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# The ability of zoning and land acquisition to increase property values and maintain largemouth bass growth rates in an amenity rich region

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## HIGHLIGHTS

- Zoning and land acquisition affect property prices and the environment.
- These effects are typically positive but small in our setting.
- Both policies have larger effects when geographically targeted.
- The cost of land acquisition is more than the increased tax revenue it generates.

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## ABSTRACT

Land use change is a leading cause of environmental degradation in amenity rich rural areas. Numerous policies have been used to combat these negative effects, including zoning and land acquisition. The empirical effects of these policies on the environment and land markets are still debated. Using a coupled economic–ecological model in conjunction with landscape simulations we investigate the effect of zoning and land acquisition on property prices and largemouth bass (*Micropterus salmoides*) growth in Vilas County, WI, an amenity rich region with growing rural development. Using econometric models of land use change and property prices, we simulate four alternative land use scenarios: a baseline simulation, a zoning change simulation, a land acquisition program simulation, and a land acquisition program + zoning simulation. Each scenario is simulated over 82 separate lakes. For each scenario we calculate the length of a 20-year old largemouth bass, property prices, and number of new residences at simulation years 20, 40 and 60. The policies have small effects on largemouth bass size and property prices on most lakes, although the effects are more pronounced on some. We also test if the increased property values due to land acquisitions are greater than the cost of the land acquisition program and find that in our case, land acquisition does not "pay for itself". Our methodology provides a means to untangle the complex interactions between policy, land markets, and the environment. Empirically, our results indicate zoning and land acquisition are likely most effective when targeted to particular lakes.

## 1. Introduction

Housing growth, particularly in rural areas, is a leading cause of land-use change throughout much of the United States (Radeloff, Hammer, & Stewart, 2005; Radeloff, Hammer, Stewart, Fried, et al., 2005). This trend is likely to continue (Radeloff et al., 2010) and will exacerbate a host of ecosystem changes already influenced by housing growth including increased exotic invasions (Gavier Pizarro, Radeloff, Stewart, Huebner, & Keuler, 2010; Gavier Pizarro, Stewart, Huebner, Keuler, & Radeloff, 2010), biodiversity losses (Green & Baker, 2003; Hansen et al., 2005; Lepczyk et al., 2008), and increasing wildfire risk to home (Bar Massada, Radeloff, Stewart, & Hawbaker, 2009; Syphard et al., 2007). In response to these environmental changes, communities throughout the United States commonly use zoning and land acquisition to manage rural growth and preserve the environment (Ingram, Carbonell, Hong, & Flint, 2009).

Rural planning to preserve the environment, however, impacts more than just natural systems. Zoning and land acquisition impact land markets and thus directly impact the wealth and land use decisions of landowners. Zoning influences land markets by determining permissible use, which in turn influences property prices and land conversion rates (Lewis, Provencher, & Butsic, 2009;

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Mills, 1990; Spalatro & Provencher, 2001). Likewise, land acquisition can affect land markets by both limiting the supply of land (Armsworth, Daily, Kareiva, & Sanchirico, 2006; Armsworth & Sanchirico, 2008) and by adding amenity value to properties near newly-protected open space (Albers, Ando, & Chen, 2008; Geoghegan, 2002; McConnell & Walls, 2005). The challenge to policy makers charged with organizing rural growth is to understand the dynamic interplay of land use policy, land markets, and the environment in order to make decision that do not result in unintended consequences.

Understanding this interplay is further complicated by the complex, heterogeneous, and often feedback driven relationships between policy, markets, and the environment. Zoning sometimes works to direct growth and manage the landowner decisions (Bowers & Daniels, 1997). In other instances though, zoning simply codifies market outcomes (Butsic, Lewis, & Ludwig, 2011; Wallace, 1988). Likewise, the effect of zoning on property prices is both theoretically (Spalatro & Provencher, 2001) and empirically (Netusil, 2005) heterogeneous and depends on the relative effects of zoning on amenity creation and development regulation. And last but not least, the environmental impact of zoning is largely unknown (Butsic, Lewis, & Radeloff, 2010; Conway & Lathrop, 2005; Lewis, 2010).

Land acquisition, theoretically (Lewis et al., 2009; Wu & Plantinga, 2003) and empirically (Lewis et al., 2009) also has heterogeneous effects on the decision to subdivide. In the worst case, acquisition can lead to the perverse effect reducing open space across the broader landscape (Armsworth et al., 2006). Land acquisition generally increases property prices (McConnell & Walls, 2005). In some situations, this increase in property prices due to land protection may be able to pay for the cost of land purchases, a pattern known as the proximate principle (Crompton, 2001). However, while there is ample evidence for this in urban areas (Nelson, 1986; see Crompton, 2001 for a review), the existence of the proximate principle in rural settings is less certain.

The conflicting theoretical and empirical effects of zoning and land acquisition on the environment, land owner decisions, and property prices, have made many skeptical of their overall effectiveness, and ultimately hindered their implementation. Planners in rural areas are left with a situation where uncertainty over changes in property values coupled with unproven environmental results make the application of any policy difficult. To provide guidance to these complex interactions we propose a method to jointly estimate the effects of zoning and land acquisition on the environment, land development decisions, and property prices. Directly estimating these effects helps to clarify the complex and interacting effects of policy, property prices, and the environment; provides a mechanism to directly compare the effectiveness of alternative policies; provides a way to target specific areas where each policy will be most effective; and provides a way to compare direct fiscal cost of the policies implementation with potential changes in tax revenue due to changing land values. Ultimately, we propose that our modeling approach provides the information planners need to engage their constituents in the planning process.

We conducted our analysis in Vilas County, WI, a lake-rich landscape with high amenity value (Peterson et al., 2003), using land-use simulations based on econometric models of land development and land prices, which incorporate land market feedbacks on land development, zoning, and land acquisition. We tested for the ecological effects of zoning and land acquisition by simulating land development under four policy scenarios: a baseline simulation, a zoning simulation, a land acquisition simulation, and a land acquisition + zoning simulation over a 60-year time frame. We coupled the output of these simulations with models of largemouth bass (*Micropterus salmoides*; hereafter referred to as LMB) growth and property prices, which allowed us to compare the ecological and land market outcomes under alternative land use planning scenarios.

We used this methodology to address four questions. First, using LMB growth as a metric of ecologically relevant disturbance, we ask if LMB growth rates change under alternative policies. Second, we ask how the land market effects of zoning and land acquisition programs affect individual property prices. Third, we test if these property price effects are large enough to offset the cost of land acquisition, i.e., does the proximate principle hold? And fourth, we ask on which specific lakes are each policy more successful.

## 2. Methods

### 2.1. Study area

Vilas County, located in Northern Wisconsin harbors over 1300 lakes and water covers over 15% of the County (Vilas County, 2008) (Fig. 1). The county has long been a bastion for second home development. Since the 1960s, over half of all homes have been built on parcels with lake frontage (Schnaiberg, Riera, Turner, & Voss, 2002). The dense development along some lakes has lead to a host of ecosystem changes including: decreased growth rates for bluegills (*Lepomis macrochirus*; Schindler, Geib, & Williams, 2000), decreased amounts of coarse woody habitat (Christensen, Herwig, Schindler, & Carpenter, 1996), species extirpation (Woodford & Meyer, 2003), and invasions by exotic species (Carpenter et al., 2007).

Recreational fishing, in particular, has been a pillar of the region economy in Vilas County (Postel & Carpenter, 1997; Peterson et al., 2003). Largemouth bass are a commonly sought game fish in the region and are known to act as keystone species (Mittelbach, Turner, Hall, Rettig, & Osenberg, 1995) that can affect entire lake ecosystems (e.g., Carpenter, Kitchell, & Hodgson, 1985; Mittelbach et al., 1995). Altered LMB ecology is associated with lakeshore residential density (e.g., Francis & Schindler, 2009; Lawson, Gaeta, & Carpenter, 2011; Scheuerell & Schindler, 2004). Indeed, recent research has shown that growth rates of adult LMB are negatively correlated with lakefront residential density (Gaeta, Guarascio, Sass, & Carpenter, 2011). This effect is especially pronounced in larger fish that are most sought after by anglers, indicating that residential growth may be negatively related to fishery quality. The sensitivity of LMB to lakeshore residential density in conjunction to this species potential to alter entire lake ecosystems makes LMB an ideal candidate to detect ecologically relevant levels of anthropogenic disturbance on lake ecosystems. In this study we use LMB growth as a metric of ecologically relevant anthropogenic disturbance.

Zoning is the main land use control in Vilas County, and Vilas County was one of the first counties in Wisconsin to require more stringent shoreline zoning than the state minimum frontage of 100 ft. In 1999 all of the lakes in the County were rezoned based on a matrix of residential density and ecological sensitively. Lakes deemed sensitive to development and that had low residential density were zoned 300 ft. Lakes deemed insensitive to development and that had higher levels of residential density were zoned 200 ft or 150 ft.

Recently, local and national land trusts, along with the state government have begun to purchase private land for public use. Between 2004 and 2007, the Nature Conservancy with joint funding from the State's Knowles–Nelson Stewardship fund purchased over 3000 acres in Vilas County at a cost of over $4,000,000 (State of Wisconsin, 2007). In addition, a local land trust – the Northwoods Land Trust – has acquired properties in the county (Northwoods Land Trust, 2010). Thus, land conservation in Vilas County appears to follow the upward nationwide trend (Land Trust Alliance, 2010).

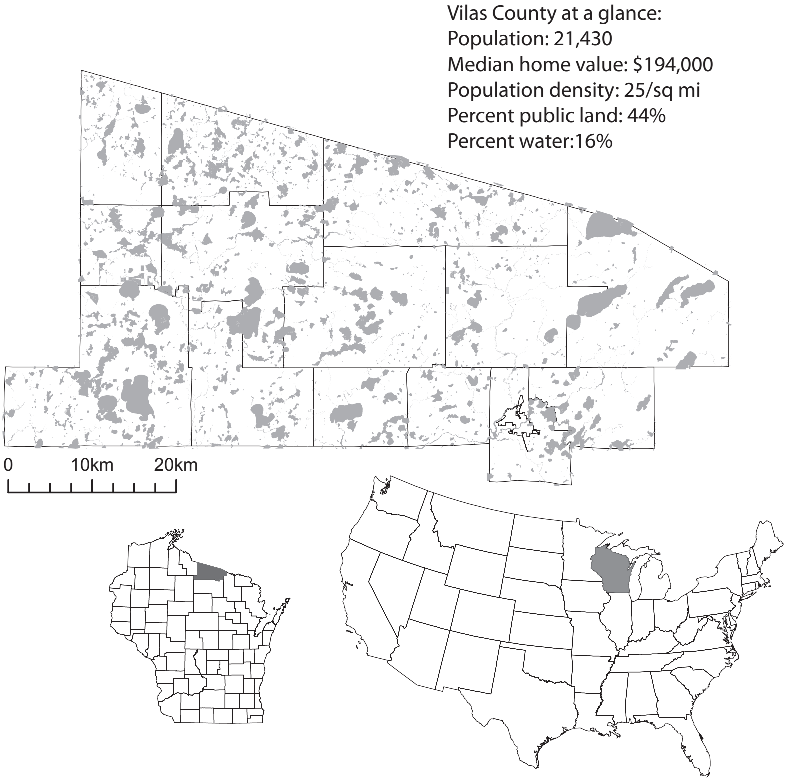

**Fig. 1.** The study area, Vilas County, as situated in Wisconsin and the United States.

### *2.2. Overview of the simulation methodology*

We integrated three separate models to examine the environmental and land market effects of zoning and land acquisitions. First, a land development model was used to assign a transition probability to each parcel and to assign the number of parcels that would be created in the event of a subdivision (Lewis et al., 2009). Second, a hedonic model predicted the cost of purchasing each parcel for conservation (Horsch & Lewis, 2009) and was also used to estimate the effect of land acquisition on property prices. Third, an ecological model predicted the length specific growth rates of LMB based on lake level residential density (Gaeta et al., 2011). These three models were coupled in order to track land development and ecological response over a 60-year simulation.

#### *2.2.1. Land development model*

We used an existing land development model to calculate the likelihood a parcel would subdivide, and to predict the number of new parcels created in the event of a subdivision (Lewis et al., 2009). This model was composed of a jointly estimated probit-Poisson econometric model, which estimates the likelihood a parcel will subdivide and the number of new parcels developed in the event of a subdivision based on lake (size, depth, clarity, location), time (as represented by time dummies), and parcel specific (feet of lake frontage, soil restrictions, lots size) characteristics, along with lake and parcel specific random effects. This model was parameterized using data on the development of 1200 individual lots from 1974 to 1998.

#### *2.2.2. Conservation cost model*

To calculate the cost of land acquisition in Vilas County we modified a previously estimated hedonic model of property prices (Horsch & Lewis, 2009). The model used a spatial difference-in-differences specification to estimate the effect of lake (size, access, parcel density, zoning, clarity, depth, exotic invasion and fishing quality), parcel (feet of lake frontage, lot size), and time specific (an estimated time trend) characteristics on the price of lake front properties. The model was parameterized using data on 1841 individual parcel sales on 172 lakes from 1998 to 2006 in Vilas County, WI.

#### *2.2.3. Land market effects*

Important for our simulation methodology are the dual assumption that the policy variables of interest – zoning and percent of shoreline government owned – were exogenous in the land development and conservation costs models. If these variables were endogenous then it would be incorrect to interpret the estimated coefficients as policy effects (Lewis, 2010). We argue here, as we have done before (Butsic et al., 2010; Lewis et al., 2009), that zoning and percent of shoreline government owned land were exogenous in our models of land development and property prices because (1) government land was primarily the result of defaults to the state during the great depression and not correlated with variables that would influence land development or property prices and (2) lake front zoning was decided at the township level for much of our study, and therefore was not correlated with unobserved factors which may affect property prices and land development at the individual lake level. Therefore, we assumed that the estimated coefficients of the policy variables in Lewis et al. (2009) and Horsch and Lewis (2009) were the true impacts of changes in the land market, and can be used to simulated land market changes.

#### *2.2.4. LMB growth rate model*

We used an existing model of LMB growth rates, which estimated the correlation between residential density and the growth rate of LMB across fish length (Gaeta et al., 2011). The model was built using size-specific growth rates sampled from lakes with a large range of residential development in Vilas County. Specifically,

**Table 1**
Four simulation scenarios for original zoning levels.

| Original zoning level | Baseline simulation | Zoning change simulation | Land acquisition simulation | Land acquisition + zoning simulation |
|---|---|---|---|---|
| 150 ft | Baseline simulation with zoning set to 150 ft | Simulation with zoning set to 300 ft | Simulation with zoning set to 150 ft and land acquisition at $125,000 a year | Simulation with zoning set to 300 ft and land acquisition at $125,000 a year |
| 200 ft | Baseline simulation with zoning set to 200 ft | Simulation with zoning set to 300 ft | Simulation with zoning set to 200 ft and land acquisition at $125,000 a year | Simulation with zoning set to 300 ft and land acquisition at $125,000 a year |
| 300 ft | Baseline simulation with zoning set to 300 ft | Simulation with zoning set to 150 ft | Simulation with zoning set to 300 ft and land acquisition at $125,000 a year | Simulation with zoning set to 150 ft and land acquisition at $125,000 a year |

the model used a longitudinal multilevel model to estimate the effect of residential density, length, and maximum depth on LMB growth rates and also includes annuli (year), fish, and lake specific random effects. In total, 473 LMB representing 2032 annuli were sampled from 16 lakes. Annual growth rates (mm/year) were determined using Fraser–Lee's method of back calculation with Carlander's recommended constant of 20 mm for LMB (Carlander, 1982; Schindler et al., 2000). A stepwise procedure was used to select the best fitting model. The model includes an interaction term between length and residential density, which are negative and statistically significant. This indicates that as fish grow larger the negative effect of residential density on growth rates grows stronger. At small sizes LMB grow quickly even on lakes with large residential populations, but a strong negative effect of residential density hampers growth once the fish reach about 220 mm. In total, the model predicts that fish on lakes with high levels of residential density take about 1.5 years longer to reach 14 in., the minimum size limit for sport anglers, compared to LMB on lakes with no residential density.

In addition to the LMB growth rate model, we also model the mass of LMB. As LMB increase in length, relatively small increases in length can have much larger increases in mass. Using data from the North Temperate Lakes Long Term Ecological Research (NTL-LTER) program's Biocomplexity database (https://secure.limnology.wisc.edu/lterquery/abstract_new.jsp?id=BIO_FISH1) we estimated a length–weight relationship for LMB based on 324 individuals from 36 lakes with lengths ranging from 25 to 501 mm. The result was the following power model:

$$\text{weight} = \exp(-11.77 + 3.09(\log(\text{length})))$$

$$R^2 = 0.99, \quad p < 0.01, \quad DF = 322$$

The model indicates, for example, that for a 16 in. LMB a 3% increase in length will lead to a roughly 9% increase in mass.

### 2.3. Simulation model

The land development, conservation costs, and LMB growth rate models were coupled in land use simulations. At the start of all simulations each parcel on each lake was in one of three states: developed (which refers to parcels which were too small to legally subdivide and could not develop further and thus were excluded from the simulation), undeveloped (in which case the parcels are large enough to subdivide and can either develop, become protected, or remain undeveloped), or protected (in which case the parcel stayed protected throughout the simulation). The simulation procedure works as follows:

1. The land development model assigns transition probabilities to each undeveloped parcel according to the parcels' specific characteristics.
2. A random number from the unit interval is drawn for each parcel and compared to the estimated transition probability.
3. In the event that the transition probability is greater than the random number, the parcel subdivides, otherwise it remains undeveloped.
4. If the parcel subdivides, the number of new lots created is determined based on the number of expected lots estimated by the Poisson model.
5. Landscape variables that were affected by subdivisions such as residential density were updated and new transition probabilities and conservation cost were estimated for each parcel.
6. Steps 1–5 were repeated 15 times. Each time step represents four years for a total landscape simulation of 60 years.
7. Steps 1–6 were repeated 1000 times to generate a distribution of landscapes.
8. Using the residential density at years 20, 40, and 60 as input we simulate LMB growth for 20 years (in one year time steps) for each simulation, resulting in a distribution of average sizes for LMB at age twenty for each lake at years 20, 40, and 60 of the program.

Throughout the landscape simulation, errors were fully propagated in the land development, conservation costs, and LMB growth rate model. This was accomplished using the Krinsky–Robb (1986) method which draws random coefficients from the estimated distribution of coefficients. A more detailed description of this error propagation approach is provided in Lewis (2010) and Butsic et al. (2010).

### 2.4. Scenarios

In order to calculate the effect of land acquisition and zoning changes on LMB growth and property prices, we systematically varied the level of zoning and simulate a land acquisition program (Table 1). We simulated three alternative zoning scenarios. On lakes that are currently zoned 300-ft minimum frontage zoning, we simulated land development with 150-ft zoning. For lakes that are currently zoned 200-ft and 150-ft minimum frontage we simulated land development with 300-ft zoning.

We also simulate the implementation of a land acquisition program. The program worked as follows:

1. A budget was provided to acquire land at the beginning of each 4-year period. Before the first step in the landscape simulation, a parcel (or parcels if the budget is large enough to purchase multiple parcels) was purchased. If the budget is less than the least expensive parcel, no parcels were purchased.
2. The amount of land purchased was equal to the total frontage of the lot minus the minimum frontage size. The acquisition program purchased the land only. It is assumed that any structure on the lot stayed in private ownership on a parcel of land equal to the minimum frontage size allowed under zoning.
3. After a parcel was purchased, the parcel was considered government owned (in fee title), and the percent of total shoreline government owned was updated.
4. The land use simulation moved forward one 4-year time step.

**Table 2**
Summary statistics grouped at the parcel level.

| Variable | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|
| Lake depth (ft) | 42.63 | 20.39 | 8 | 86 |
| Water clarity (ft) | 7.25 | 5.10 | 1.23 | 20.64 |
| Lake size (acres) | 562.26 | 520.59 | 15 | 3555 |
| Percent govt. owned (% of shoreline) | 0.06 | 0.13 | 0 | 0.8 |
| Number of parcels | 106.59 | 74.85 | 4 | 328 |
| % soil not rated | 0.045 | 0.11 | 0 | 1 |
| % soil limited | 0.70 | 0.35 | 0 | 1 |
| Lake association (1 = presence of association) | 0.50 | 0.50 | 0 | 1 |
| Frontage (ft) | 937.14 | 966.76 | 300.21 | 16,974.61 |

$N = 935$.

5. A new budget was provided to the land acquisition program and was added to the leftover funds from the first period.
6. Steps 1–5 were repeated until the end of the land use simulation.

Theoretically, optimal conservation decisions are based upon the cost of purchasing each parcel, the probability that the parcel will develop, and the conservation value of each parcel (Costello & Polasky, 2004; Newburn, Berck, & Merenlender, 2006). In a prior study (Butsic, 2011), dynamic programming was used to solve for optimal reserve selection strategy in our study area based on all of these criteria. This work compared the optimal outcome (which takes site characteristics, parcel cost and threat level into account) to two heuristic models—a maxgain algorithm (which protects the most land at the least cost) and a minloss algorithm (which protects parcels which are the most threatened). For our study area, the maxgain strategy performed very well, and was statistically indistinguishable from the optimal conservation strategy. Furthermore, it is computationally impossible to apply the optimal conservation strategy to the large choice sets that we used for this analysis. Therefore, we applied the maxgain algorithm to select which parcels to protect in each time step, as it preformed the closest to the optimal strategy.

We simulated numerous budgets and found that as expected, the effect of the program became greater with larger budgets, but there were also diminishing returns to increasing the budget. Based on past expenditures for conservation purchases in the area, we show here results for a budget of $125,000 per year per lake for the land acquisition program ($500,000 every four year time step).

### 2.5. *Testing the proximate principle*

The proximate principle held if the incremental increase in tax revenue due to increased property values which result from land acquisition was large enough to pay the debt charges from the purchase. We tested if the proximate principle held using the following methodology. First, we assumed that the land acquisition program was funded for each four-year period by selling general obligation bonds which mature over 20 years. Therefore, the debt charges for each year t, was the sum of annualized debt charges for all purchases from the past 20 years. Assuming a 2% property tax rate, the incremental tax increase due to the land acquisition program was 0.02 multiplied by the difference in land values under the baseline simulation and the land acquisition simulation. If this incremental increase was larger than the debt obligation for a given year, the proximate principle held for that year. If the incremental increase was larger than the debt obligation in each year of the program, the proximate principle held for the whole program. We tested for the proximate principle for each year of each simulation.

### 2.6. *Summary statistics*

We ran our simulations for 82 lakes in Vilas County. Eleven of these lakes (103 undeveloped parcels) were zoned 300-ft minimum frontage, 23 lakes (267 undeveloped parcels) were zoned 150 ft, and 48 (565 undeveloped parcels) lakes were zoned 200 ft. The average lake was 35 ft deep, 370 acres in size, had 74 parcels, and water clarity of 6.9 feet. The average undeveloped lot had 937 ft of frontage, most of the soil (70%) was somewhat limited for building, but only 4% was rated as unsuitable for building (Table 2).

We tested for differences in natural and anthropogenic characteristics between lakes zoned 150 ft, 200 ft, and 300 ft using a *t*-test for unequal samples. Lake size did not differ statistically between zoning regimes nor did the percentage of the lake that is government owned. Lakes zoned 300 ft were statistically deeper and had fewer parcels than lakes zoned 150 ft. Lakes zoned 300 ft did not differ statistically from lakes zoned 200 ft except that there were fewer parcels on lakes zoned 300 ft. Lakes zoned 200 ft were significantly different than lakes zoned 150 ft in depth, clarity, and number of parcels. At the individual parcel level, we note that parcels on lakes with 300 ft zoning typically had larger frontage than lakes zoned 200 ft or 150 ft.

## 3. Results

### 3.1. *The effect of zoning and land acquisition on LMB length*

When we grouped lakes based on their original zoning level, we found that there were only small changes in mean LMB length under the alternative programs (Table 3). In general group level mean changes in length were less than 2 mm. Interestingly, this was the case even though there was some differences between the baseline simulation for each zoning group, with LMB size equal to 421.73 mm for 150 ft zoning, 427.73 mm for 200 ft zoning, and 431.63 mm for 300 ft zoning (Table 3).

Using our 1000 simulations to generate a distribution of outcomes, we test for differences in the distributions of LMB size at age 20 in simulation year 60 using a two-sided Kolmogorov–Smirnov test at the level of the individual lake under the alternative policy scenarios. The null hypothesis is that the distributions of outcomes were from the same continuous distribution. On nearly every lake and under nearly every policy situation the null hypothesis is rejected, meaning that on the individual lake level, LMB size was influenced by land use policy over time. We also used a Wilcoxon rank sum test to test for equal medians between scenarios; we rejected this hypothesis at a similar rate as the KS test. We find similar results for lakes originally zoned at 200 ft and 150 ft (Fig. 2).

In general, the effects of the policies diverged over time. At year 20, alternative policies were more likely to produce distributions of LMB sizes and residential density that were equivalent than at year 60. This difference is most pronounced in the LMB size model. We test this by comparing the number of lakes in each original zoning category whose distribution of LMB size was significantly different under alternative policies. In all scenario comparisons, more lakes have significantly different distributions as time increases (Fig. 2).

**Table 3**
Mean LMB length (mm) at age 20 and property prices ($) on lakes zoned 150 ft, 200 ft, and 300 ft under four policy scenarios, at years 20, 40 and 60. Standard errors in parentheses.

| | Zone 150 | | | Zone 200 | | | Zone 300 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Year 20 | Year 40 | Year 60 | Year 20 | Year 40 | Year 60 | Year 20 | Year 40 | Year 60 |
| Mean LMB length (mm) | | | | | | | | | |
| Baseline | 422.80 | 422.11 | 421.73 | 428.68 | 427.96 | 427.57 | 431.63 | 431.16 | 430.89 |
| | (3.64) | (3.70) | (3.71) | (3.24) | (3.29) | (3.30) | (3.14) | (3.14) | (3.12) |
| Zoning change | 423.45 | 423.09 | 422.91 | 429.20 | 428.74 | 428.49 | 429.90 | 428.84 | 428.28 |
| | (3.46) | (3.48) | (3.48) | (3.10) | (3.12) | (3.12) | (3.69) | (3.65) | (3.59) |
| Land acquisition program | 423.97 | 423.94 | 423.94 | 429.98 | 429.92 | 429.91 | 432.59 | 432.55 | 432.53 |
| | (3.41) | (3.41) | (3.41) | (2.94) | (2.94) | (2.94) | (2.95) | (2.94) | (2.94) |
| Land acquisition + zone | 423.98 | 423.96 | 423.96 | 430.01 | 429.97 | 429.96 | 432.00 | 431.87 | 431.82 |
| | (3.37) | (3.37) | (3.37) | (2.92) | (2.92) | (2.92) | (3.00) | (2.99) | (2.99) |
| Mean change in property price ($) | | | | | | | | | |
| Baseline | 1801 | 2404 | 2731 | 1854 | 2508 | 2861 | 1595 | 2148 | 2455 |
| | (2287) | (2809) | (3056) | (1649) | (2140) | (2397) | (976) | (1297) | (1475) |
| Zoning change | 1088. | 1396 | 1544 | 1369 | 1807 | 2032 | −4020 | −5227 | −5868 |
| | (1047) | (1285) | (1394 | (1100) | (1415) | (1556) | (2381) | (3070) | (3434) |
| Land acquisition | 504 | 521 | 524 | 459 | 503 | 513 | −290 | −323 | −340 |
| | (533) | (555) | (561) | (547) | (658) | (691) | (353) | (456) | (508) |
| Land acquisition + zone | 488 | 498 | 499 | 459 | 488 | −494 | −898 | −1009 | −1051 |
| | (459) | (470) | (472) | (481) | (557) | (582) | (1284) | (1623) | (1757) |

While most lakes had significantly different distributions of LMB size under alternative policies, the size of this effect is heterogeneous. A few lakes had relatively large changes in LMB size under the land acquisition policy, where mean length increased up to 13.74 mm and mass increased over 10%. Most of these lakes were originally zoned 150 ft or 200 ft. This suggests that lakes already zoned 300 ft were effective at maintaining LMB growth rates compared to lakes with lesser zoning (Table 4).

The effect of zoning on LMB size at the individual lake level was likewise heterogeneous, although the effect is not as pronounced as the land acquisition program (Table 4). Also, it was less clear which original zoning group is most affected by a zoning change. Out of the 10 lakes that had the largest changes due to zoning changes, four were originally zoned 300 ft, three 200 ft and three 150 ft.

### 3.2. *The effect of zoning and land acquisition on residential density and property values*

Using the same simulations discussed previously we next considered the effects of zoning and land acquisition on the number of new residences and property values. On the lakes originally zoned 300 ft an average of 8.45 new parcels developed over 60 years in the baseline simulation. When zoning was decreased to 150 ft, the number of new parcels increased to 15.82 new parcels. For the land acquisition the mean increase was 2.20 new parcels while for land acquisition + zoning it was 5.75 new parcels. Amplified residential density decreased property prices by an average of $2,455.94 per parcel (0.8% of the total value of the average parcel and structure at year 60 which is about $350,000) at year 60 for the base case, $5,868.82 (2%) for the simulated zoning case, $340.46 (0.1%) for the land acquisition program, and $1,051.90 (0.3%) for the land acquisition + zoning case. The median and distribution of the changes in property prices statistically differ ($p < .05$) (Wilcoxon rank-sum test and Kolmogorov–Smirnoff test) for each policy, on each lake (Fig. 3).

For lakes originally zoned 150 ft, the number of new parcels increased by an average of 8.23 for the base case, 4.85 parcels for the zoning increase, 2.91 for the land acquisition program, and 1.51 for the land acquisition program + zone. This decreased property prices by $2,731.84 (1%) in the base case, $1,544.98 (0.5%) in the simulation case, $524.61 (0.2%) for the conservation program and $499.18 (0.2%) for the land acquisition + zone. The median and distribution of decreased property values statistically differ significantly ($p < .05$) (Wilcoxon rank-sum test and Kolmogorov–Smirnoff test) for each policy, on each lake (Fig. 3).

For lakes originally zoned 200 ft, the number of new parcels built for the baseline scenario is 10.33. For the zone change simulation the number of new lots increased by 8.13. When the land acquisition program is in effect, the number of new parcels was 3.43, and when the conservation and zoning program were both in effect the number of new parcels was 1.98. The lost property values due to increased development density increased by $2,861.33 (1%) for the base case, $2,032.09 (0.7%) for the zoning simulation, $513.08 (0.2%) for the land acquisition program and $494.93 (0.2%) for the land acquisition program + zone. The median and distribution of both of these changes statistically differ ($p < .05$) (Wilcoxon rank-sum test and Kolmogorov–Smirnoff test) for each policy, on each lake (Fig. 3).

**Table 4**
10 lakes with largest average changes (compared to the baseline simulation) in 20-year LMB length (mm) due to the land acquisition program in year 60.

| Changes due to land acquisition | | | | Changes due to zoning | | | |
|---|---|---|---|---|---|---|---|
| Lake ID | Absolute change in LMB size (mm) | Zone | Percent change in LMB mass at age 20 | Lake ID | Absolute change in LMB size (mm) | Zone | Percent change in LMB mass at age 20 |
| 66 | 13.97 | 200 | 10.97% | 66 | 6.75 | 200 | 5.21% |
| 41 | 8.08 | 150 | 6.09% | 2 | 5.78 | 300 | 4.26% |
| 51 | 7.031 | 150 | 5.29% | 80 | 5.51 | 300 | 4.05% |
| 39 | 6.24 | 200 | 4.66% | 41 | 5.30 | 150 | 3.88% |
| 76 | 5.98 | 200 | 4.36% | 76 | 4.87 | 200 | 3.54% |
| 64 | 4.95 | 200 | 3.68% | 39 | 3.74 | 200 | 2.78% |
| 36 | 4.64 | 200 | 3.43% | 51 | 3.56 | 150 | 2.66% |
| 21 | 4.08 | 150 | 3.07% | 78 | 3.45 | 150 | 2.62% |
| 2 | 3.89 | 300 | 2.88% | 19 | 3.26 | 300 | 2.39% |
| 40 | 3.47 | 150 | 2.54% | 56 | 2.90 | 300 | 2.11% |

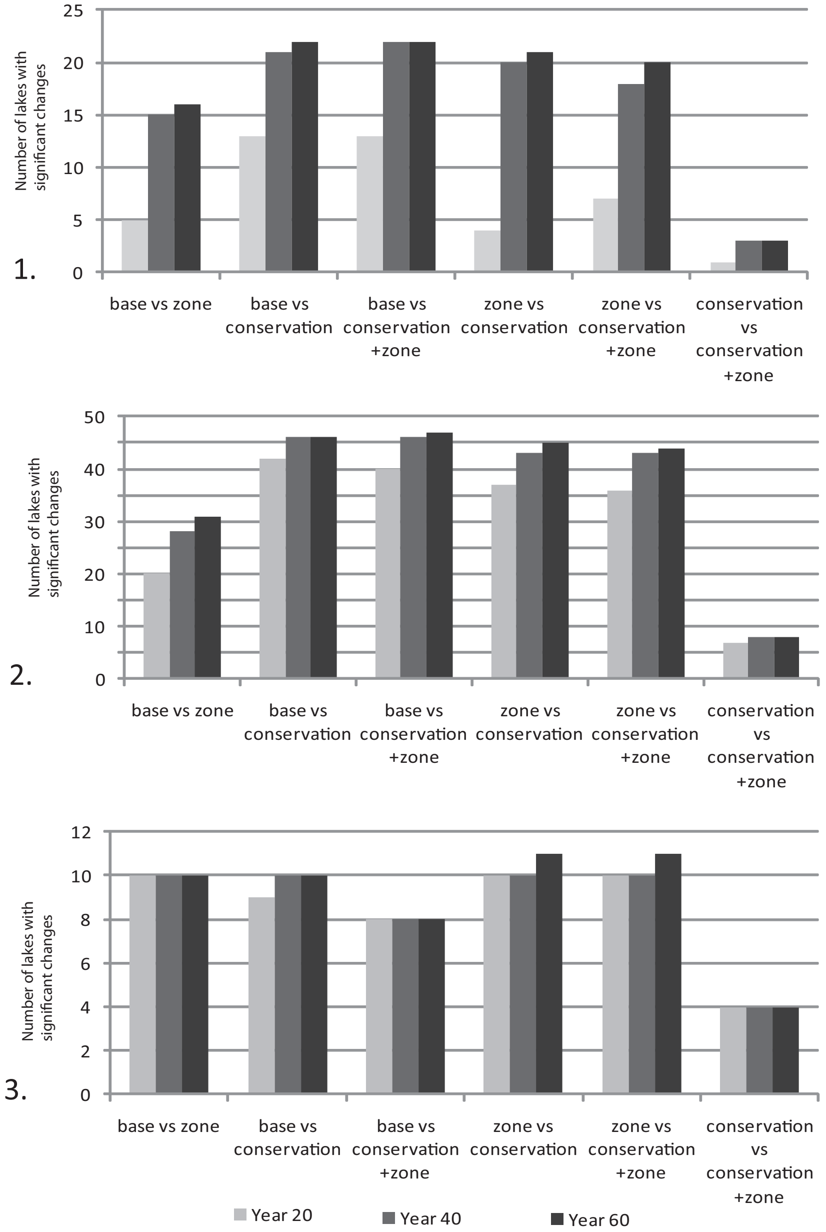

**Fig. 2.** Number of lakes with significantly different distributions (KS-test) of LMB size at age 20 for lakes at year 20, 40 and 60. Part 1 represent lakes that are zoned 150 ft, part 2 represents lakes zoned 200 ft and part 3 represents lakes zoned 300 ft.

### 3.3. *The proximate principle*

We assumed that the land acquisition program is funded every 4 years through municipal bonds which mature in 20 years at 5% interest (these numbers reflect how the Knowles–Nelson Stewardship fund is funded). The debt charge for a single year when the full $125,000 is spent is about $10,000. That is, to retire the debt in 20 years the program must pay back about $10,000 a year. Therefore, for the proximate principle to hold, property values must increase by slightly over $500,000 per lake (assuming a 2% property tax) for each $125,000 spent on land acquisition. In our case, we found that this never occurred. For the majority of the lakes, the incremental increase in tax revenue covered less than 10% of the cost of the program. Land acquisition on lakes zoned 150 ft and 200 ft came the closest to achieving the proximate principle, but even on these lakes, the incremental tax increase was 46% of debt charges (Table 5). Of course, lower interest rates or higher tax rates would

**Table 5**
10 lakes with the highest percent of debt charges covered by tax revenue increases over the full 60 years of the program.

| Lake ID | Percent of debt charges covered by tax revenue increase | Zone |
|---|---|---|
| 21 | 46.4% | 150 |
| 9 | 36.2% | 200 |
| 12 | 26.2% | 150 |
| 3 | 25.2% | 150 |
| 51 | 23.7% | 150 |
| 8 | 19.0% | 200 |
| 41 | 16.0% | 150 |
| 22 | 14.1% | 200 |
| 33 | 12.8% | 200 |
| 5 | 12.2% | 150 |

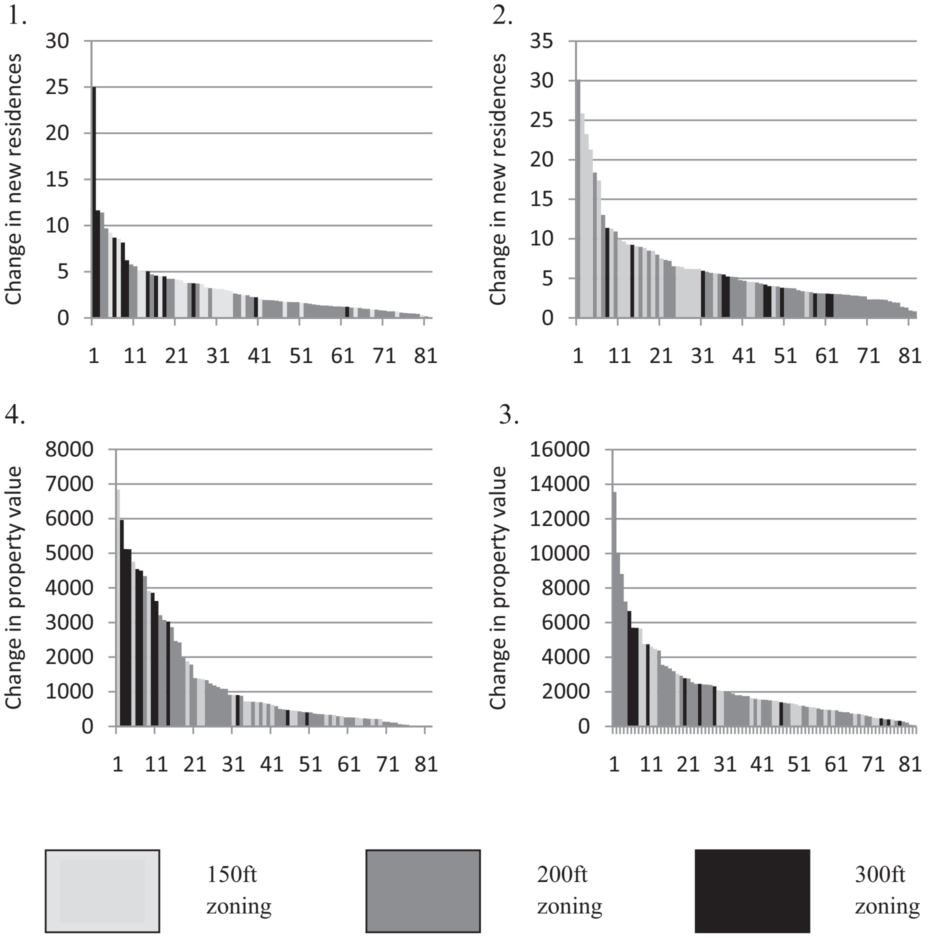

**Fig. 3.** Each part displays the relevant change versus the baseline for all 82 lakes, ranked from the lake with the largest change to the smallest. Light grey lines indicate lakes originally zoned at 150 ft, grey are lakes originally zoned at 200 ft, and black are lakes originally zoned 300 ft. Part 1 is the change in number of new residences over the 60-year simulation with zoning versus a baseline simulation. Part 2 is the number of new residences over the 60-year simulation with the land acquisition program in place. Part 3 is the change in property values per parcel under the zoning simulation. Part 4 is the change in property values per parcel under the land acquisition program.

increase the percent of debt charges covered by the incremental increase.

## 4. Discussion and conclusions

In this paper, we compare the effectiveness of two common conservation policies (zoning and land acquisition) to protect LMB growth. We also analyze how these policies affect land markets by changing subdivision rates and property prices. Overall, we find that land acquisition and zoning have heterogeneous effects on LMB growth. Both policies can be effective when applied to the right lakes, but when applied broadly, they will be effective only on occasion. The mean changes in LMB size when grouped by zoning-level tend to be modest, but at the individual lake level these changes can be more substantial. Land acquisition is most effective at preserving LMB size on lakes zoned 150 and 200 ft.

While there are statistically significant changes in LMB growth on most lakes, the ecological and social implications of this change less clear. We feel the mean lake change of 2 mm for a 20-year old LMB is unlikely to be noticed by anglers, and is unlikely large enough to cause the cascading effects on lake ecology caused by large changes in LMB densities. However, on a few targeted lakes land acquisition and zoning increases LMB mass by over 5% (with a maximum of 10.6%). Such changes may very well be noticed by anglers, and potentially could affect lake ecology. This suggests that the targeted use of land acquisition and zoning may be a valuable tool in creating trophy sport fisheries.

In terms of land markets, we find that both zoning and land acquisition reduce the property price effects of increased residential density, as both polices reduce the number of new lots created. In general, land acquisition reduces the negative impacts of increased residential density more than zoning. The magnitude of these effects ranges from a few hundred dollars to a few thousand dollars per home in year 60 of the simulation. Given that average land prices are about $250,000 per lot, and $350,000 for parcel plus home, the overall effect of increased residential density on property values is modest under both policies.

We also test for the proximate principle and find that in all cases incremental tax increases due to land acquisition are smaller than the cost of the program itself. This is in contrast to the common argument of the land acquisition movement that the proximate principle is justification for funding land acquisitions programs and for tax free land ownership for conservation non-profits (Gies, 2009; Wentworth, 2003). Most of the empirical examples used to justify these claims are for urban areas, while most land acquisitions for conservation purposes are in rural area. Our results caution against expanding urban claims to rural settings and question these tightly held beliefs of the land acquisition movement.

It is important to stress that while we test for the validity of a specific claim – that the proximate principle holds – we do not conduct a thorough cost benefit analysis. Clearly, on some lakes there are ecological benefits to the land acquisition program, some of which will not be capitalized in land values. Likewise the land acquisition program would conceivably grant the public increased access to lakes and public land. To the extent that these values are real and possibly large, the failure of the proximate principle in this case should not be confused with inefficient policy.

We model a land acquisition program that purchased land in fee title. A popular alternative is to purchase conservation easements. Often times, conservation easements can be purchased at a lower price than fee title purchases and may guarantee similar protection. Due the complications of estimating an easement price (there are too few conservation easements in the area to produce a reliable model), we do not test the efficacy of this policy in our setting. Intuitively, if easement prices are less expensive, and they guarantee the same level of protection (although potentially a different level of access), they could be a less expensive tool then fee title purchases in this setting.

Our methodology provides an intriguing advancement toward better welfare estimates for land use policies. Welfare shifts tied to land-use policy will likely be expressed through land market and environmental outcomes, both of which we are able to measure for alternative scenarios using this landscape simulation coupled-model methodology. Land values will undoubtedly capture many of the welfare effects of land-use policy and integrating land values into land use simulations provides a way to capture these values under alternative policies. To the extent that changes in environmental quality are also capitalized in land markets (e.g., via decreased values on crowded lakes), land-use simulations provide a way to estimate this value as well. Finally, the coupled models can quantify changes in environmental quality which may not be capitalized in the land market. These changes could potentially be linked to measures from other studies which value the effect of environmental changes. For instance, in our study region angler surveys have been used to estimate the willingness-to-pay for increased sport fishing, and in other studies changes in fish size have been found to lead to large increases in WTP (Loomis, 2006). These values could be coupled with the estimated changes in a sport fishery to estimate the partial benefits of the land use policy. In this way, landscape simulations and coupled models could provide a new source of benefits estimates which form the basis for cost–benefit analysis.

The effectiveness of the two policies becomes more pronounced over time. After 20 years, results from zoning and land acquisition are more similar than after 60 years, although differences at the mean LMB length remain small. The fact that the long term effects of alternative land-use policies are more different than the short term effects brings up the issue of perpetuity in land conservation, and our results point to the long term benefits of conserving land. To the extent that long-term benefits may be hard to quantify, and that their value will depend largely on how society values the present versus the future (i.e., society's discount rate), land conservation as a policy may be a conservative investment into the future of ecosystems if protection for this land can be assured.

Our work provides a blueprint for how planners and other involved in rural land use policy can assess the complex interactions between land use policy, land markets and the environment. As rural communities struggle to manage growth there is an ongoing tension between protecting the environment on one hand and landowners insistence that policies that protect the environment do so without diminishing their property values or increasing their tax burden on the other. Our linked methodology provides planners a way to share with their constituents estimates of both environmental and land market change. This type of information can thus be used to engage the public and guide policy.

Finally, our methodology allows planners to target the application of zoning and land acquisition. Our results highlighted that on many lakes both policies lead to very small changes in LMB growth, and planners may need to look for other policies (for example mitigation) to impact the environment. On a few lakes, however, one or the other policy provided more substantial growth to largemouth bass, indicating that a targeted approach may be successful. We also suggest that such a targeted approach to rural land use policy, one where planners can show demonstrative gains, may prove more popular with constituents and ultimately help to break the gridlock and contentiousness that can often characterize landscape management.

## References

Albers, H. J., Ando, A. W., & Chen, X. (2008). Spatial-econometric analysis of attraction and repulsion of private conservation by public reserves. *Journal of Environmental Economics and Management*, *56*, 33–49.

Armsworth, P. R., Daily, G. C., Kareiva, P., & Sanchirico, J. N. (2006). Land market feedbacks can undermine biodiversity conservation. *Proceedings of the National Academy of Sciences of the United States*, *103*, 5403–5408.

Armsworth, P. R., & Sanchirico, J. N. (2008). The effectiveness of buying easements as a conservation strategy. *Conservation Letters*, *1*, 182–189.

Bar Massada, A., Radeloff, V. C., Stewart, S. I., & Hawbaker, T. J. (2009). Wildfire risk in the wildland–urban interface: A simulation study in northwestern Wisconsin. *Forest Ecology and Management*, *258*, 1990–1999.

Bowers, D., & Daniels, T. (1997, March). *Holding our ground: Protecting America's farms and farmland* (1st ed.). Island Press.

Butsic, V. (2011). *Land use and conservation: Causal policy analysis and coupled modeling at the social-ecological interface*. Dissertation. University of Wisconsin, Madison.

Butsic, V., Lewis, D. J., & Ludwig, L. (2011). Estimating the effect of endogenous zoning. *Land Economics*, *87*, 412–432.

Butsic, V., Lewis, D. J., & Radeloff, V. C. (2010). Lakeshore zoning has heterogeneous ecological effects: An application of a coupled economic–ecological model. *Ecological Applications*, *20*, 867–879.

Carlander, K. D. (1982). Standard intercepts for calculating lengths from scale measurements for some centrarchid and percid fishes. *Transactions of the American Fisheries Society*, *111*, 332–336.

Carpenter, S. R., Benson, B. J., Biggs, R., Chipman, J. W., Foley, J. A., Golding, S. A., et al. (2007). Understanding regional change. A comparison of two lake districts. *Bioscience*, *57*, 323–335.

Carpenter, S. R., Kitchell, J. F., & Hodgson, J. R. (1985). Cascading trophic interactions and lake productivity. *Bioscience*, *35*, 634–639.

Christensen, D. L., Herwig, B. L., Schindler, D. E., & Carpenter, S. R. (1996). Impacts of lakeshore residential development on coarse woody debris in north temperate lakes. *Ecological Applications*, *6*, 1143–1149.

Conway, T. M., & Lathrop, R. G. (2005). Alternative land use regulations and environmental impacts: Assessing future land use in an urbanizing watershed. *Landscape and Urban Planning*, *71*, 1–15.

Costello, C., & Polasky, S. (2004). Dynamic reserve site selection. *Energy and Resource Economics*, *26*, 157–174.

Crompton, J. L. (2001). The impact of parks on property values: A review of the empirical evidence. *Journal of Leisure Research*, *33*, 1–31.

Francis, T. B., & Schindler, D. E. (2009). Shoreline urbanization reduces terrestrial insect subsidies to fishes in North American lakes. *Oikos*, *118*, 1872–1882.

Gaeta, J. W., Guarascio, M. J., Sass, C. G., & Carpenter, S. R. (2011). Lakeshore residential development and growth of largemouth bass (*Micropterus salmoides*): A cross-lakes comparison. *Ecology of Freshwater Fish*, *20*, 92–101.

Gavier Pizarro, G. I., Radeloff, V. C., Stewart, S. I., Huebner, C., & Keuler, N. S. (2010). Rural housing is related to plant invasions into forests of southern Wisconsin, USA. *Landscape Ecology*, *25*, 1505–1518.

Gavier Pizarro, G. I., Stewart, S. I., Huebner, C., Keuler, N. S., & Radeloff, V. C. (2010). Housing effects on invasive plant distributions in New England, USA. *Ecological Applications*, *20*, 1913–1925.

Geoghegan, J. (2002). The value of open spaces in residential land use. *Land Use Policy*, *19*, 91–98.

Gies, E. (2009). *Conservation: An investment that pays the trust for public land*.

Green, D. A., & Baker, M. G. (2003). Urbanization impacts on habitat and bird communities in a Sonoran desert ecosystem. *Landscape and Urban Planning*, *63*, 225–239.

Hansen, A. J., Knight, R. L., Marzluff, J. M., Powell, S., Brown, S., Gude, P. H., et al. (2005). Effects of exurban development on biodiversity: Patterns, mechanisms, and research needs. *Ecological Applications*, *15*, 1893–1905.

Horsch, E. J., & Lewis, D. J. (2009). The effects of aquatic invasive species on property values: Evidence from a quasi-experiment. *Land Economics*, *85*, 391–409.

Ingram, G. K., Carbonell, A., Hong, Y., & Flint, A. (2009). *Smart growth policies: An evaulation of programs and outcomes*. Cambridge, MA: Lincoln Institute of Land Policy.

Krinsky, I., & Robb, A. (1986). On approximating the statistical properties of elasticities. *The Review of Economics and Statistics*, *68*, 715–719.

Land Trust Alliance. (2010). *2010 National Land Trust Census Report: A look at voluntary land conservation in America*. Washington, DC: Land Trust Alliance.

Lawson, Z. J., Gaeta, J. W., & Carpenter, S. R. (2011). Coarse woody habitat, lakeshore residential development, and largemouth bass nesting behavior. *North American Journal of Fisheries Management*, *31*, 666–670.

Lepczyk, C. A., Flather, C. H., Radeloff, V. C., Pidgeon, A. M., Hammer, R. G., & Liu, J. G. (2008). Human impacts on regional avian diversity and abundance. *Conservation Biology*, *22*, 405–416.

Lewis, D. J. (2010). An economic framework for forecasting land-use and ecosystem change. *Resource and Energy Economics*, *32*, 98–116.

Lewis, D. J., Provencher, B., & Butsic, V. (2009). The dynamic effects of open-space conservation policies on residential development density. *Journal of Environmental Economics and Management*, *57*, 239–252.

Loomis, J. (2006). Use of survey data to estimate economic value and regional economic effects of fishery improvements. *North American Journal of Fisheries Management*, *26*, 301–307.

McConnell, V., & Walls, M. (2005). The value of open space: Evidence from studies of non-market benefits. *Resources for the Future*.

Mills, D. E. (1990). Zoning rights and land-development timing. *Land Economics*, *66*, 283–293.

Nature Conservancy (2011). *About Us* http://www.nature.org/aboutus/?src=t5 (accessed 03.03.11).

Mittelbach, G. G., Turner, A. M., Hall, D. J., Rettig, J. E., & Osenberg, C. W. (1995). Perturbation and resilience: A long-term, whole-lake study of predator extinction and reintroduction. *Ecology*, *76*, 2347–2360.

Nelson, A. C. (1986). Using land markets to evaluate urban containment programs. *American Planning Association Journal*, (Spring), 156–171.

Netusil, N. R. (2005). The effect of environmental zoning and amenities on property values: Portland, Oregon. *Land Economics*, *81*, 227–246.

Newburn, D., Berck, P., & Merenlender, A. (2006). Habitat and open space at risk of land-use conversion: Targeting strategies for land conservation. *American Journal of Agricultural Economics*, *88*, 28–42.

Northwoods Land Trust (2010). *NWLT properties*. http://www.northwoodslandtrust.org/nwlt_properties.htm (accessed 20.10.10).

Peterson, G. D., Beard, T. D., Beisner, B. E., Bennet, E. M., Carpenter, S. R., Cumming, G. S., et al. (2003). Assessing future ecosystem services a case study of the Northern Highlands Lake District, Wisconsin. *Conservation Ecology*, *7*, 24.

Postel, S., & Carpenter, S. R. (1997). Freshwater ecosystem services. In A. Hiraki, & G. Daily (Eds.), *Nature's services* (pp. 195–214). Washington, DC: Island Press.

Radeloff, V. C., Hammer, R. B., & Stewart, S. I. (2005). Rural and suburban sprawl in the US Midwest from 1940 to 2000 and its relation to forest fragmentation. *Conservation Biology*, *19*, 793–805.

Radeloff, V. C., Hammer, R. B., Stewart, S. I., Fried, S. I., Holcomb, S. S., & McKeefry, J. F. (2005). The wildland–urban interface in the United States. *Ecological Applications*, *15*, 799–805.

Radeloff, V. C., Stewart, S. I., Hawbaker, T. J., Gimmi, U., Pidgeon, A. M., Flather, C. H., et al. (2010). Housing growth in and near United States protected areas limits their conservation value. *Proceedings of the National Academy of Sciences of the United States*, *107*, 940–945.

Schindler, D. E., Geib, S. I., & Williams, M. R. (2000). Patterns of fish growth along a residential development gradient in north temperate lakes. *Ecosystems*, *3*, 229–237.

Schnaiberg, J., Riera, J., Turner, M. G., & Voss, P. R. (2002). Explaining human settlement patterns in a recreational lake district: Vilas County, Wisconsin, USA. *Environmental Management*, *30*, 24–34.

Scheuerell, M. D., & Schindler, D. E. (2004). Changes in the spatial distribution of fishes in lakes along a residential development gradient. *Ecosystems*, *7*, 98–106.

Spalatro, F., & Provencher, B. (2001). An analysis of minimum frontage zoning to preserve lakefront amenities. *Land Economics*, *77*, 469–481.

State of Wisconsin (2007). *Knowles–Nelson stewardship grants—Inception through December 31, 2006*. State of Wisconsin. http://dnr.wi.gov/stewardship/documents/StewardshipSenate12.pdf (accessed 20.10.10).

Syphard, A. D., Radeloff, V. C., Keeley, J. E., Hawbaker, T. J., Clayton, M. K., Stewart, S. I., et al. (2007). Human influence on California fire regimes. *Ecological Applications*, *17*, 1388–1402.

Vilas County (2008). *GIS and map portal*. http://co.vilas.wi.us/dept/mapping.html (accessed 23.11.08).

Wallace, N. E. (1988). The market effects of zoning undeveloped land: Does zoning follow the market? *Journal of Urban Economics*, *23*(3 (May)), 307–326.

Wentworth, R. (2003). *Economic benefits of open space protection. Land trust alliance fact sheet*. Washington, DC: The Land Trust Alliance.

Woodford, J. E., & Meyer, M. W. (2003). Impact of lakeshore development on green frog abundance. *Biological Conservation*, *110*, 277–284.

Wu, J. J., & Plantinga, A. J. (2003). The influence of public open space on urban spatial structure. *Journal of Environmental Economics and Management*, *46*, 288–309.