

Conserving Biodiversity and Ecosystem Function through Limited Development: an Empirical Evaluation

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Abstract: *Suburban, exurban, and rural development in the United States consumes nearly 1 million hectares of land per year and is a leading threat to biodiversity. In response to this threat, conservation development has been advanced as a way to combine land development and land conservation while providing functional protection for natural resources. Yet, although conservation development techniques have been in use for decades, there have been few critical evaluations of their conservation effectiveness. We addressed this deficiency by assessing the conservation outcomes of one type of conservation development project: conservation and limited development projects (CLDPs). Conducted by land trusts, landowners, and developers, CLDPs use revenue from limited development to finance the protection of land and natural resources. We compared a sample of 10 CLDPs from the eastern United States with their respective baseline scenarios (conventional development) and with a sample of conservation subdivisions—a different conservation development technique characterized by higher-density development. To measure conservation success, we created an evaluation method containing eight indicators that quantify project impacts to terrestrial and aquatic ecosystems at the site and in the surrounding landscape. The CLDPs protected and managed threatened natural resources including rare species and ecological communities. In terms of conservation benefits, the CLDPs significantly outperformed their respective baseline scenarios and the conservation subdivisions. These results imply that CLDPs can offer a low-impact alternative to conventional development and a low-cost method for protecting land when conventional conservation techniques are too expensive. In addition, our evaluation method demonstrates how planners and developers can incorporate appropriate ecological considerations when designing, reviewing, and evaluating conservation development projects.*

Keywords: biodiversity, conservation development, ecological impact assessment, landscape pattern, limited development, project evaluation

Conservación de la Biodiversidad y el Funcionamiento del Ecosistema por Medio del Desarrollo Limitado: una Evaluación Empírica

Resumen: *El desarrollo suburbano, exurbano y rural en los Estados Unidos consume casi un millón de hectáreas por año y es la mayor amenaza para la biodiversidad. En respuesta a esta amenaza, el desarrollo con conservación ha sido propuesto como una forma de combinar el desarrollo de tierras con la conservación de tierras al mismo tiempo que se proporciona protección funcional a los recursos naturales. Sin embargo, aunque las técnicas de desarrollo con conservación han estado en uso por décadas, ha habido pocas evaluaciones críticas de su efectividad para la conservación. Abordamos esta deficiencia mediante la evaluación de los resultados de conservación de un tipo de proyecto de desarrollo con conservación: proyectos de desarrollo limitado y conservación (PDLC). Los PDLC, llevados a cabo por fundaciones, propietarios e inmobiliarias, utilizan ingresos del desarrollo limitado para financiar la protección de suelos y recursos naturales. Comparamos una muestra de 10 PDLC en el este de Estados Unidos con sus escenarios de base (desarrollo convencional) y con una muestra de subdivisiones de conservación - una técnica de desarrollo con conservación caracterizada por un desarrollo de mayor densidad. Para medir el éxito de conservación,*

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creamos un método de evaluación con 8 indicadores que cuantifican los impactos del proyecto a los ecosistemas terrestres y acuáticos del sitio y en el paisaje circundante. Los PDLC protegieron y manejaron recursos naturales amenazados, incluyendo especies y comunidades ecológicas raras. En términos de beneficios para la conservación, los PDLC fueron significativamente mejores que sus escenarios de base y que las subdivisiones de conservación. Estos resultados implican que los PDLC pueden ofrecer alternativas de bajo impacto al desarrollo convencional y un método de bajo costo para la protección de tierras cuando las técnicas de conservación convencionales son demasiado caras. Adicionalmente, nuestro método de evaluación demuestra cómo los planificadores y las inmobiliarias pueden incorporar consideraciones ecológicas apropiadas en el diseño, la revisión y evaluación de proyectos de desarrollo con conservación.

Palabras Clave: biodiversidad, desarrollo con conservación, desarrollo limitado, evaluación de impacto ecológico, evaluación de proyectos, patrón del paisaje

Introduction

In the United States suburban and rural land development is becoming an increasingly ubiquitous force on the landscape, not just in metropolitan areas but also in amenity-rich hinterlands such as the Rocky Mountains, southern Appalachians, and rural New England (Moss 2003; Brown et al. 2005; Radeloff et al. 2005). This trend is expected to continue due to factors such as population growth, increasing per capita land consumption, and the centrifugal forces of telecommuting, access to high-speed travel, and growing numbers of retirees (Heimlich & Anderson 2001).

The detrimental ecological effects of conventional suburban and rural development have been documented at both the site and landscape scale. These impacts include habitat loss and fragmentation, replacement of sensitive native species with generalist and non-native species, and degradation of aquatic habitats (Hansen et al. 2005; Radeloff et al. 2005). Furthermore, these effects can extend off site, diminishing the long-term viability of protected areas elsewhere on the landscape (Hansen et al. 2002). Overall, urbanization is a leading threat to endangered biodiversity nationwide (Czech et al. 2000; Ewing et al. 2005).

One possible way to reduce the negative ecological consequences of land development—and perhaps even to harness it as a positive force for conservation—is through conservation development. Conservation developments are projects that combine land development, land conservation, and revenue generation while providing functional protection for conservation resources (Milder 2007). Conservation development is created through a process of ecologically based planning and design (McHarg 1969; Perlman & Milder 2005), whereby planners assess a site's natural resources and environmental context and use this knowledge to conserve portions of the site with high resource value while designing a development that minimizes environmental impacts (Pejchar et al. 2007). In addition, conservation developments set aside conservation land in perpetuity and rely on development revenues to finance conservation outcomes (Milder 2007).

Conservation development encompasses a range of techniques, which vary significantly in scale, development density, context, and expected conservation benefits (Milder 2007). The four principal types of conservation development are (1) conservation buyer projects, (2) conservation and limited development projects (CLDPs), (3) conservation subdivisions, and (4) conservation-oriented planned development projects. Conservation buyer projects, typically initiated by land trusts, contain a minimal amount of development (often just a single house for the landowner). Many land trusts use this technique as a cost-effective land protection strategy. Conservation and limited development projects—initiated by land trusts, landowners, or developers—use limited development as a means to finance land conservation or to create a multiobjective project with both profit and conservation goals. Conservation subdivisions, also known as cluster developments or open-space residential developments, are built at or near the full density allowable by zoning, but housing is clustered onto smaller lots to protect a portion of the site as conservation land. For-profit developers conduct these projects. Conservation-oriented planned developments, also conducted by for-profit developers, typically occupy sites of 500–1500 ha and include a mix of development types and large protected areas.

Although conservation development appears to have much potential to protect biodiversity and ecosystem services, there have been few attempts to evaluate its actual conservation benefits. In practice the conservation success of such projects is typically measured by the percentage of the total site area set aside as protected land, but this indicator says little about whether the site's conservation values are being protected functionally. A more scientifically rigorous evaluation would reveal whether conservation development is providing true conservation benefits and how such projects could be situated, designed, and reviewed so as to contribute meaningfully to landscape-scale conservation.

We conducted such an evaluation by assessing the conservation effectiveness of one of the four types of conservation development: conservation and limited devel-

opment projects, hereafter CLDPs. We addressed the following questions: How effective are CLDPs in conserving biodiversity and ecosystem function? Do CLDPs result in significantly improved conservation outcomes compared with a baseline scenario of conventional land development? Do CLDPs provide significantly greater conservation benefits than conservation subdivisions?

Conservation and Limited Development Projects

Conducted by land trusts, landowners, and for-profit developers, CLDPs use limited development to finance the protection of land and natural resources. It is instructive to compare CLDPs to conservation subdivisions, which have been the focus of most previous literature on conservation development (e.g., Arendt 1996; Theobald & Hobbs 2002; Odell et al. 2003; Lenth et al. 2006). Most important, CLDPs are built at greatly reduced housing densities—typically 5–25% of the maximum density ordinarily allowable by zoning laws, compared with 100–200% maximum density for conservation subdivisions. In addition, CLDPs do not always use a clustered layout (although they frequently do). Land trusts are often involved in planning or implementing CLDPs, underscoring the fact that conservation is a principal objective of such projects. In contrast, private developers build conservation subdivisions, and the main objective is usually to earn money through land development but in a conservation-friendly manner.

Despite containing relatively little development, most CLDPs are financially self-sustaining and many realize a profit (Milder 2006). This is because the difference between the per-acre value of “raw” undivided land (such as a large tract of forest) and subdivided, permitted land ready for construction is quite high—often a factor of 2–10. Thus, the sale of a relatively small amount of subdivided land ready for construction can finance the protection of a much larger amount of raw, undivided land. In

addition, many CLDPs benefit from federal, state, and/or local tax incentives for land conservation (Milder 2005).

Because of these financial advantages, some land trusts use CLDPs as a conservation strategy in situations where they cannot afford full protection for a given property. On a larger scale, the use of CLDPs and similar techniques can help conservation groups move beyond opportunism to target high-priority sets of parcels as part of a strategic landscape conservation plan (Milder 2006). Doing so may hold considerable appeal in light of the past failure of both land-use regulations (Beatley 2000) and conventional conservation approaches that rely on the purchase and donation of land and easements (Brewer 2003) to protect critical masses of land in key landscapes.

Methods

CLDP Characteristics

Given the lack of prior research on CLDPs, we first conducted a nationwide survey of such projects to understand their essential characteristics and their variability (Milder 2005). From this initial sample of 101 CLDPs, we used a multiple case-study method (Yin 2003) to select 10 representative projects from the eastern U.S. for detailed evaluation. These study CLDPs varied in size, development density, and landscape context, reflecting the range of projects contained in the larger sample (Table 1). Nevertheless, all 10 projects had as a principal conservation goal the protection of biodiversity and ecosystem functions. We also compared these CLDPs with a sample of three conservation subdivision projects, which we expected to have poorer conservation outcomes considering that conservation subdivisions are usually built at a higher density than CLDPs and tend to place less emphasis on conservation.

In addition, we compared each conservation development project with a realistic baseline scenario, which

Table 1. Characteristics of the 10 conservation and limited development projects (CLDPs) evaluated in this study.

<i>Project</i>	<i>Location</i>	<i>Size (ha)</i>	<i>Dwelling units</i>	<i>Aggregate development density (dwellings/ha)</i>	<i>Landscape context^a</i>
CLDP 1	North Carolina	141	21	0.15	rural
CLDP 2	Maine	153	39	0.25	exurban
CLDP 3	Pennsylvania	44	3	0.07	exurban
CLDP 4	Massachusetts	49	7	0.14	exurban
CLDP 5	North Carolina	1760	350	0.20	rural
CLDP 6	Massachusetts	45	12	0.27	suburban
CLDP 7	Pennsylvania	29	5	0.17	suburban
CLDP 8	North Carolina	115	10	0.09	rural
CLDP 9	Massachusetts	67	120 ^b	1.79	suburban
CLDP 10	Maryland	162	22	0.14	rural

^aCharacterizations of landscape context follow the definitions of Hansen et al. (2005).

^bOne hundred of the 120 units were apartment-style dwellings contained in two buildings. The project contained only 20 detached single-family dwellings—an average density of 0.30 detached dwellings/ha.

we defined as the most likely outcome for the site if the conservation development project had not occurred. As noted by Ferraro and Pattanayak (2006), it is only through the enumeration of such “counterfactual” alternative scenarios that the real impacts of a conservation intervention can be determined. To define the baseline scenarios, we used a standard build-out approach, which assesses development potential in light of a site’s zoning and its physical constraints and opportunities for development (Lacy 1992). We also considered prevailing development patterns in the surrounding area and alternative development plans created for the site, if available.

Evaluation Method

To assess conservation effectiveness, we created a multi-criteria evaluation method based on eight indicators that quantify a project’s positive and negative impacts to terrestrial and aquatic ecosystems on the site and in the surrounding landscape. In their recent paper on applying ecological knowledge to rural land-use planning, Theobald et al. (2005:1911) called for this type of evaluation, noting that “there is a need to develop a set of standardized indicators for rural landscapes that have received scientific review, are based on detailed spatial data that resolves fine-scale features (e.g., houses, small wetlands and riparian zones), and that respond directly to changes in land use.” The method we developed for use in this study attempts to meet this challenge.

We designed the evaluation method to measure the net conservation impact of a conservation development project, that is, the difference between the pre- and postproject condition of the site and contribution of the site to conservation in the surrounding landscape. Use of this method also allows comparison of the conservation outcome of two or more alternative land-use scenarios (e.g., conservation development, conventional development, and full protection). Our method was not, however, designed to compare the conservation value of different sites or to monitor the status of protected areas over time because credible methods for doing so already exist (e.g., Smith & Theberge 1987; NatureServe 2002; TNC 2005).

Our method emphasizes coarse-filter and mesofilter assessment tools, which measure community and structural characteristics as a proxy for individual species and ecosystem processes. The premise of this approach is that the protection of intact natural communities will safeguard the species and ecological processes indigenous to these communities (Poiani et al. 2000; Groves 2003; Hunter 2005). Such proxy indicators are especially well suited to evaluating land development projects because many community-level impacts of development—such as reduced habitat size or connectivity—are detectable immediately, whereas populations may display significant

lag times (Saunders et al. 1991). Thus, for the present application, we believe that measures of land cover, spatial pattern, and community structural characteristics are more cost-effective, comprehensive, and forward looking than fine-filter measures of species richness and abundance. These proxies are based on ecological principles and studies and can be refined over time as the state of knowledge improves (Theobald et al. 2000).

Indicators of Conservation Success

We used eight indicators to evaluate conservation success: land alternation, edge effect, spatial configuration and connectivity, impervious surface, riparian buffers, impacts to site conservation targets, restoration, and land management (Table 2). Complete information on the design and measurement of the indicators—and an example of their use in this study—is available (see Supplementary Material).

INDICATOR 1: LAND ALTERATION

Land development affects terrestrial biodiversity by changing the amount of native habitat present and its spatial configuration (Theobald et al. 1997). We designed indicators 1 through 3 to measure these effects. The land-alteration indicator quantified the net change in developed or altered land attributable to the development project, including buildings, roads, road margins, other paved areas, lawns, gardens, golf courses, and other areas where human uses have supplanted native habitat.

INDICATOR 2: EDGE EFFECT

Where developed land abuts natural habitat, it creates a distinctive zone of edge habitat. In forested areas, for example, edges tend to be sunnier, warmer, drier, and more favorable to invasive exotic species, shade-intolerant plants, and generalist predators at the expense of many native species (Forman 1995; Harper et al. 2005). The edge-effect indicator quantified the net change in the portion of the site affected by proximity to altered land. To calculate this indicator, we buffered altered areas on and near the site by context-appropriate edge effect distances for six different altered land types: 8 m for narrow driveways, 15 m for buildings with minimal clearing, 30 m for local roads and for houses with lawns, and 60 m for major roads and for wide swaths of developed land. We based these values on studies measuring the distance over which each of five edge effects are manifest: altered microclimate, other abiotic influences, altered plant species composition, altered animal species composition, and increased predation or parasitism.

Table 2. Summary of the method used to evaluate conservation effectiveness of the projects examined in this study.^a

<i>Goal (weight)</i>	<i>Subgoal (weight)</i>	<i>Indicator (weight)</i>	<i>Indicator scoring method</i>
I: minimize negative impacts (75%)	A: minimize impacts to terrestrial habitats in general (37.5%)	1: land alteration (12.5%)	quantitative, continuous
		2: edge effect (12.5%)	quantitative, continuous
	B: minimize impacts to aquatic habitats in general (18.8%)	3: spatial configuration	quantitative, continuous
		a: perforation (4.2%) ^b	quantitative, 7-point scale
II: maximize positive impacts (25%)	C: minimize impacts to site-specific conservation targets (18.8%)	b: fragmentation (4.2%)	quantitative, continuous
		c: off-site connectivity (4.2%)	quantitative, continuous
	D: restore native habitats and natural systems (12.5%)	4: impervious surface (9.4%)	quantitative, continuous
	E: manage land to maintain conservation values (12.5%)	5: riparian buffers (9.4%)	quantitative, 9-point scale
		6: impacts to site conservation targets (18.8%)	quantitative and qualitative, 6-point scale
	7: effectiveness of restoration efforts (12.5%)	7: effectiveness of restoration efforts (12.5%)	qualitative, 4-point scale
8: effectiveness of land management for ecological conservation (12.5%)	8: effectiveness of land management for ecological conservation (12.5%)	qualitative, 8-point scale	

^aWe evaluated two aspects of conservation effectiveness: minimization of negative project impacts (goal I) and maximization of positive project impacts (goal II). Each goal was resolved into subgoals and indicators to measure specific impacts.

^bPerforation involves the creation of developed outposts in a matrix of natural habitat.

INDICATOR 3: SPATIAL CONFIGURATION AND CONNECTIVITY

To understand the ecological effects of fragmentation, it is important to consider the spatial layout of habitats and their functional utility for species with different needs (Beier & Noss 1998; Tischendorf & Fahrig 2000). We incorporated this concept of “functional connectivity” by measuring three aspects of structural connectivity likely to be especially important to native species on the sites we studied: perforation, fragmentation, and off-site connectivity.

Perforation (indicator 3a) involves the creation of developed outposts, such as houses or clearcuts, in a matrix of natural habitat and is especially detrimental to species that require large habitat patches (Forman 1995). The perforation subindicator quantified the net change in perforated habitat attributable to the project as a percentage of the total site area.

Whereas perforation consists of disturbance zones that are not contiguous, fragmentation refers to continuous barriers on the landscape that divide natural habitat into smaller patches (Saunders et al. 1991; Debinski & Holt 2000). Perforation and fragmentation are not always correlated and can have different effects on species (Forman 1995; Theobald et al. 1997). Because the effect of different types of human barriers varies from species to species, we designed the fragmentation subindicator (indicator 3b) to provide a measure of fragmentation from both minor barriers (e.g., driveways, low-traffic roads, and narrow “necks” of habitat subject to edge effect) and major barriers (e.g., main roads and contiguous swaths of developed land).

We also measured off-site connectivity (indicator 3c) to assess the degree to which each project maintained or compromised spatial connections between the project

site and adjacent natural areas. To calculate off-site connectivity we used GIS to create and sum the largest possible rectangular polygons of continuous natural habitat, extending from the project site onto adjacent sites, that exceeded a context-appropriate size threshold. We then determined the net change in the total area of these “spatial connections” of continuous habitat.

INDICATOR 4: IMPERVIOUS SURFACE

We measured two key effects of land development on water resources: creation of impervious surfaces and alteration of riparian areas. Impervious surface is a reliable and widely used indicator of the impacts of land-use change on water resources, which include altered hydrology, increased non-point-source pollution, and impaired biotic and abiotic conditions in receiving water bodies (Paul & Meyer 2001; Gergel et al. 2002). The impervious surface indicator quantified the net change in the percentage of each site covered by impervious surface.

INDICATOR 5: RIPARIAN BUFFERS

Vegetated riparian buffers play several important ecological roles. They contribute terrestrial biomass to the aquatic food chain, regulate water temperature, control floods, provide wildlife habitat, and reduce erosion, sedimentation, and pollution (Perlman & Milder 2005). We used the riparian-buffer indicator to quantify the distribution of widths of the vegetated buffer zone around ponds, streams, and wetlands. We gave heavy consideration to the presence of gaps or narrow parts of riparian buffers because these areas can play a disproportionately large role in transmitting pollutants to water bodies (Weller et al. 1998).

INDICATOR 6: IMPACTS TO SITE CONSERVATION TARGETS

Whereas indicators 1–5 were measured the same way on every site, indicator 6 was measured relative to site-specific conservation values. Inclusion of both general and specific indicators ensured that the method was consistent from site to site and accounted for the unique needs of different conservation targets.

For indicator 6 we used a simplified version of The Nature Conservancy's Measures of Success (MOS) framework (Parrish et al. 2003; TNC 2003) to evaluate the degree to which the project protected site-specific conservation targets. As in the MOS method, we began by using existing biodiversity data and field work to identify for each site a small number of conservation targets: species, communities, ecosystems, or ecological functions that represented the site's biodiversity or were in particular need of management attention. For each target we then identified key ecological attributes—aspects of the target's size, condition, and landscape context that were critical for conserving the conservation target over time (TNC 2005). We focused on coarse-filter and mesofilter ecological attributes, such as habitat area, landscape connectivity, community structure, woody debris, water features, dominant and characteristic species (including invasive species), successional stage, and evidence of natural or anthropogenic disturbances. On the basis of these ecological attributes, we then used a predefined scale to evaluate the project's effectiveness at conserving each conservation target, similar to the MOS method.

INDICATOR 7: RESTORATION

Some conservation development projects provide funding and personnel to restore and manage conservation resources to a degree that conventional land-protection projects could not afford (Milder 2005). We used the restoration indicator to assess the project's success at restoring key ecological attributes of the site's conservation targets. This indicator considers the type and extent of restoration activities conducted and the total area of habitat restored.

INDICATOR 8: LAND MANAGEMENT

Long-term stewardship is essential for maintaining or enhancing the conservation value of protected land in the face of external threats. We used six criteria to evaluate the current effectiveness of a project's program of land management and the capacity for future management activities: (1) adequate funding for ongoing management activities, (2) organization with conservation expertise responsible for stewardship, (3) baseline documentation and regular monitoring of the site's biodiversity, (4) current activities to stabilize or improve the viability of con-

servation targets, (5) covenants requiring ecologically based management of private land within the project, and (6) current evidence of ecologically sensitive land management by private owners.

Data Collection and Analyses

We used several data sources to evaluate the indicators. To calculate the spatial metrics, we created digital layers of development features (roads, driveways, houses, landscaped areas, and property boundaries) from ground-verified aerial photographs overlaid with a scanned, registered copy of the project site plan. We conducted site mapping at a scale of 1:2000, and in most cases, we were able to resolve features and boundaries to 1-m accuracy. Other relevant layers, such as water resources, were also added. We then used ArcView 3.3 and Microsoft Excel spreadsheets to calculate each spatial indicator.

To evaluate the other indicators we obtained information on project details and land management plans from project documents and interviews with project participants. We also conducted field work to help identify and evaluate conservation targets. Prior to going into the field we obtained recent aerial photographs and classified land cover according to the National Land Cover Dataset Classification System (USGS 2003). In the field we used the aerial photographs in conjunction with a handheld global positioning system unit to verify and refine land-cover delineations and to inventory microhabitats and other areas of potential conservation value not apparent in the photographs. We also assessed key ecological attributes important to the integrity of conservation targets.

We used either continuous quantitative data (i.e., raw data on the project's spatial attributes) or point scales derived from quantitative and/or qualitative data to assign scores to the indicators (Table 2). Point scales were predefined to minimize the possibility of subjectivity.

In addition to the individual indicator scores, which were useful for documenting each project's specific positive and negative impacts, we calculated composite impact scores to compare the overall conservation success of each project with that of a baseline land-use scenario. The overall composite project-impact score, which was calculated on a 100-point scale, was the sum of the negative project-impact score (75 points) and the positive project-impact score (25 points). Higher scores corresponded to greater conservation success.

To calculate the composite scores we normalized and then weighted the indicators to reflect their relative contribution to the overall goal of conserving biodiversity and ecosystem functions (Trewick 1999). (See Table 2 for weighting values.) We weighted the avoidance of negative impacts three times as heavily as the provision of positive impacts because it is much easier, more certain, and more cost-effective to prevent resources from

becoming degraded than to restore and manage them once they are damaged (Dobson et al. 1997). Among the indicators of negative impact we weighted indicators of terrestrial habitat impact twice as heavily as indicators of aquatic habitat impact because conservation development projects alter land directly but generally alter water bodies only indirectly. We calculated composite scores with an "open-code" spreadsheet to maximize transparency and allow weighting and summation rules to be modified, if necessary, to reflect different sets of priorities and evaluation needs.

We conducted statistical analyses with the software program JMP (version 6). Because some of our data did not satisfy the assumptions for parametric tests, we used nonparametric tests to evaluate statistical significance. To compare the CLDPs to the conservation subdivisions, we used a Wilcoxon–Mann–Whitney test. To compare the CLDPs to the baseline scenarios, we used a Wilcoxon matched-pairs test.

Results

The spatial-pattern indicators revealed that, on average, the CLDPs created less than one-fifth as much land alteration, barely one-fourth as much edge-affected area, and barely one-eighth as much impervious surface as the conservation subdivisions (Table 3). These differences reflected the lower development density in CLDPs and their low-impact design features such as reduced road width and lawn size.

The two sets of projects performed similarly in terms of maintaining off-site connectivity and protecting riparian buffers. The similar results for off-site connectivity, however, reflected the fact that the conservation subdivisions were located in suburban contexts where connectivity was already significantly compromised, so there was less potential for further decline.

The CLDPs were generally successful at identifying and protecting site-specific conservation targets, especially small-patch ecosystems and species restricted to small habitats such as rare plants, reptiles, and amphibians. In most of the CLDPs, these resources were protected from alteration, adequately buffered, and appropriately managed. In addition, almost all the CLDPs were buffering nearby protected areas (in effect, expanding the functional size of these areas) and contributing to landscape corridors.

Seven of the 10 CLDPs included some type of restoration work: 2 removed buildings or closed roads, 2 revegetated formerly altered land, 4 removed invasive species, 2 conducted stream restoration, and 4 worked to reestablish natural succession and disturbance regimes. Nevertheless, restoration effort varied greatly, with scores ranging from 0 to 3 out of the 3 points possible. None of the conservation subdivisions conducted restoration work.

Land management in the CLDPs also varied in effectiveness. Of the 10 projects, 5 were conducting long-term biodiversity monitoring, 8 were engaging in ecologically based management of the conservation and/or development areas, 9 had restrictive covenants to guide land management in the development areas, 4 had a long-term funding source for land management, and 7 had

Table 3. Conservation effectiveness of conservation and limited development projects (CLDPs) compared with conservation subdivisions^a on the basis of 10 indicators and subindicators.

Measure of conservation effectiveness	Possible values ^b	Conservation subdivisions (average of 3 projects)	CLDPs (average of 10 projects)	CLDPs significantly different from conservation subdivisions? (p ^c)
Indicator				
1: land alteration	<u>0</u> –100%	33%	6%	0.02
2: edge effect	<u>0</u> –100%	53%	14%	0.01
3a: perforation	<u>0</u> –100%	51%	20%	0.03
3b: fragmentation	<u>0</u> – <u>6</u> points	1.3	3.9	0.01
3c: off-site connectivity	<u>0</u> –300%	88%	82%	0.67
4: impervious surface	<u>0</u> –30%	10.8%	1.4%	0.01
5: riparian buffers	<u>0</u> – <u>8</u> points	5.0	6.7	0.43
6: site conservation targets	<u>0</u> – <u>5</u> points	2.0	4.1	0.01
7: restoration	<u>0</u> – <u>3</u> points	0.0	1.7	0.02
8: land management	<u>0</u> – <u>7</u> points	1.0	4.3	0.03
Composite impact score				
negative	<u>0</u> – <u>75</u> points	40	64	0.01
positive	<u>0</u> – <u>25</u> points	2	15	0.03
overall	<u>0</u> – <u>100</u> points	41	79	0.01

^aConservation subdivisions are residential developments in which housing is clustered onto smaller lots to protect a portion of the site as conservation land. In contrast to CLDPs, conservation subdivisions are generally built at or near the full density allowable by local zoning laws.

^bUnderlined values indicate greater conservation success.

^cFor each indicator, we used a Wilcoxon–Mann–Whitney test to compare the two sets of projects.

Table 4. Comparison of conservation subdivisions and conservation and limited development projects (CLDPs) with their respective baseline scenarios.^a

Indicator	Possible values	Net conservation benefit ^b		CLDPs provide significantly more net benefit than conservation subdivisions? (p) ^e
		conservation subdivisions ^c	CLDPs ^d	
1: land alteration	0–100%	23%	44%	0.15
2: edge effect	0–100%	28%	57%	0.05
3a: perforation	0–100%	44%	50%	0.35
3b: fragmentation	0–6 points	1.0	2.9	0.05
3c: off-site connectivity	0–300%	8%	143%	0.01
4: impervious surface	0–30%	1.9%	7.4%	0.03
5: riparian buffers	0–8 points	4.3	5.1	0.67
6: site conservation targets	0–5 points	1.0	3.0	0.02
7: restoration	0–3 points	0.0	1.7	0.02
8: land management	0–7 points	1.0	4.2	0.03

^aThe baseline scenario is the most likely conventional development outcome for the site if the conservation development project had not occurred. We used a standard build-out approach (Lacy 1992) to define the baseline scenarios.

^bAverage improvement in each indicator attributable to the conservation development project compared with the baseline scenario.

^cThe sample size for conservation subdivisions was too small to evaluate the statistical significance of these net benefits.

^dNet benefits for all 10 indicators and subindicators were significant at the $p < 0.001$ level based on a Wilcoxon matched-pairs test.

^eFor each indicator, we used a Wilcoxon–Mann–Whitney test to compare net conservation benefit between the two sets of projects.

adequate organizational capacity for land management. Overall, the CLDPs performed much better than the conservation subdivisions with respect to land management (Table 3).

In terms of overall conservation effectiveness, the CLDPs earned higher positive impact scores, negative impact scores, and composite impact scores than the conservation subdivisions, and all of these differences were statistically significant (Table 3). We also compared the conservation development projects with their respective baseline scenarios (i.e., conventional development). The difference between the conservation development project and the baseline scenario can be considered the net conservation benefit attributable to the project. The CLDPs yielded a statistically significant net conservation benefit ($p < 0.001$) for all 10 indicators and subindicators (Table 4). Furthermore, the net conservation benefit of CLDPs significantly exceeded the net benefit of conservation subdivisions for 7 of the 10 indicators and subindicators (Table 4).

The composite scores suggested that, overall, the conservation subdivisions reduced negative impacts relative to the baseline scenario, but did not increase positive impacts, whereas the CLDPs did both (Table 5). This result implies that a key aspect of the CLDPs' success is the restoration and management activities that help maintain conservation targets in good condition. Overall, the CLDPs provided significantly more net conservation benefit than the conservation subdivisions with respect to minimizing negative impacts, contributing positive impacts, and overall conservation effectiveness (Table 5).

Discussion

We concluded that the CLDPs evaluated were protecting threatened conservation resources, including rare biodiversity and ecosystem functions, and that they resulted

Table 5. Comparison of average composite impact scores of the conservation subdivisions and conservation and limited development projects (CLDPs) with their respective baseline scenarios.

Composite impact score	Conservation subdivisions			CLDPs			Difference in average net benefits (p) ^c
	Average of 3 projects	Average of 3 baseline scenarios	Average net conservation benefit ^a	Average of 10 projects	Average of 10 baseline scenarios	Average net conservation benefit (p) ^b	
Negative (max. 75)	39.5	21.0	18.5	63.8	25.5	38.2 (0.001)	19.7 (0.05)
Positive (max. 25)	1.8	0.0	1.8	14.8	0.2	14.6 (0.001)	12.6 (0.03)
Overall (max. 100)	41.3	21.0	20.3	78.5	25.7	52.8 (0.001)	32.5 (0.01)

^aThe sample size for conservation subdivisions was too small to evaluate the statistical significance of these net benefits.

^bWe used a Wilcoxon matched-pairs test to evaluate the statistical significance of these net benefits.

^cDifference between net conservation benefits for CLDPs versus conservation subdivisions. We used a Wilcoxon–Mann–Whitney test to evaluate significance.

in significantly more conservation benefits than their respective baseline land-use scenarios. On average more than 85% of each CLDP site was protected as interior habitat, and project design and management generally addressed the conservation, restoration, and stewardship needs of site-specific conservation targets.

These results provide initial validation of CLDPs as an effective yet low-cost conservation strategy that can be used by land trusts, landowners, and conservation-minded developers. The results also suggest that CLDPs can sometimes offer a satisfactory alternative to full protection of a site in situations where conservation funding is scarce. Although these indications are promising, it is important to note that the long-term consequences of CLDPs for native species and ecosystems have not been studied. Long-term biological monitoring at a network of CLDP sites would be an important focus for future research.

Overall, the conservation subdivisions we evaluated provided significantly less conservation benefit than the CLDPs. Our results and those of a previous study on conservation subdivisions (Lenth et al. 2006) suggest that although these projects tend to have a somewhat more conservation-friendly spatial pattern than conventional developments—which would be expected to maintain some conservation value in the long term—their lack of functional conservation, restoration, and stewardship activities may significantly limit their overall conservation effectiveness.

As indicated by the divergent results for CLDPs versus conservation subdivisions, conservation development should not be considered a single technique with a characteristic set of outcomes. Instead, different project types must be distinguished, evaluated on their merits, and treated accordingly for purposes of landscape-scale conservation, regional planning, and public policy. It is likely that all project types will have a legitimate role to play in landscape-scale conservation, yet, as our results imply, these roles will depend greatly on the project type, design, and context.

For this reason it is critically important to document the conservation outcomes of different types of conservation development projects. If such projects are held to high standards, they can serve two valuable functions. First, they can provide an important source of conservation finance, allowing conservation organizations to select and conserve high-priority lands in a proactive manner, while increasing the overall capacity of the conservation movement. Second, they can significantly reduce the negative impacts of for-profit land development in suburban, exurban, and rural areas, creating a landscape mosaic that is more hospitable and more permeable to native species and more capable of providing ecosystem services.

On the other hand, without carefully defined standards and methods for planning, reviewing, and evaluating con-

servation development projects, the conservation development concept could easily become co-opted as a marketing ploy to “greenwash” conventional suburban and rural sprawl. Indeed, this concern has already been borne out in some projects, fueling scrutiny and criticism of both good and bad projects by the media (Stephens & Ottaway 2003), the U.S. Congress, and the U.S. Internal Revenue Service (Stephens & Ottaway 2004).

Our evaluation method demonstrates a cost-effective way for planners, developers, and land trusts to incorporate appropriate sets of ecological considerations when designing, reviewing, and evaluating conservation development projects. Tools such as these can bring a solid scientific foundation and a focus on functional conservation to the growing field of conservation development, allowing these land-use techniques to realize their full potential as conservation strategies.

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Supplementary Material

Additional information on the design and measurement of the indicators, an example of their use in this study, and raw data for the projects we evaluated are available as part of the on-line article from <http://www.blackwell-synergy.com/> (Appendix S1). The authors are 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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