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Socio-economic benefits from protected areas in southeastern Australia

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Abstract: *International case studies of protected area performance increasingly report that conservation and socio-economic outcomes are interdependent. Effective conservation requires support and cooperation from local governments and communities, which in turn requires that protected areas contribute to the economic well-being of the communities in which they are sited. Despite increasing recognition of their importance, robust studies that document the socio-economic impacts of protected areas are rare, especially in the developed world context. We proposed 3 potential pathways through which protected areas might benefit local communities in the developed world: the improved local housing value, local business stimulus, and increased local funding pathways. We examined these pathways by undertaking a statistical longitudinal analysis of 110 regional and rural communities covering an area of approximately 600,000 km^2 in southeastern Australia. We compared trends in 10 socio-economic indicators describing employment, income, housing, business development and local government revenue from 2000 to 2010. New protected areas acquisitions led to an increased number of new dwelling approvals and associated developer contributions, increased local business numbers, and increased local government revenue from user-pays services and grants. Longer-term effects of established protected areas included increased local council revenue from a variety of sources. Our findings provide support for each of our 3 proposed benefit pathways and contribute new insights into the cycling of benefits from protected areas through the economy over time. The business and legislative models in our study are typical of those operating in many other developed countries; thus, the benefit pathways reported in our study are likely to be generalizable. By identifying and communicating socio-economic benefits from terrestrial protected areas in a developed world context, our findings represent an important step in securing local support and ongoing high-level protection for key components of the world's biodiversity.*

Keywords: general linear mixed model (GLMM), longitudinal analysis, national parks

Beneficios Socioeconómicos de las Áreas Protegidas en el Sureste de Australia

Resumen: *Los estudios internacionales de caso del desempeño de las áreas protegidas cada vez más reportan que los resultados socio-económicos y de conservación son interdependientes. La conservación efectiva requiere apoyo y cooperación por parte de los gobiernos y comunidades locales, lo que a cambio requiere que las áreas protegidas contribuyan al bienestar económico de las comunidades en las que se ubican. A pesar del creciente reconocimiento de su importancia, los estudios generales que documentan los impactos socio-económicos de las áreas protegidas son raros, especialmente en el contexto de los países desarrollados. Proponemos tres vías potenciales mediante las cuales las áreas protegidas podrían beneficiar a las comunidades locales en los países desarrollados: el aumento del valor de las viviendas, el estímulo a los negocios locales y el financiamiento local incrementado. Examinamos estas tres vías al emprender un análisis estadístico longitudinal de 110 comunidades regionales y rurales en aproximadamente 600, 000 km^2 en el sureste de Australia. Comparamos las tendencias de 10 indicadores que describen los ingresos públicos del gobierno local, el empleo, el ingreso, las viviendas y el desarrollo de negocios desde el 2000 hasta el 2010. La adquisición de nuevas áreas protegidas derivó en un incremento en la aprobación de nuevas residencias y en las contribuciones de los desarrolladores asociados, en el número de negocios locales y en los ingresos*

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públicos del gobierno local a partir de los servicios y permisos pagados por los usuarios. Los efectos a más largo plazo de las áreas protegidas establecidas incluyen el incremento de los ingresos públicos de los consejos locales a partir de una variedad de fuentes. Nuestros hallazgos proporcionan un apoyo para las tres vías de beneficio propuestas y nuevo conocimiento acerca del ciclo de beneficios de las áreas protegidas por medio de la economía a través del tiempo. Los modelos legislativo y de negocios en nuestro estudio son típicos de aquellos que operan en otros países desarrollados; así que las vías de beneficio reportadas en nuestro estudio probablemente sean generalizables. Al identificar y comunicar los beneficios socio-económicos de las áreas protegidas terrestres en el contexto de los países desarrollados, nuestros descubrimientos representan un paso importante hacia la garantía del apoyo local y el continuo alto nivel de protección para los componentes clave de la biodiversidad mundial.

Palabras Clave: análisis longitudinal, GLMM, modelos generales lineales mixtos, parques nacionales

Introduction

Protected area management has moved away from the historical land-use conflict paradigm, whereby conservation gains were generally seen to come at the expense of local economic interests. It is now widely acknowledged that protected areas should contribute to the sustainable development and economic well-being of the communities in which they are sited (McNeely 2008). Positive socio-economic outcomes from protected areas are important in their own right, but they may also be necessary to ensure that protected areas continue to deliver strong ecological outcomes. A lack of community support has been linked to failed conservation outcomes from protected area initiatives in international case studies from both developing and developed countries (Ezebilo & Mattsson 2010; Hirschnitz-Garbers & Stoll-Kleemann 2011; Ezebilo 2012). Accordingly, international best practice standards promote protected area assessment that accounts for both ecological and socio-economic outcomes (UNESCO 1996; IUCN 1998).

Quantitative longitudinal analysis has been recommended as best practice for quantifying ecological and economic outcomes from protected areas (Agrawal 2001; Lotze-Campen et al. 2008; Caro et al. 2009). In practice, however, longitudinal economic analyses are rare because large-scale long-term socio-economic monitoring programs are costly; consequently, robust socio-economic data sets that allow comparison across large numbers of sites are uncommon (Stoll-Kleemann & Job 2008). Longitudinal analysis has been used to investigate the socio-economic impact of terrestrial protected areas in Thailand (Andam et al. 2010; Sims 2010), Costa Rica (Andam et al. 2010), and Bolivia (Canavire-Bacarreza & Hanauer 2013). These studies show that protected areas can play a role in long-term poverty alleviation in developing countries. To date, longitudinal analysis of the impacts of protected areas in the developed world has been restricted to northern forests of the United States, and results show no significant effect of protected areas on either employment or wage growth (Lewis et al. 2002, 2003). Consequently, understanding of the socio-economic impacts of protected areas in the developed world is limited. This is a critical knowledge gap given that high-income countries contain 715 million km^2 of protected lands, equivalent to 39% of the global total, and have contributed 43% of global growth in protected area coverage from 2004 to 2012 (World Databank 2014).

It is reasonable to assume that the nature of costs and benefits associated with the implementation and management of protected areas differs between developed and developing countries. We drew on economic theory and models relating to the impact of public open spaces on population and housing development (Mansfield et al. 2005; Armsworth et al. 2006; McDonald et al. 2007) and on a number of case studies relating specifically to the impacts of protected areas in the developed world (Driml & Common 1995; Fortin & Gagnon 1999; Selby et al. 2011; Orr 2011) to propose 3 potential benefit pathways through which protected areas might impact the surrounding local economy: the improved local house value, local business stimulus, and increased local funding pathways. Each of these is described in greater detail below.

Economic theory and modeling suggest that protected areas increase house values (Mansfield et al. 2005; Armsworth et al. 2006). An observational study that tracked patterns of development across three large sites in the United States throughout the 1990s shows that at two out of three sites development rates were elevated close to protected areas (McDonald et al. 2007). We propose that increased local housing values may be a more general response to protected area acquisition and management that may arise across a range of settings.

Driml and Common (1995) document the value of tourism expenditure in towns located near World Heritage protected areas across Australia, Selby et al. (2011) document the development of tourism businesses in communities adjacent to protected areas in Finland. Two surveys of business communities operating in or near protected areas in Canada show that local business operators attribute a considerable portion of their customer base, revenues (Orr 2011), and new business opportunities (Fortin & Gagnon 1999) to nearby protected areas. We hypothesize that local business development and associated income effects may be a relatively general

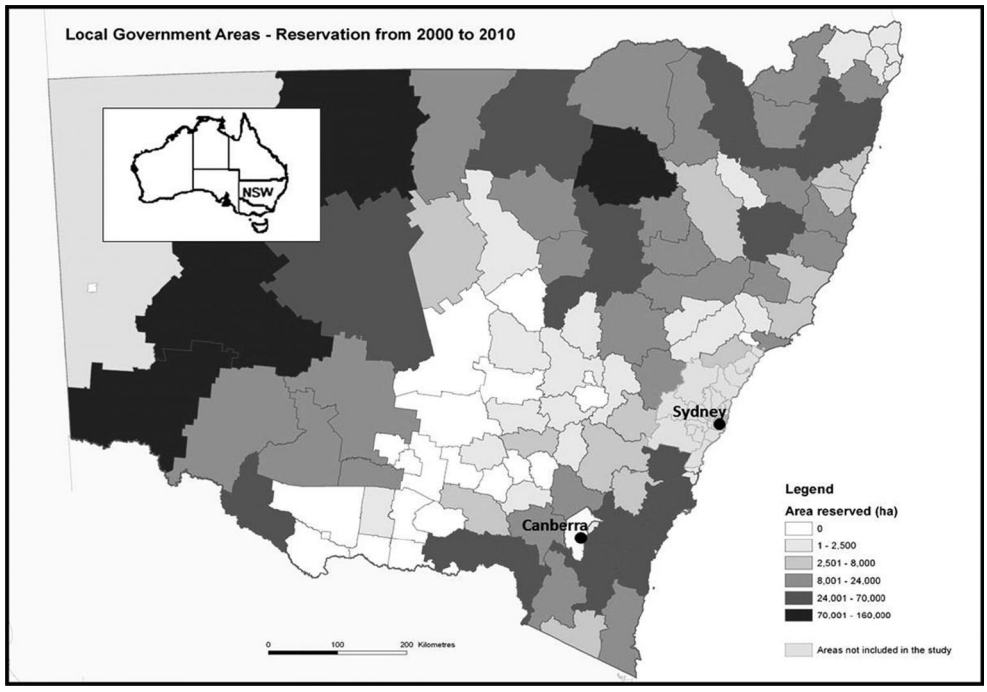

Figure 1. Map of NSW showing new protected area land acquisitions from 2000 to 2010. This map was prepared by the NSW Office of Environment and Heritage.

socio-economic outcome associated with the implementation and management of protected areas in the developed world.

Given that protected areas are often implemented and managed by state or national governments, we expect some financial benefits to accrue to local governments and communities as a result of local expenditures by the funding body. The housing and business impacts described in the preceding paragraphs are also expected to have flow-on effects for local government institutions (including demand for municipal services and increased local rates and associated impacts on local government revenues).

In this study we sought to determine whether, and to what extent, protected areas affect the surrounding local community. We moved beyond the use of single benefits indicators to an assessment of benefit pathways that identify and account for interrelated benefits and the cycling of benefits through the economy over time. Our study is the first to undertake longitudinal analysis of multiple socio-economic indicators to provide a deeper understanding of the socio-economic impacts of protected areas in the developed world, and the first to use annual time series data to look at both the intermediate-term (3–5 year) impacts of newly acquired protected areas and longer-term impacts of established protected areas. Our study is also the second-largest longitudinal analysis of the impact of protected areas undertaken to date, covering an area ~600,000 km^2 in southeastern Australia.

Methods

Study Site

New South Wales (NSW) covers roughly 10% of Australia's landmass in the southeast. The network of protected areas in NSW includes ~860 national parks and reserves, totaling ~70,000 km^2 and covering roughly 9% of the state. From 2000 to 2010, approximately 13,500 km^2 of land was acquired for conversion to national park or reserve areas (Fig. 1). Over 99% of these acquisitions were made in regional and rural areas, causing a degree of community angst regarding potential impacts on local employment and the ongoing viability of smaller rural communities. However, acquisitions over the decade of interest coincided with a severe and prolonged drought that substantially affected agricultural production and regional communities from 2001 to 2009 (Horridge et al. 2005; Edwards et al. 2009). In addition, the global financial crisis had a major impact on investment, income, and revenue of some councils and businesses (CoA 2009). It is likely that the true impact of protected areas and associated land acquisitions over this period has been obscured, to some degree, by this complex socio-economic background.

Generalized Linear Mixed Modeling

Impacts of land acquisitions and established protected areas were assessed using generalized linear mixed

modeling (GLMM) in the SPSS software package. A GLMM is considered best practice for longitudinal studies because it can accommodate missing data (Krueger & Tian 2004) and enables simultaneous analysis of both fixed and random effects (Heck et al. 2010). We assumed a normal distribution and used restricted maximum likelihood estimation and applied an auto-regressive (first order) covariance structure for time-series trends in economic performance indicators to account for the influence of previous-year performance on current-year outcomes.

We tracked economic trends in 110 local government areas (LGAs) across approximately 600,000 km^2 of NSW from 2000 to 2010. We isolated the influence of protected areas from background economic trends with the following model: X = time effects + place effects + (time∗place effects) + protected area impacts, where X is 1 of 10 social and economic variables chosen as indicators of the 3 benefit pathways proposed in this paper (Table 1). All response variables were reported annually by LGA by either the Australian Bureau of Statistics or the NSW Division of Local Government (DLG).

Time effects = year (1-10) for the specified period. This model parameter sets a variable baseline that accounts for inter-annual trends in response variables. Place effects = economy type + (population density, latitude, longitude), where economy type is a categorical variable that describes each LGA as either regional or rural based on classifications made by the NSW DLG (2011). *Regional* refers to towns and centers with a relatively diversified, urban economy base, and *rural* refers to more remote communities with a heavier economic reliance on agriculture. Population density, latitude, and longitude are random variables used to summarize a variety of other (usually unobserved) influences on performance indicators (see Robust Modeling below). Because social and economic trends in NSW generally vary along simple east–west and north–south gradients (e.g., NSW LPI 2011), population density, latitude, and longitude were included as linear variables.

Time∗ place effects = year (1-10) ∗ economy type. This interaction term accounts for differences in inter-annual baseline trends in regional versus rural economy types. Protected area effects = protected area acquisitions∗ economy type + established protected areas ∗ economy type, where protected area acquisitions∗economy type is cumulative acquisitions from 2000 to 2010 reported by year by LGA type (regional versus rural) and established protected areas∗economy type is the extent of the protected area network in each regional or rural LGA in 2000. Summary statistics for both parameters are provided in Table 2. Including interactions with economy type allowed the model to account for different impacts of protected areas in regional versus rural LGAs. Preliminary modeling included the interaction term protected area acquisitions ∗ established protected areas to account for the possibility that the impacts of new land acquisitions may vary depending on the extent of protected areas already present within a given LGA. Including the interaction term resulted in a poor model fit, so it was excluded from final model.

In preliminary modeling, we used untransformed data relating to the extent of land acquisitions and established parks. Repeat modeling was undertaken with square-root- then fourth-root-transformed data to test for diminishing returns with increasing protected area size. We used Akaike's information criterion (AIC) to compare models, and the best model (of the subset tested) was used as the basis for all subsequent modeling. Results of the model testing are provided in Supporting Information.

ACCOUNTING FOR POTENTIAL BIAS

We accounted for model bias that might arise from reverse causality, unobserved effects, and confounded baseline and covariate effects. We investigated the possibility that our modeling results might be biased as a result of pre-existing differences among LGAs with respect to the response variables, whereby the selected socio-economic performance indicators might influence the likelihood that land acquisitions would be made in a specific LGA (e.g., low incomes might indicate poor agricultural returns, low land values, a high rate of land sales, and an increased likelihood the government will purchase land in a specific LGA). We believe the patterns of protected area land acquisition in our study are independent of the selected response variables because, in NSW, protected area acquisition decisions are generally made with reference to the spatial configuration of the existing protected areas network (e.g., decisions are based on whether comprehensive, representative, and adequate ecosystem protection will be achieved) rather than economic considerations. We further investigated the potential bias that might arise from non-independence between protected area acquisition and pre-existing socio-economic factors by testing for correlation between the area of new and existing protected areas and the socio-economic index for areas (SEIFA) reported for each LGA at the start of our study. The SEIFA uses a broad range of data relating to employment, income, and other family and household characteristics to rank Australian LGAs according to their relative socio-economic advantage or disadvantage (Pink 2011). We observed no correlation between SEIFA and the area of new or established protected areas (Spearman's, $p = 0.19$ and $p = 0.79$, respectively) and concluded that the variables protected area acquisitions and established protected areas are exogenous (Fig. 2).

We accounted for potential bias that might arise from other (unobserved) underlying differences among LGAs by including the random factors population density, latitude, and longitude in all GLMM analyses. Using these random variables minimizes the potential for confounded baseline effects and accounts for spatial auto-correlation,

Table 1. Indicators of the 3 potential benefit pathways associated with protected areas and rationale for their selection.

Benefit pathway	*Indicator*	*Description and rationale*
Improved local housing value	value of residential building approvals	Residential construction is an important component of economic growth across Australia and is considered a lead indicator of general economic activity and investment. NSW planning laws require that all residential building be preapproved by local council or other government planning authorities, which provides good information about construction activity in each local government area (LGA).
	developer contributions	This portion of council revenue relates to charges and contributions that are levied on developers by local council under state planning laws. Contributions are designed to help local councils meet associated increase in demand for services such as roads and infrastructure. Land acquisitions for national parks may affect council revenue from developer contributions via impacts on surrounding development - by excluding development on the acquired site or stimulating development in surrounding areas.
	rates revenue	Private landholders are required to make an annual rates payment to local councils calculated based on their land value. On average, rates contribute 40% of the total revenue of regional and rural councils across NSW. State and federal government agencies are exempt from paying rates on their land holdings, so government acquisition of private land may affect local council revenue by reducing the total area of rateable land in a given LGA.
Local business stimulus	number of businesses	Changing business numbers are used to reflect general business activity within an LGA. Decreasing business numbers in response to land acquisitions may indicate reductions in primary production on follow-on processing industries; increasing business numbers may reflect new opportunities in construction and maintenance associated with park management, or increased opportunities in tourism and hospitality.
	value of non- residential building	Non-residential building includes building of offices, factories and production houses, warehouses, etc. It is used as an indicator of businesses expansion and investment within a given LGA.
	employment (number)	Employment is widely used as an indicator of economic activity. Unemployment also has strong links with a number of social problems, including domestic discord, family breakdown, and employment-related emigration, which can have impacts on ongoing service viability in smaller rural communities. Employment levels can therefore be used to indicate both economic and social well-being in regional and rural LGAs.
	mean income	Average income is used as an indicator of local community wealth. It is sensitive to local employment levels, but it also accounts for changes in employment type (to higher or lower-paid jobs) or business profitability.
Increased local funding	grants	Local councils can apply for state or federal grants for a range of purposes, including infrastructure, community, or conservation programs. On average, grants comprise around 15% of the total revenue of regional and rural councils across NSW, but in western parts of the state the figure may be as high as 50%. We speculate that LGAs that contain national parks may be more likely to receive funding to carry out infrastructure or conservation work that is compatible with conservation goals driving land acquisitions in the local area.
	user fees and charges	In NSW local councils charge for a range of services, such as water and waste collection and disposal, on a user- pays basis. National parks managers have an informal policy of engaging user-pays council services where appropriate, but the overall impact of land acquisition on user fees and charges depends on how national park use of these services compares with services supplied in association with the prior land use.
	total revenue	sum of all council revenues

Table 2. Summary statistics relating to established protected areas and rates of land acquisition for new protected areas from 2000 to 2010 in regional and rural LGAs across New South Wales.

	Established protected areas as of 2000	*New protected area land acquisitions*										
		2000-01	*2001-02*	*2002-03*	*2003-04*	*2004-05*	*2005-06*	*2006-07*	*2007-08*	*2008-09*	*2009-10*	*total*
Regional LGAs (n = 37)												
no. LGAs with acquisitions	30	8	13	17	16	12	17	15	14	13	10	*25
total area (ha)	1674328	130386	4794	61836	25564	14139	61409	28401	18156	7381	4056	356122
mean size (ha)	44061	16298	369	3637	1598	1178	3412	1578	1210	568	406	14245
median size (ha)	13140	5183	121	799	1255	301	288	129	102	158	118	6588
Rural LGAs (n = 73)												
no. LGAs with acquisitions	59	6	8	18	7	14	19	15	11	13	8	*43
total area acquired (ha)	2527674	47917	8029	352554	10425	101933	320763	105284	18497	19694	19935	1005029
mean size (ha)	35601	7986	1004	19586	1489	7281	16882	7019	1682	1515	2492	23373
median size (ha)	9378	4191	241	6185	1141	2590	9280	2054	749	1066	183	13918

**Totals do not sum from annual values because multiple acquisitions have been made within some LGAs.*

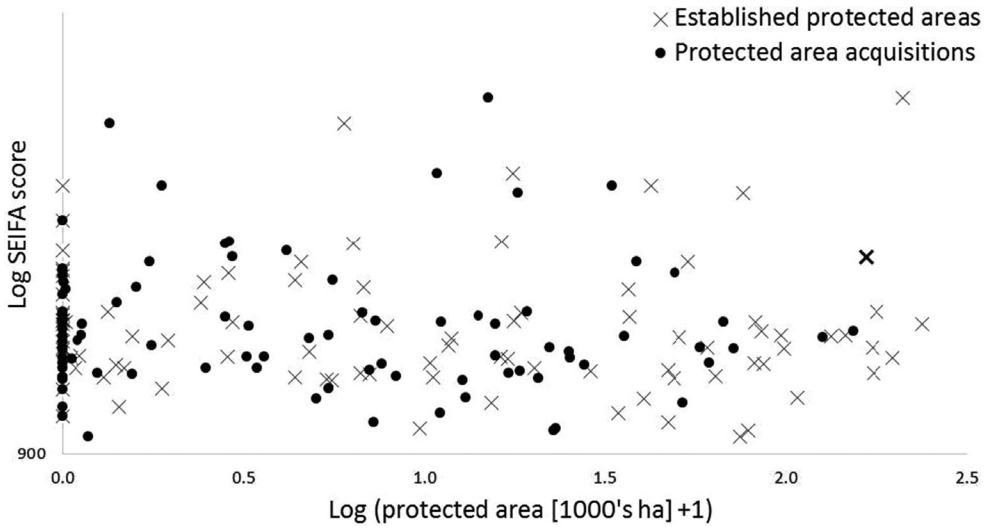

Figure 2. Lack of correlation between the socio-economic index for areas (SEIFA) scores and extent of protected areas (established protected areas and new land acquisitions) in 2000.

which is inherent in all land management studies (Benton 2012), by specifying that sites that are closer together are likely to have similar economic trajectories arising from underlying similarities in their natural resource base (soils, vegetation types), climate, and economic factors (e.g., distance to market). The GLMM accounted for these background environmental and economic conditions such that the influence of fixed effects (i.e., new and established protected areas) was determined by comparing outcomes from LGAs that have similar random factor values. This is analogous to "site matching" used by Andam et al. (2010) in their analysis of protected areas in Costa Rica and Thailand, but it treats baseline conditions as continuous rather than categorical inputs.

Given that the 3 benefit pathways proposed in this study rely on the potential for protected areas to affect amenity values (housing stimulus pathway) and local economic opportunities (business stimulus pathway), we undertook additional robustness checks to ensure that our results were not arising from confounded baseline or covariate effects whereby existing local amenity values and land-use patterns drive patterns of protected area acquisitions or contribute to the observed socio-economic outcomes. For example, if protected areas are more likely to be established in LGAs with larger proportions of natural vegetation coverage or where water bodies are present, any modeled socio-economic outcomes from protected areas may be wholly or partly attributable to these underlying differences. We tested

for potential confounded baseline and covariate effects by undertaking repeat GLMM analyses that included a number of alternate random variable sets relating to local amenity values (proportion of the LGA that is vegetated; proportion of an LGA covered by natural water bodies; proportion of the LGA classified as conservation and natural environments [encompassing both national parks and private lands that are subject to some form of conservation in place of or in addition to alternate land-uses]) and land-use patterns (proportion of the LGA under agricultural use; proportion of the LGA under production from relatively natural systems; proportion of the LGA that is built). All amenity and land-use variables were sourced with remotely sensed data published by the Australian Bureau of Statistics. We used an information theoretic approach, comparing Akaike's information criterion (AIC) to assess the goodness of fit of our original and alternate models (Anderson 2008). This comparative modeling approach allowed us to estimate the likelihood that the socio-economic benefits we observed arose in response to protected areas, rather than in response to underlying differences in amenity values and land-use patterns among LGAs. Full details of alternate random variable sets and associated model probabilities are provided in Supporting Information. After alternate modeling was undertaken, the best model (of the subset tested) was selected, and histograms of residuals were inspected to ensure an approximate normal distribution (Supporting Information).

Because our model assessed ex-post policy outcomes relative to the counter factual, while holding all other aspects of the (temporal and spatial) environment equal, it is consistent with the criteria for establishing a causal link between policy (in this case protected areas) and observed socio-economic outcomes, as outlined by Heckman (2008).

Results

Impact of Protected Areas on Economic Performance Indicators

The GLMM identified significant effects of protected area land acquisitions on eight out of ten socio-economic performance indicators (Table 3). In each case, protected areas were associated with positive outcomes for the surrounding local community. We found support for each of the benefit pathways we proposed. A summary of significant benefits arising from each of the proposed pathways is provided in Fig 3. Protected area land acquisitions in regional LGAs were associated with an increase in the value of new residential building approvals. This increase in local housing construction delivered benefits to the local council on both intermediate- and longer-term time frames consistent with expectations from our improved local housing value pathway. Intermediate term benefits arose from increased developer contributions (which are levied on all building works under NSW planning laws to help local councils meet increasing infrastructure demand). In the longer term, increased building improved local land values and increased the local council rates base, which translated into higher rates revenue (Table 3). Increased rates revenue was the largest contributor to increased council budgets, contributing roughly two-thirds of the increase in total council revenue (Table 3).

New protected areas provided a stimulus for business building and investment in both regional and rural areas. In regional LGAs, local business building investment led to higher total income levels within the LGA; it also led to an intermediate term increase in local council revenue from user charges (a class of revenue includes waste tipping fees and other user-pays services provided by councils) (Table 3). In the longer term, local business investment also increased the business rates base and contributed to increased total council (Fig. 3).

New protected area land acquisitions were associated with increased local council revenue from grants (Table 3). Grants to local councils usually come from state or Commonwealth granting agencies and may reflect an increased likelihood of receiving funding to carry out local conservation or development works that are consistent with conservation objectives for newly acquired lands. Increased local funding also accrued from increased rates and user charge revenues associated with increased economic activity arising from improved housing value and stimulus to local business (Fig. 3).

Model Testing and Selection

For all 10 economic performance indicators, the best model fit was achieved using a fourth-root transformation for data relating to both the size of recent land acquisitions and the extent of established protected areas within an LGA. This pointed to a decreasing per hectare impact as protected area size increased, and is consistent with expectations based on economic theory relating to the law of diminishing returns. Our model also showed that the socio-economic impacts of new versus established protected areas were different. There was little overlap in the nature of impacts observed for recent land acquisitions compared with longer-term impacts associated with established protected areas.

None of the alternate models that incorporated random variable sets relating to local amenity and land-use characteristics provided a better model fit than our original model. Our results appeared not to be confounded by serial correlation between the expansion of the protected area network and other landscape characteristics.

Table 3. Results from longitudinal modeling of socio-economic indicators: effects from new land acquisitions and established protected areas.

	Benefit pathway									
	improved housing value			*local business stimulus*			*increased local funding*			
Effect[a]	*dwelling app^*	*contributions (number)*	*rates ($)*	*businesses revenue ($)*	*business (number)*	*employment building app^ ($)*	*income (number)*	*user ($)*	*grants charges*	*total*
Fixed										
intercept	393.8[b]	25.4	39.1	2027	101.3	191.7	1572.0	24.3	13.5[b]	167.5
economy type (regional)	27.6	4.3	18.0	596.8	28.9	42.7	550.7	9.2[b]	2.8	38.2
time (regional)^^	−1.5	−0.69	−2.08[c]	−28.5	−8.0	−1.4	−26.3[b]	−1.7[c]	−3.4[b]	10.2[c]
Protected area acquisition (1000 ha)										
regional town or city	4.70[b]	4.2[b]	0.07	−2.59	7.07[c]	0.64	13.7[b]	0.36[b]	1.38[c]	1.57
rural	0.34	0.03	−0.02	−0.41	3.71[b]	0.07	0.34	−0.09	0.04	0.03
Established protected areas (1000 ha)										
regional town or city	1.15	0.14	2.14[b]	50.54	−1.2	2.84	26.5	0.58	0.55[b]	3.31[b]
rural	−0.41	−0.15	0.11	7.18	−0.18	0.17	3.75	0.33	0.13	0.26
Random										
population density	<0.0005	<0.0005	0.001	0.278	0.001	0.004	0.008	<0.0005	.	0.006
latitude										
longitude			<0.0005	<0.0005		<0.0005	0.016	0.003		0.001

[a] *Values for random effects are levels of significance only.*
[b] *$p < 0.05$.*
[c] *$p < 0.01$.*
^ *Applications.*
^^ *Maximum coefficient for years 1–10.*

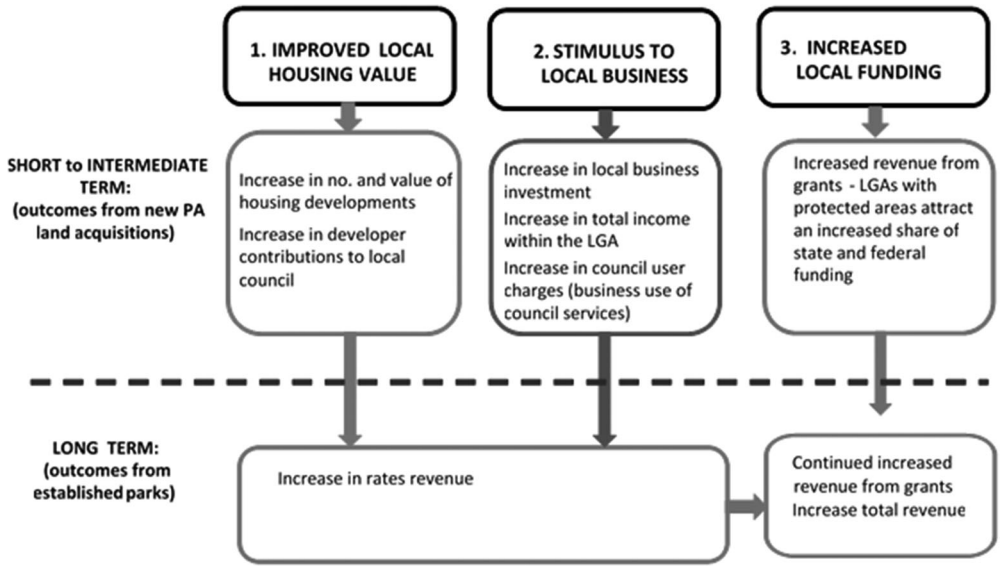

Figure 3. Protected area benefit pathways describing statistically significant impacts on indicators variables selected in this study (PA, protected area; LGA, local government area).

However, alternate random variable sets provided a model fit that was roughly equivalent to that of our original model in a small number of cases (n = 3). Thus, rather than being absent from our study area, serial correlations were adequately accounted for through the random model terms population density, latitude, and longitude, which provided a broad reflection of land-use, population, and vegetation patterns across the state.

Discussion

Our study provides important quantitative evidence that protected areas can provide economic benefits to surrounding local communities in the developed world. Within this study setting, protected areas presented new opportunities for regional growth and development: protected areas led to increased local housing demand,

stimulated local business investment, and improved local council financing. The effects of new and established protected areas observed in our study were different, indicating that the impacts of protected areas changed and developed over time as they cycled through the economy or as the management needs and inputs of protected areas changed. It follows that both intermediate- and longer-term outcomes need to be considered when the socio-economic impacts of protected areas are assessed. Our pathways approach is an important development in this regard; it accounts for interrelated benefits and the cycling of benefits through the economy over time.

We propose that the 3 benefit pathways we describe are causal rather than associative given that the GLMM adequately accounted for potential bias in initial conditions for protected area versus non-protected area LGAs and for potential serial correlation of the distribution and expansion of the protected area network with other landscape factors (see Accounting for Potential Bias in Methods). However, of all the socio-economic impacts of protected areas we observed, only one (increased investment in local business building) was common to both regional and rural economies. This indicates some degree of conditional causality (Heckman 2008), whereby the proposed benefits did not arise as an automatic consequence of protected areas; rather, they arose as an interaction between protected areas and some characteristic or characteristics of the existing local economy. This raises an important question about the degree to which benefits we report can be generalized to other locations. In this context, it is useful to consider the benefits of protected areas we observed under two broad categories: those that arose through market mechanisms and those that arose in response to regulatory and legislative mechanisms.

Market-Based Benefits

Results of studies undertaken in the United States suggest that rural and regional population and business growth is driven, in part, by the distribution of natural amenity values (Johnson & Rasker 1995; Beale & Johnson 1998; Hansen et al 2002; Levitt 2002). Our findings highlight the potential for protected areas to play a key role in these more general market-based processes. Benefits that arise from market-based mechanisms introduce important issues for strategic conservation and land-use planning. Lands adjoining protected areas often have high biodiversity values, including high species richness and abundance (Shackleton 2000; Smart et al. 2005). Increased rates of development may encourage clearing of biodiverse areas on properties close to protected areas, with potentially adverse impacts on ecosystem quality and function inside protected areas (Hansen & DeFries 2007; Radeloff et al. 2010; Butsic et al. 2012). In economic terms, increased demand for housing could also increase land values, increasing the cost of acquiring land for additional protected areas and diminishing marginal benefits of landholder participation in conservation initiatives on private land. The potential for interactions between land acquisitions and the success of future conservation initiatives highlights the need for long-term strategic spatial planning that accounts for market-based feedbacks that arise as a consequence of protected area land acquisition.

Legislated Benefits

It is difficult to determine whether the legislated benefits observed in our study, particularly those relating to improved local council finances, are a more generalized impact of protected areas because these types of impacts have rarely been the subject of formal investigation. Our finding that local councils with protected areas experienced increased levels of funding from government grants mirrors examples of co-investment from the international literature relating to protected areas in developing countries, where national or international agencies make financial contributions to conservation management, local infrastructure, or associated social projects (Wittemyer et al. 2008). Our findings suggest that local governments in developed countries may be able to leverage funds from state or federal governments in a similar way. Improvements in other local council revenue streams such as rates and developer contributions in response to protected areas have not been reported (or investigated) in the peer-reviewed literature to date, but there is no reason to expect that these are not a generalized effect because they arise as a consequence of market-based effects that have been observed in a wide range of settings and most developed economies have a system of payments similar to that imposed under NSW law; all states of Australia and the United States, United Kingdom, Canada, and New Zealand have a requirement for rates payments to be made to the local government body in proportion to land or improved capital values (sometimes called property taxes) and a system by which developers contribute to local infrastructure costs (sometimes called monetary exactions, development levies, or community infrastructure levies). If one expects the rate and value of residential and business investment to increase in association with new protected areas across a range of settings, then so too should payments to local governments from the associated revenue streams increase.

Variation in the Impacts of Protected Areas in Different Economies

If protected area benefits can arise in a range of developed world contexts, then why were the benefits we reported (with the exception of business stimulus) only in regional and not rural economies? Variability in individual community outcomes has also been identified in

longitudinal analyses of the impacts of protected areas in the developing world (Sims 2010). Indeed, variable outcomes are inevitable given that the impacts of protected areas arise through interaction with the existing local economy; particular economic or social characteristics may act as barriers or enablers as local communities respond and adapt to new conditions (Brooks et al 2005; ABARE-BRS 2010). Comparable longitudinal research of the impacts of protected areas across a broader range of economic, social, political, and legislative contexts could provide insights into the key factors that determine the degree to which individual communities might benefit from protected areas.

Implications for Biodiversity Conservation

Developed countries contain nearly 40% of the global extent of protected areas, and a higher proportion of protected lands in selected geo-regions, including 58% in the Middle East and North Africa, 90% in East Asia and the Pacific, and 100% in North America (based on figures for high-income countries in the World Databank 2014). Understanding and communicating the socio-economic benefits of protected areas to surrounding local communities in the developed world is likely to be an important step in securing local support and ongoing high-level protection of key components of the world's biodiversity. Our findings suggest that protected areas should be considered an alternate economic land-use with the potential to stimulate the local housing development sector, encourage local business growth, and sustain local government finances. We encourage further use of longitudinal techniques to investigate the socio-economic impacts of protected areas across a broader range of developed world settings.

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Supporting Information

The results of information-theoretic modeling undertaken to assess data transformations (Appendix S1), alternate random variable sets (Appendix S2), and histograms of model residuals (Appendix S3) are available online. 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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