the scale of sub-national regions.

Infant mortality rates are significantly higher among populations in sub-national units with larger protected areas but the causal relationship is uncertain (an issue addressed below). The area consecrated to the most

Table 2 Mean infant mortality rates for all protected areas, the strictest protected areas, and at the national level (see text for data sources), by income category.

Income category		Mean (all)	Mean (strictest)	Mean national
Low income	Mean	89.6	91.6	88.8
	n (countries)	32	30	32
	SD	26.6	25.2	28.1
Lower middle income	Mean	43.0	43.1	42.5
	n (countries)	24	23	24
	SD	29.0	28.3	30.0
Upper middle income	Mean	34.7	32.4	34.1
	n (countries)	13	12	13
	SD	23.3	25.1	21.0

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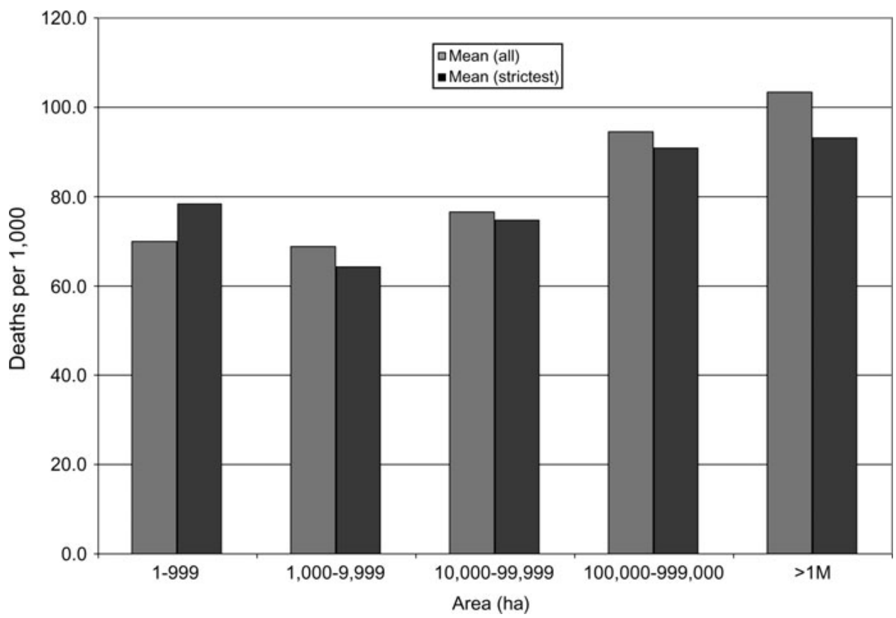

Fig. 2 Mean infant mortality rates for low income country protected areas by size category (marine protected areas not included), for all protected areas (IUCN categories I-VI) and strictest protected areas (categories I-III) only.

restrictive protective areas was 2.3 times higher in 1991-2001 than in 1980-1990 but the average infant mortality rates in surrounding areas are lower in the latter period. Thus, while more land area is being dedicated to the most restrictive types of protected areas, they are apparently being established in areas within developing countries that are less poor than previously. Finally, the Latin America regional analysis generally supported the null hypotheses that infant mortality rates surrounding protected areas are not significantly different from national rates and that there are no major differences in infant mortality rates by protected area category. As with the global analysis, infant mortality rates tend to be highest around the larger protected areas but the differences are less pronounced.

It is unlikely that any global or regional scale study can definitively settle the issue of the impacts of protected areas on the welfare of populations in the surrounding areas or be able to introduce enough controls to tease out the causal connections. To do this one would require time series poverty metrics of a higher spatial resolution than those currently available, and a suitable number of control variables such as time series national GDP and meteorological data (in rainfall dependent regions). There is a continuing need for carefully constructed local, social and conservation science research of the kind proposed by Wilkie *et al.* (2006) and demonstrated in the case studies compiled by Cernea & Schmidt-Soltau (2006). These studies are better able to tease out the causal connections between protected areas, their management strategies, local livelihood strategies, and the welfare of surrounding communities, even if the particularities of each case are often so site-specific that it is not possible to scale these studies up to a global view of any relationship between protected areas and poverty. Although my analysis and that of Upton *et al.* (2008) demonstrate the limitations of such studies at a global scale, there is potential for these approaches to inform the selection of study sites and to assist in long-term monitoring. There is a need to invest, however, in the creation of higher resolution infant mortality and other poverty metrics, and to develop

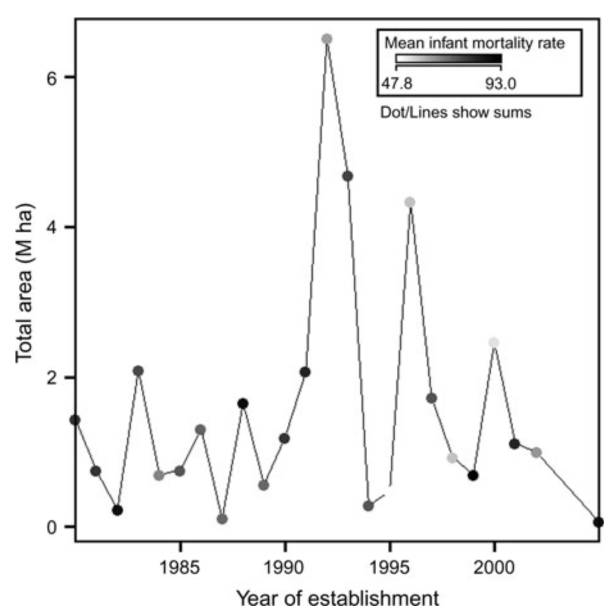

Fig. 3 Total area established as strictest protected areas (IUCN categories I-III) from 1980 to 2003 (dot grey intensity reflects the mean infant mortality rate).

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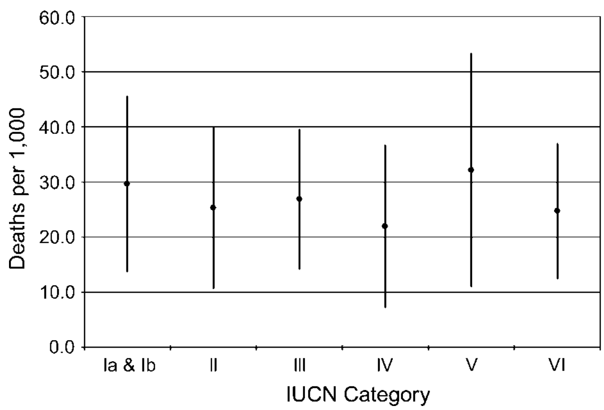

Fig. 4 Mean infant mortality rates in Latin American protected areas by IUCN category (bars represent 1 SD above and below the mean).

longitudinal data sets that allow researchers to track changes over time. Fortunately, the development community appears to be embracing poverty mapping and is increasingly investing in data acquisition (Henninger & Snel, 2002; World Bank, 2007a; WRI *et al.*, 2007).

Another potential weakness of aggregated global studies that rely on IUCN classifications as surrogate measures of local access to resources is the possibility that many protected area management authorities have little awareness or understanding of the IUCN category system (Naughton-Treves *et al.*, 2005). For example, it is known that categories have often been assigned by third parties on the basis of expert judgement (Chape *et al.*, 2005), and hence national or local protected area authorities may or may not be managing a protected area consistent with its official designation within the WDPA. It seems reasonable to expect that in many cases the particular IUCN category of a given protected area has only a loose relationship with the way that conservation is actually carried out. In addition, even the strictest protected areas may experience illicit use of resources that contribute to the welfare of local populations, from tree felling to poaching, and the degree of illegal activity is likely to be highest in low income countries where the resources to manage reserves are often inadequate. Thus, it would be potentially misleading to make too great a distinction, or to draw firm conclusions, about differences in levels of protection among adjacent classes (e.g. between classes II and III), and even analyses based on the two broad classes (strictly protected and not strictly protected), such as constructed here, may be questionable.

For these reasons, and owing to the limitations of the data, conclusions can only be tentative. In particular, the degree of co-occurrence of high infant mortality rates (poor populations) and protected areas of any given category or size cannot directly support or refute purported negative economic impacts of protected areas on local communities. For example, although in low income countries the correlation between the size of protected areas and infant mortality rates in surrounding areas is positive and significant, seemingly confirming that large and restrictive protected areas exacerbate poverty in their regions, the reason for high poverty rates near these protected areas is probably more complex. In the remote regions where many of the largest protected areas are located economic opportunities are few and populations frequently suffer from physical isolation and a lack of health services and infrastructure (Izurieta, 2007), what some term 'spatial poverty traps' (Scott, 2006).

Yet the question remains, can and should protected area management and government authorities be doing

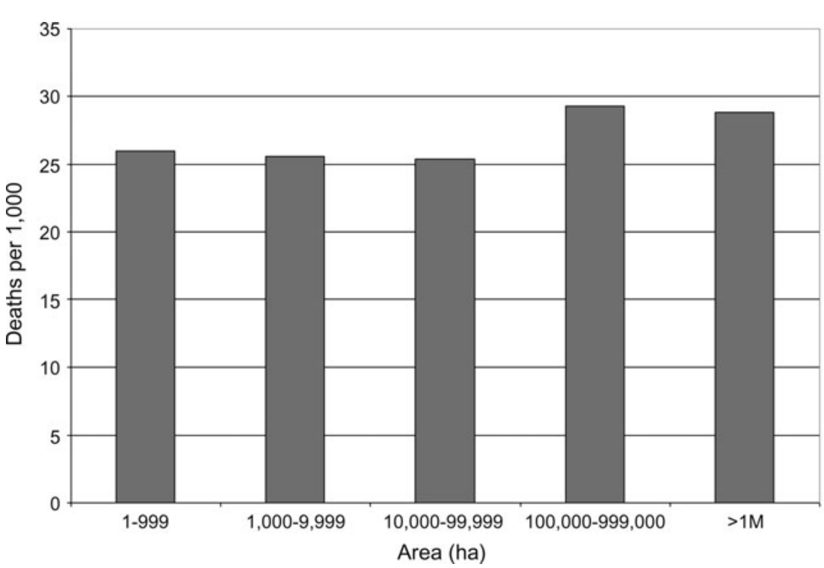

Fig. 5 Mean infant mortality rates for Latin American protected areas by size category (marine protected areas not included; only countries with >4 sub-national infant mortality rate units included).

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more to spread the benefits of protection to local communities, especially in light of the large revenues brought in by international tourism? In areas in Kenya surrounding four of the most highly visited protected areas (Masai Mara, Amboseli, and Tsavo East and West National Parks), accounting for one third of total visitor numbers to all protected areas in the country, 54-63% of the populations have incomes that fall below the poverty line (WRI *et al.*, 2007). These protected areas are all located in sparsely populated and poor parts of Kenya outside the central region. Beyond the need to spread tourism revenues, participants in an online forum on protected areas and poverty in Latin America (Izurieta, 2007) agreed that although protected area managers may have little ability to reduce poverty directly or to improve social services, they do have an obligation to ensure a means of subsistence to local and indigenous populations. This implies opening protected areas to a sustainable use of resources by neighbouring communities.

Although infant mortality rates may be higher surrounding selected protected areas, especially the largest protected areas in remote locations, the low density of populations makes development interventions potentially more costly and difficult. Without getting into the relative merits of Integrated Conservation and Development Projects, which have been addressed elsewhere (Scherl *et al.*, 2004; Wells & McShane, 2004; Horwich & Lyon, 2007), efforts to move the largest number of poor people out of poverty are likely to be most successful in those regions that have the highest densities of poor people, which are generally the long-established agricultural regions and urban areas. Nevertheless, use of poverty information for the protected areas system in a given country, whether in the form of infant mortality rates or other poverty metrics (WRI *et al.*, 2007), can help policy makers target those protected areas in need of interventions that will help reconcile conservation objectives with poverty alleviation. Furthermore, these data can assist in creating a stratified random sample of protected areas by economic development level for case studies and long-term monitoring programmes, such as the proposed Vision 2020 long-term assessment of the contribution of protected areas to conservation and development goals (WCMC, 2006b). The spatial and tabular data utilized in this analysis are available through the Socio-economic Data and Applications Center of CIESIN for these purposes.

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Appendix

The algorithm used within *ArcMap* associates the infant mortality rate data found in the polygon in which a protected area centroid is located. If a protected area falls in the ocean or on a small island off the mainland (as in the case of marine reserves) then the algorithm joins the infant mortality rate data for the nearest polygon with that point (Euclidean distance). I employed certain simple assumptions. If the closest polygon to a small island or marine reserve was found to have the same country assignment as the protected area, the protected area point was assumed to have the infant mortality rate value associated with the closest jurisdiction in that country. Because of missing data there were gaps in the infant mortality rate map for entire countries (e.g. French Guyana, Taiwan, and some small island states) and for regions within countries (e.g. the Amazonian region of Colombia, disputed territories between Pakistan and India, and southern Sudan). In the case of missing countries, all associated protected areas were removed. In the case of missing regions, protected areas that were closer to the border of a neighbouring country than to some neighbouring jurisdiction within the same country were removed. All others were assumed to have the infant mortality rate value of the neighbouring jurisdiction.

Biographical sketch

Alex de Sherbinin's research focuses on human-environment interactions, with an emphasis on human population dynamics and the environment, social aspects of conservation, remote sensing applications relevant to environmental treaties, and environmental sustainability indicators.