# Buffer Options for the Bay:
# Exploring the Trends, the Science, and the Options of Buffer Management in the Great Bay Watershed

# *Key Findings from Economic Literature*

Dana Marie Bauer

George Perkins Marsh Institute, Clark University, 950 Main Street, Worcester, MA
dbauer@clarku.edu

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## A. Overview

In New Hampshire, the need for trusted, relevant science is experienced at every scale of buffer management, from decisions made by property owners at the water's edge to those of state agencies setting policy for what's permissible on that land. Underpinning each decision is a series of tradeoffs that reflect assumptions held about the impact of that choice on the environment, the economy, and the well-being of the community. This review seeks to support these decisions by presenting a synthesis of available economic and other social science literature on the subject of buffer values and management for the Great Bay Estuary (GBE) and its tributaries in southeast New Hampshire.

The review was commissioned by the Buffer Options for the Bay ("BOB") technical team, which is a component of the larger integrated assessment BOB project entitled "Exploring the Trends, the Science, and the Options of Buffer Management in the Great Bay Watershed." This project is a grant-sponsored collaboration of public, academic, and nonprofit organizations dedicated to enhancing the capacity of New Hampshire stakeholders to make informed decisions that support the protection and restoration of buffer lands in the GBE region. The project defines buffers as naturally vegetated segments of land directly upslope of a water resource, such as a lake, stream, river, pond, estuary, or other wetland type.

In keeping with this goal, this review has been inspired by typical questions that arise in the course of local buffer management. For example, what economic values are associated with ecosystem services provided by buffers? How much are people "willing to pay" to maintain or avoid loss of these services? What role do buffers play in enhancing property values? What economic costs arise in buffer management? What lessons can we learn from previous benefit-cost analyses? What are the economic aspects of buffer-related policy options and how might they influence landowner, land trust, resource manager, and regulator decision making?

This review found that, in general, vegetative buffers have two opposing effects on property values. Improved ecosystem service provisioning may increase prices for adjacent and nearby properties. In contrast, lost development potential and degraded scenic views may reduce prices. Economic theory does not provide any guidance on which effect will dominate and, thus, it is not surprising that studies investigating the effect of vegetated buffers on housing prices have produced mixed results.

In comparison, the general consensus of relevant literature on water quality is that it has a definite effect on property prices, whereby higher property values are associated with better water quality. In addition, these positive effects, which can be as high as a 30 percent increase in property value, extend far beyond waterfront properties, although they diminish as distance from the water body increases. While this literature review is mainly focused on economic values of households living within close proximity of the focal resource, it is worth noting that additional benefits of buffer-related ecosystem services accrue to visiting recreationists and other tourists.

The spatial mismatch between buffer management benefits and costs often complicates their management. Buffers are relatively small from a landscape- or watershed-scale perspective and often located on private land with management costs typically incurred by individual landowners. In contrast, most buffer-generated benefits (e.g., water quality and fish habitat) reach well beyond parcel boundaries to other beneficiaries. In most instances, the landowner is unable to exclude others from receiving the ecosystem services provided by buffers and, thus, cannot demand payment for these benefits. As a result, waterfront landowners will likely undersupply (in terms of both quantity and quality) buffers.

To address this distributional issue, societies can establish policies, programs, or institutions that align the interests of private landowners with social interests. In some cases, this involves governments regulating landowner behavior (e.g., establishing buffer rules), forcing landowners to bear management and opportunity costs. In other cases, government agencies or nonprofits offer incentives to landowners to facilitate provisioning of the socially efficient amount of buffer-provided ecosystem services.

Untargeted buffer regulations, while administratively straightforward, could generate large costs for landowners. Although there are several ways to target land-use regulations and reduce overall opportunity costs, increases in regulatory flexibility to address ecological heterogeneity often create higher administrative costs. That is, a tradeoff exists between the opportunity costs to landowners and the transaction and management costs to the regulator, and it may be unclear which approach minimizes the total cost burden to society.

In comparison, targeted payments for ecosystem services can be made to landowners as incentives to: engage in some activity or group of activities (e.g., installing vegetated buffers) that maintain, restore, or improve the provision of one or more ecosystem services; reduce the intensity of active land uses (e.g., building fewer homes); or cease destructive land use altogether. Payments can be monetary or in-kind and can come from government agencies, nonprofit organizations (e.g., land trusts), or the direct beneficiaries. Purchased conservation easements are one way of targeting critical buffers. Payments can also come in the form of tax credits or deductions. For example, New Hampshire's Current Use Taxation Program allows property taxation at lower "traditional use" values rather than the real estate market value. A similar tax credit program for buffer areas might provide good incentives to waterfront landowners in the Great Bay watershed.

The efficacy of different buffer management policies is case-dependent and influenced by the specific ecosystem services of interest, the level of landscape connectivity required to provide the targeted services, and the magnitude and distribution of benefits and costs. If the number of landowners needed for conservation success is low and buffers providing high-quality ecosystem services can be easily targeted, then incentive-based approaches (e.g., easements and payments for ecosystem services) may work better. If many landowners need to be involved, then simple and non-targeted approaches (e.g., buffer regulations and public education) may be more appropriate. Economic incentives that reduce land-use intensity, rather than eliminating all land uses, cost less and are much more likely to fall within organizations' conservation budgets. Community attitudes towards conservation can influence the dominant property rights regime that ultimately determines who incurs what cost. Sharing the cost burden among landowners and the rest of society may result in higher total costs, but may provide more equitable (and perhaps more politically feasible) alternatives.

Several gaps in our current understanding of the economics of buffer management were uncovered through this review. First, while there is substantial literature covering the effects of water quality on property values, there are very few empirical analyses of the effects of the physical buffer itself. Anecdotal evidence provided mixed results, suggesting that some waterfront landowners enjoy the privacy of a densely vegetated buffer while others prefer an unobstructed view of the water body. Second, only two case studies of New Hampshire residents could be found, both of which were conducted using lakefront property sales data from the early 1990s. As a result, the Buffer Options for the Bay project has been forced to extrapolate willingness to pay values from other diverse locations. Third, no studies comparing a full set of benefits and costs associated with buffer management could be located and existing benefit-cost analyses were highly inconclusive. Finally, no studies that compared the economic and ecological outcomes of buffer regulations to outcomes of other buffer policies were found. This has ramifications for the efficiency of long-term buffer planning and management.

The economic research synthesized in this document is intended to be used by the Buffer Options for the Bay (BOB) project team, though the explicit intent is to then create a number of informational products that translate this science into a more accessible form for end users. Ultimately, the products that are shaped from this review will be of service to all buffer management stakeholders in the Great Bay region, including landowners and the consultants who work with them, regulatory agencies and municipalities, conservation organizations and foundations, and scientists interested in conducting research that will lead to more effective buffer management.

Economics, however, is only one piece of the buffer management puzzle. To augment this economic literature review, the BOB collaborative has conducted a review of the natural science aspects of buffer management, an analysis of regulatory and non-regulatory policy options for New Hampshire, an economic analysis of the values placed on the water quality benefits provided by buffers, a buffer-focused GIS analysis of the GBE region, and an assessment of the barriers and opportunities related to buffer management at the community level in the Exeter-Squamscott subwatershed.

The results of these analyses have been captured in individual reports. They have also been integrated into an online framework intended to inform discussions around buffer management, restoration, and protection in the GBE region. We anticipate that this website will open the door to new and needed research; strategic and complementary investments by state agencies, nonprofits, and foundations; and a collective strategy for outreach professionals to work with communities on advancing effective buffer policy and practice at the local level.

## B. What are the economic benefits and costs of buffer management?

Buffers provide many valuable ecosystem services including water purification, wave and storm surge protection, and wildlife habitat. However, intensive land uses (e.g., conversion to residential and commercial development) threaten the continual provisioning of these services in part because the ecosystem services provided by buffers are not bought and sold through formal markets, and traditional economic analyses often ignore them. Quantifying the values of ecosystem services in monetary units can assist in land-use and buffer management decision making. This section synthesizes the existing literature reporting on economic benefits and costs of buffer preservation, restoration, and ongoing management. The section begins with a look at the benefits that accrue to households, with a particular focus on the effects of buffers on residential property values. Information on these values may incentivize private landowner stewardship behavior including voluntary buffer management. This section then investigates the various costs associated with maintaining or improving the quantity and quality of buffers. Examining both the magnitude and the distribution of all costs is important. Finally, this section concludes with an exploration of studies that conduct benefit-cost analyses (BCAs) in order to discover lessons that may be applicable to managing buffers in the Great Bay watershed.

### I. What economic values are associated with ecosystem services provided by buffers?

Non-market valuation methods developed over the past few decades can be used to quantify the benefits and costs associated with the goods and services provided by nature and not sold in traditional markets in order to improve decision making regarding their use and conservation. Two of these methods are commonly used to assess the values of ecosystem services accruing to households within the local community, county, or watershed. The first—contingent valuation or discrete choice survey—is a stated-preference technique that uses responses to hypothetical scenarios to estimate household willingness to pay (WTP) for potential future programs or policies that would improve environmental quality. A small number of WTP survey studies focused on buffer management have been conducted as part of larger BCAs and are discussed later. Two additional stated-preference studies investigating public WTP for full stream restoration—Collins et al. (2005) studied the restoration of Deckers Creek in West Virginia, while Weber and Stewart (2009) studied the restoration of the Middle Rio Grande in New Mexico—found strong support for projects that include buffer restoration ($50 to $150 per household per year), although specific values for buffers were not estimated.

The second non-market valuation method—hedonic property pricing—is a revealed-preference technique that breaks down the price of a property into a set of implicit prices for building characteristics (e.g., number of bedrooms), parcel attributes (e.g., parcel size), community characteristics (e.g., school quality), and environmental amenities (e.g., scenic views) of the parcel and surrounding neighborhood. The next two sections report on hedonic studies that assess the effects of vegetated buffers and water quality on residential property prices.

While this literature review is mainly focused on economic values of *households* living within local communities, counties, or watersheds of the ecological resource, it is worth noting that additional benefits of buffer-related ecosystem services accrue to visiting recreationists and other tourists (Phaneuf et al. 2008, Colby and Smith-Incer 2005, Colby and Orr 2005, Lipton 2004). These values are not covered in this review, but could be substantial in some locales. Further, additional benefits (or costs) may accrue to communities, due to changes in property tax revenues; these are discussed later in the policy section of this review.

### *i. Effect of vegetated buffers and riparian restoration on residential property prices*

In general, vegetative buffers can have two opposing effects on property values. Improved water quality, fish and other wildlife habitat, stream bank stabilization, and overall aesthetics of the surrounding environment may increase prices for adjacent and nearby properties. In contrast, lost development potential and degraded scenic views (e.g., hidden water) may reduce prices. Economic theory does not provide any guidance on which effect will dominate and, thus, it is not surprising that studies investigating the effect of vegetated buffers on housing prices have produced mixed results ranging from a 27 percent gain to a 5 percent loss, depending on geographic region, location of property (e.g., waterfront vs. non-waterfront), and whether public access is allowed (Table 1). While no hedonic buffer studies were found for New Hampshire, several other studies provide good insights for the Great Bay watershed. Of the ten studies examined, the two studies that examined the impact of mandatory buffer rules both found no price effect. Five studies report positive price effects, but three of these are for public greenways rather than vegetated buffers on private lands. Of the remaining three studies, one reports negative price effects, and two report mixed effects depending on the location of the property.

Bin et al. (2009) examined the impact of a mandatory buffer rule on riparian properties in the Neuse River Basin (Craven County, North Carolina) using housing sales data from before and after the rule went into effect. The rule requires a 50-foot riparian buffer with undisturbed forest vegetation in the first 30 feet and shrubs and other plants in the remaining 20 feet. They found that, while waterfront properties are on average 25.9 percent higher priced than otherwise equivalent non-waterfront properties, there was no significant difference between waterfront housing prices before and after the buffer rule (i.e., the buffer regulation had no impact on house prices). The authors suggest that the lack of impact may be due to the lost development opportunities of waterfront landowners being balanced out by the amenity benefits received by all nearby property owners. Alternatively, they also suggest that the rule may not have been binding because the land in buffers was not buildable buildable and many waterfront properties already maintained a vegetated buffer meeting the requirements of the regulation. A similar "no effect" result was found by Maurer and Soldavini (2013) who investigated the impact of mandatory riparian ordinances on residential property values in Jackson County, Oregon.

In comparison, Mooney and Eisgruber (2001) found a negative effect of planting treed riparian buffers on waterfront properties in the Mohawk Watershed of western Oregon. While waterfront properties had a premium price 10 percent higher than equivalent non-waterfront properties, the planting of a treed riparian buffer reduced the values of waterfront properties by 0.33 percent per foot if the buffer width was less than or equal to 30 feet or by 0.07 percent per foot if the buffer width exceeded 30 feet. For an average waterfront property in the region, a new 50-foot treed buffer (i.e., assuming no treed buffer as the baseline) would result in an 11 percent reduction in market value. The authors suggest that the dense vegetation diminished the view of the river in a region where trees are abundant.

Similarly, Münch et al. (2016) found a negative price effect of a ten-meter buffer on properties with the buffer in two rural municipalities in Denmark. However, non-buffer properties nearby incur a positive price effect, which increases the closer the property is to a public access point in the buffer zone (rather than a direct line distance to the buffer). That is, public access to the protected area is key to achieving positive price effects. This case study is an interesting illustration of the potential distributional effects that can result from mandatory buffers, whereby the owners of the buffer properties incur the costs of lost productive use of their lands, while nearby residents gain the positive recreational and other amenities.

In contrast, Streiner and Loomis (1995) examined the impact of seven urban buffer restoration projects on property values in three California counties (Contra Costa, Santa Cruz, and Solano), and found that property values in areas near the improved streams increased by 3 to 13 percent depending on the specific restoration activities (e.g., stream bank stabilization, flood reduction, improved fish habitat). While distance to the stream was significant (i.e., higher values for properties closer to the stream), the authors did not distinguish between waterfront and non-waterfront properties.

Qiu et al. (2006) also found positive effects of streams and related open space on suburban property values in the Dardenne Creek watershed near St. Louis, Missouri. Properties containing the stream and/or related open space *could* incur a price premium as much as 4 percent. Nearby properties *could* also receive higher prices, although the premium fell as distance from the stream increased. The novelty of this study is that it pointed out that not all properties would necessarily receive the price premium, as properties within a flood zone could drop as much 4.7 percent, leading to a potential overall loss in value when accounting for both effects.

Similarly, Hamilton and Quayle (1999) found positive impacts of riparian greenways on property values in four suburban neighborhoods around Vancouver and Victoria, British Columbia. Price premiums varied from 11.9 to 15.6 percent for properties adjacent to the greenways. No price effect was found for non-adjacent, nearby properties. In this study, the greenways are publicly-owned riparian zones, so private properties are not directly adjacent to the waterway. A related survey of households in the four areas revealed that 75 percent thought the greenway increased their property value with an average impact of 20.6 percent (higher than the statistically estimated actual effect), 67 percent "felt a sense of collective ownership," and amenities ranked in order of preference were recreation, flood control, and wildlife preservation. Bark-Hodgins et al. (2005) and Colby and Wishart (2002) also report positive values for nearby vegetative riparian areas in semi-arid Tucson, Arizona, where vegetation of all kinds is in short supply.

In a slightly different analysis, Netusil (2006) examined the effect of riparian *corridor* quality on property values in the Fanno Creek Watershed in Portland, Oregon. Corridor refers to the waterway *and* the surrounding land. In one model specification, which measured corridor quality with a riparian functional score (based on microclimate, bank stabilization, sediment and pollution control, streamflow, water storage, woody debris, and channel dynamics), properties containing riparian buffers experience a positive 4.7 percent price increase for a one standard deviation increase in the riparian score. In a second model specification, which measured corridor quality using a three-class ecological system, properties containing Class I (the highest quality) riparian buffers experienced positive (although not statistically significant) price effects, while properties containing Class II or Class III riparian buffers experienced negative price effects (although only the Class II effect was statistically significant).

**Table 1.** Comparison of property price effects due to adjacent or nearby riparian buffers.

| Study | Location | Water Body | Buffer Metric | Price Effect* |
|---|---|---|---|---|
| Bark-Hodgins et al. 2005 | Arizona (Tucson area) | urban streams | densely-vegetated riparian corridor | 20% |
| Bin et al. 2009 | Craven County, North Carolina | Neuse River | 50-foot buffer requirement | no effect |
| Colby and Wishart 2002 | Arizona (Tucson area) | urban streams | densely-vegetated riparian corridor | 10% to 27% depending on distance to corridor |
| Hamilton and Quayle 1999 | Vancouver and Victoria, British Columbia | suburban streams | riparian greenways (public access vegetated buffers) | 11.9% to 15.6% adjacent properties; no effect elsewhere |
| Maurer and Soldavini 2013 | Jackson County, Oregon | Rogue River and tributaries | 75-foot for river, 50-foot for streams | no effect |
| Mooney and Eisgruber 2001 | Western Oregon | Mohawk Watershed | variable-widths (mean 30-foot), treed riparian buffer | -0.33% per buffer foot for width ≤30 feet; -0.07% per buffer foot for width >30 feet; -11% of sales price for average property with 50-foot buffer |
| Münch et al. 2016 | Denmark (two rural regions) | rivers, streams, and lakes | 10-meter buffer zone | negative effect on buffer properties, positive effect on non-buffer properties |
| Netusil 2006 | Portland, Oregon | Fanno Creek Watershed | riparian function score | 4.7% for a one standard deviation increase in riparian score |
| Qiu et al. 2006 | St. Charles County, Missouri | Dardenne Creek Watershed | stream with buffer/open space | 4% decreasing as distance increases; -4.7% if in floodplain |
| Streiner and Loomis 1995 | California (three counties) | urban streams | riparian buffer restoration projects | 3% to 13% depending on restoration activities |

*Price effects shown as percent increases or decreases in the mean house sales price unless otherwise specified.

### *ii. Effect of water quality on residential property prices*

A number of hedonic property price studies estimating the effect of water quality on residential property prices have been conducted over the past 30 years (Table 2). While these studies include different geographic regions and a variety of water quality metrics (e.g., water clarity, pollutant concentrations, indicator species), the general consensus is that water quality has a definite effect on property prices whereby higher property values are associated with better water quality. In addition, these positive effects—ranging from less than 1 percent to 30 percent increases—extend beyond waterfront properties, although they diminish as distance from the water body increases. Reductions in water quality also affect property prices.

Two hedonic water quality studies were conducted in New Hampshire. In the first, Gibbs et al. (2002) examined the effect of water clarity (measured by secchi disk visibility depth) on sales prices of waterfront properties on 69 public access lakes across 59 communities. Results showed that house prices were higher on lakes with better water quality, and that estimated implicit prices varied among four New Hampshire regions, likely due to variations in average water clarity, lake area, and housing markets: $1,135 per meter in Conway/Milton, $3,923 per meter in Derry/Amherst, $5,541 per meter in Winnipesaukee (but not including properties on Lake Winnipesaukee, which is much larger than other lakes), and $9,756 per meter in Spofford/Greenfield. (All prices above are in 1995 U.S. Dollars (USD) per meter of additional visibility.) Using the mean house price in each region, these implicit prices can be converted to a percent increase in average sales price of 0.91, 3.39, 3.50, and 6.64 percent, respectively, for a one-meter increase in secchi disk depth.

In the second New Hampshire study, Halstead et al. (2003) investigated the effects of an invasive species (water milfoil) on lakefront property values. Milfoil can spread at exponential rates, limiting boating and swimming activities, crowding out native plants essential for fisheries, and reducing overall aesthetics. Results showed extensive losses in property values (20 to 40 percent) due to the presence of milfoil in the lake, although even the authors note that these results may be inconclusive due to the relatively simple metric used (presence/absence of milfoil at the lake scale). In addition, other researchers questioned their use of ordinary least squares (OLS) statistical methods (Horsch and Lewis 2009). However, several more recent studies using different metrics and statistical approaches corroborate the negative effect of milfoil on property values, although the magnitude of the losses is less, ranging from 8 to 24 percent (Tuttle and Heintzelman 2015, Zhang and Boyle 2010, Horsch and Lewis 2009). Additional insights for the Great Bay watershed can be found in other studies conducted outside New Hampshire.

Walsh et al. (2011) found that while waterfront properties have positive implicit prices for water clarity improvements (1.25 percent increase in the mean house price for a one-foot increase in visibility), non-waterfront properties also have positive implicit prices with prices decreasing as distance from the lake increases from a 0.73 percent increase for homes 100 meters from the lakeshore to a 0.18 percent increase for homes 1000 meters from the lakeshore. Although the effect of water clarity is greater for waterfront properties, the much larger number of non-waterfront properties allows for aggregate benefits from non-waterfront properties to be a substantial portion of total benefits (50 to 80 percent in their examples). Tuttle and Heintzelman (2015) and Walsh et al. (2017) also show positive implicit prices for water quality extending beyond waterfront properties in Adirondack Park (New York) and counties around the Chesapeake Bay (Virginia), respectively.

In one of the earlier water quality hedonic property studies, Epp and Al-Ani (1979) found that when water quality is low, the effects of other property characteristics are larger. For example, the effect of flood hazard (i.e., the potential for flooding) on prices was insignificant for properties on streams with good water quality but was significantly negative for properties on streams with poor water quality.

The choice of environmental quality metrics to use in hedonic property valuations is important and should ideally be suited to the ultimate use of estimated economic values. Michael et al. (2000) examined nine different water quality metrics, all based on secchi disk readings, to explore the effect of short-term versus long-term measures on property prices. In particular, they investigate whether home buyers care more about current water quality conditions versus expectations about future conditions, and whether they consider historical conditions as representative of future trends. Results were mixed, suggesting that different property owners may perceive water quality in different ways. Walsh et al. (2017) also found mixed results (i.e., positive and negative implicit prices for water quality) when using three-year water quality averages versus all positive values when using one-year averages.

In another comparison of alternative water quality metrics, Walsh et al. (2016) show that a three-nutrient composite Trophic State Index (TSI), including total nitrogen, total phosphorus, and chlorophyll-a, performs better than each of the single-nutrient measures as well as a one-out, all-out (OOAO) composite indicator, in large part due to the way the TSI encompasses physical conditions and controls for nutrient-limiting threshold situations. Single-nutrient metrics may overestimate economic values by an order of magnitude, which can be critical if conducting a full benefit-cost analysis or making policy decisions.

Bin and Czajkowski (2013) compared the use of technical measures of water quality (water clarity, salinity, pH, and dissolved oxygen) against the use of non-technical measures (percent and letter "grades") thought to be more intuitive to the general public. Their results showed that the technical measures were better predictors of house prices, indicating that waterfront homebuyers in the study area (Martin County, Florida) are "relatively sophisticated" in their understanding of technical water quality issues. However, the authors suggest that these homebuyers may have acquired this knowledge by going through the process of interpreting the grades from the underlying technical metrics used to calculate them.

In a similar study, Poor et al. (2001) compared an objective scientific metric of water clarity (i.e., secchi disk depth) with individual subjective perceptions of water clarity obtained through a mail survey in which new lakefront home buyers were asked to rate the minimum water clarity of the lake during the first summer they owned the property. Results showed that most (61 percent) respondents in four regions of Maine underestimated water clarity by more than one foot, while another substantial group (23 percent) overestimated water clarity by more than one foot. Only 16 percent of respondents were able to accurately estimate water clarity within one foot of its scientifically monitored and reported depth. Thus, concerns about the use of objective scientific measures in hedonic property analyses may be unfounded and the use of subjective measures may lead to substantial over-or under-valuation of the environmental amenity.

A number of studies investigated the impact of the recent economic recession (2007–2009) on implicit prices for water quality and other environmental amenities. Bin et al. (2016) found that the recession had no effect on water quality values (implicit prices) for sales of waterfront homes in Martin County, Florida-- a result that may be due to the relative wealth of homebuyers in this study (mean house sale price of $810,000). In contrast, Cho et al. (2011) found a reduction in implicit prices for other environmental amenities during the recession. Specifically, the value of developed and forested open space within a one-mile radius of the property fell from 6.16 to 4.26 percent and from 4.42 to 2.41 percent of the mean housing price, respectively, for homes in Nashville-Davidson County, Tennessee. They also found that while implicit prices for a water view fell from $52,348 to $45,923 in dollar amounts, they rose slightly when calculated as a percentage of the mean housing price (from 23 to 23.5 percent) because the mean housing price of homes with a water view fell more than the value of the water view. Hillard (2015) also found a negative impact of the recession on implicit prices for water resource amenities for house sales in Duval County, Florida, and showed that this effect increased for properties farther away (that is, waterfront properties lost less value than non-waterfront properties).

While the majority of hedonic water quality studies focus on surface waters, Guignet et al. (2016) examined the impact of *groundwater* quality on residential property values in Lake County, Florida. Results show that finding contamination in private wells within three years prior to the sale will reduce the price by 3 to 6 percent. As the time between finding contamination and sale increases beyond three years, the reduction in price diminishes and gradually approaches zero. While the case study takes place in a region dominated by agricultural runoff, the concern for groundwater contamination may also be relevant for residential properties with private wells in the Great Bay watershed.

**Table 2.** Comparison of property price effects due to changes in water quality in adjacent or nearby water bodies.

| Study | Location | Water Body | Quality Metric | House Type | Price Effect* |
|---|---|---|---|---|---|
| Artell 2014 | Finland | lakes, rivers, and Baltic Sea | water usability index incorporating 15 ecological and chemical criteria into five water usability classes | waterfront lots (land only) | 19-30% for excellent<br>9-13% for good<br>-9 to -14% for passable<br>-65 to -69% for poor relative to the satisfactory class |
| Bin et al. 2016 | Martin County, southern Florida | St. Lucie River, St. Lucie Estuary, Indian River Lagoon | composite grade (visibility, pH, salinity, dissolved oxygen) | waterfront | 0.2%<br>for 1% increase in grade |
| Bin and Czajkowski 2013 | Martin County, southern Florida | St. Lucie River, St. Lucie Estuary, Indian River Lagoon | water visibility, composite grade (visibility, pH, salinity, dissolved oxygen) | waterfront | 3.8% and 4.6%<br>for a 1% increase in visibility and grade, respectively |
| Cary and Leftwich 2007 | Greenwood County, South Carolina | Lake Greenwood | algae bloom, chlorophyll-a | within 1000 feet of lake | No significant price effect for either water quality metric |
| Clapper and Caudill 2014 | Near North Ontario ("cottage country" north of Toronto) | 74 lakes | water clarity (secchi disk depth) | waterfront and non-waterfront cottages | 2.0%<br>for a one-foot increase in visibility |
| Epp and Al-Ani 1979 | Pennsylvania | small rivers and streams | pH | waterfront | 6.0% for a one-point increase in pH |
| Halstead et al. 2003 | New Hampshire | 10 lakes in central N.H. | invasive species (milfoil) presence/absence | waterfront | 20.7% - 42.7% reduction<br>due to presence of milfoil<br>(but statistically inconclusive) |

**Table 2 Continued.** Comparison of property price effects due to changes in water quality in adjacent or nearby water bodies.

| Study | Location | Water Body | Quality Metric | House Type | Price Effect* |
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**Table 2 Continued.** Comparison of property price effects due to changes in water quality in adjacent or nearby water bodies.

| Study | Location | Water Body | Quality Metric | House Type | Price Effect* |
|---|---|---|---|---|---|
| Horsch and Lewis 2009 | Vilas County, Wisconsin | 172 lakes | invasive species (milfoil) presence/absence | waterfront | 8% reduction of average property values due to the invasion of one more lake |
| Gibbs et al. 2002 | New Hampshire (four market areas) | 69 public access lakes in 59 towns | water clarity (secchi disk depth) | waterfront | 0.91% - 6.64% for a one-meter increase in visibility |
| Kashian et al. 2006 | Delavan, Wisconsin (north of Chicago, Illinois) | Delavan Lake | water clarity (secchi disk depth) | waterfront and non-waterfront | 2.8% - 11.7% for a one-foot increase in visibility |
| Leggett and Bockstael 2000 | Anne Arundel County, Maryland | Chesapeake Bay | fecal coliform | waterfront | 1.3% - 2.6% for a decrease of 100 fecal coliform colonies per 100 mL |
| Michael et al. 2000 | Maine (three market areas) | 22 lakes in 39 towns | water clarity (secchi disk depth) | waterfront | 5.2% - 10.4% Area 1<br>1.9% - 3.4% Area 2<br>14.2% - 28.4% Area 3<br>for a one-meter increase in visibility |
| Netusil et al. 2014 | Portland, Oregon, metropolitan area | Johnson Creek watershed (Columbia River) | dissolved oxygen (DO), fecal coliform, pH, stream temp., total organic solids | waterfront and non-waterfront within 1 mile | 3.12 - 13.71% for a 1 mg/L increase in DO depending on distance from stream |
| Netusil et al. 2014 | Vancouver, Washington, metropolitan area | Burnt Bridge Creek watershed (Willamette River) | dissolved oxygen (DO), other metrics tested | waterfront and non-waterfront within 1 mile | 0 - 4.49% for a 1 mg/L increase in DO depending on distance from stream |
| Poor et al. 2001 | Maine (four market areas) | lakes and ponds | water clarity (secchi disk depth) | waterfront | 3% - 6% for a one-meter increase in visibility |

**Table 2 Continued.** Comparison of property price effects due to changes in water quality in adjacent or nearby water bodies.

| Study | Location | Water Body | Quality Metric | House Type | Price Effect* |
|---|---|---|---|---|---|
| Poor et al. 2007 | St. Mary's County, southern Maryland | St. Mary's River watershed (Chesapeake Bay) | total suspended solids (TSS), dissolved inorganic nitrogen (DIN) | waterfront and non-waterfront in local watershed | $1086 for a 1 mg/L decrease in TSS, $17,642 for a 1 mg/L decrease in DIN (2003 USD) |
| Ramachandran 2015 | Barnstable County, Massachusetts | Three Bays watershed | nitrogen | waterfront and non-waterfront | 0.41% - 0.61% for a 1% decrease in nitrogen (mg/L) |
| Steinnes 1992 | Northern Minnesota | 53 lakes | water clarity (secchi disk depth) | land only (no house) | $206 increase in value of lot for a one-foot increase in visibility |
| Tuttle and Heintzelman 2015 | Adirondack Park, New York | 52 lakes | pH, loon presence, loon abundance, invasive species (milfoil) presence of nearest lake | waterfront and non-waterfront | -18% (all homes) to -24% (waterfront) for a pH<6.5 (acidic)<br>11% for loon presence year of sale<br>1% for each loon present year of sale<br>-6% for presence of milfoil year of sale |
| Walsh et al. 2017 | 14 Maryland Counties | Chesapeake Bay | water clarity (light attenuation) | waterfront and non-waterfront within 2000 meters of bay | 0.3% - 1.6% waterfront<br>0.2% - 0.6% 500m<br>for a 10% decrease in light attenuation (4-10cm increase in visibility) |
| Walsh et al. 2011 | Orange County (Orlando), Florida | 146 natural lakes | water clarity (secchi disk depth) | waterfront and non-waterfront within 1000 meters of lake | 1.25% lakefront, 0.36% (0.18-0.73%) non-lakefront for a one-foot increase in visibility |
| Zhang and Boyle 2010 | Rutland County, Vermont | 4 lakes and 1 pond | invasive species (milfoil) and total macrophyte extent (percent cover) in front of property | waterfront homes and unimproved land | -0.3% for just over 1% coverage<br>-16.4% for 80-100% coverage |

*Price effects shown as percent increases in the mean house sales price resulting from an increase in water quality. Price effects shown in dollar amounts represent the implicit price of water quality for the house with the mean sale price.

**II. What economic costs arise in buffer preservation, restoration, and management?**

Management of water quality, wildlife habitat, and other buffer-generated ecosystem services requires substantial monetary or in-kind investments that can be as small as "free" technical assistance and as large as outright purchase of large swaths of land. While their relatively small size might lead one to believe that buffer preservation, restoration, and management will be less costly than conservation via large-scale protected areas, it is important to consider all costs that might be encountered through various buffer programs and policies so that management goals can be achieved at the lowest possible cost. It is also important to consider who incurs the burden of these costs, private landowners or the public (e.g., through the work of government agencies and nonprofit organizations). As stated by James Boyd, "What may appear to be striking differences in the cost of alternative policies are primarily differences in who bears the cost of conservation" (Boyd et al. 1999, p. 6). In this section, four categories of buffer management costs are described, followed by case studies of empirical cost analyses.[1]

***i. Opportunity costs***

In most cases, the largest cost of a buffer program or policy is the opportunity cost associated with the productive activities (i.e., farming, grazing, forestry, commercial or residential development) that are given up by the landowner in order to establish or maintain natural vegetation in the buffer area. In some policy settings, all human activities are restricted in the buffer. In others, the intensity of the use is decreased, often resulting in lower production, and the opportunity cost reflects the value of this reduced productivity. In situations of mandatory buffer rules, the landowner incurs the cost of conservation. In situations of voluntary buffer programs, landowners will likely need to be compensated for their losses (Randhir et al. 2011).

***ii. Acquisition costs***

Conservation of biodiversity and other ecosystem services often entails the protection of the land in a natural state. This can be accomplished through the outright purchase of land or through the purchase of the property's "use" rights (e.g., development rights, grazing rights, or timber harvesting rights). Acquisition costs should reflect the opportunity costs of the foregone activities. Costs of acquiring just use rights are often less than the costs of buying the land outright, particularly in the case of purchasing development rights because often some other non-harmful (e.g., recreational) uses can continue.

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[1] Naidoo et al. (2006) and Coggan et al. (2010) provide more comprehensive discussions of conservation costs.

### *iii. Transaction costs*

Many conservation programs involve an exchange between two or more parties--for example, between a government agency and one or more landowners. The exchange could be in the form of a transfer of property rights to eliminate a harmful land use, or it could be an incentive payment for a change in land-use behavior to a less-intensive use. In addition to the actual payment (i.e., acquisition cost or incentive payment), other costs associated with engaging in the exchange, known broadly as transactions costs, may occur (McCann 2013). *Information costs* are the costs associated with identifying potential conservation targets (e.g., land parcels), estimating the benefits of conservation, educating landowners and the public, understanding the conservation values of individual landowners, and other knowledge costs associated with reducing uncertainty in the exchange. Information costs can also arise when accounting for the complexity of future climate change (Mills et al. 2014). Landowners can also experience information costs—for example, the time spent learning about how the program works and determining if it is beneficial (McCann and Claassen 2016). These costs can be a barrier to landowner participation in voluntary programs. *Contracting costs* include the time and legal costs associated with negotiating a contract. These costs can be quite high if each contract needs to be context-specific. *Coordination costs* are the extra costs associated with identifying the best spatial targets or coordinating the conservation efforts of multiple landowners—for example, targeting multiple landowners in a particular watershed because of critical water quality issues. Often agencies will provide an extra incentive (i.e., a bonus payment) for spatially coordinated parcels or buffers (Parkhurst et al. 2002). Key factors that influence transaction costs include: (1) the characteristics of the transaction, including the complexity of the property right, frequency of transactions, and the level of institutional or ecological uncertainty; (2) the characteristics of the parties involved, including previous experience, level of trust in the other party, and social connectedness among participants; and (3) the institutional context including the full set of legal, social, and political rules (Coggan et al. 2013).

### *iv. Management costs*

Once a buffer conservation policy or program has been selected and participants identified, there are additional costs associated with ongoing management. *Installation, restoration, and maintenance costs* cover planting of native vegetation, removal and control of invasive species, and other onsite activities. *Administrative costs* include staffing, office space, and meeting costs for ongoing operations of the government agency or nonprofit conservation organizations (e.g., land trusts). Even “free” technical assistance and public education activities incur some level of administrative costs, although they are rarely assessed. *Monitoring costs* cover site visits and reporting associated with ensuring conservation goals are being met. *Enforcement costs* are legal and other costs associated with litigation and collecting fines.

### *v. Case study: Willamette Basin, Oregon*

Oregon's Department of Environmental Quality estimates the total cost of restoring 96,000 acres of riparian buffers and improving stream habitat throughout the Willamette Basin, where two-thirds of Oregon's population lives, to be between $593 million and $1.2 billion (average $900 million) for an initial 15-year period and annual land rental payments of $13 million thereafter to meet water quality goals of reduced sediment runoff, decreased stream temperatures, and improved aquatic habitat (Michie 2010). 75 percent of this cost would go to restoration on agricultural lands, 15 percent to restoration on lands within urban growth boundaries, and the remainder to forested lands. The analysis assumes that most restoration projects will occur at sites with little or no vegetated cover, identified as having less than 12 percent canopy cover but not impervious surface, and will utilize best management practices (BMPs). Costs would cover 60-meter buffers on larger streams and 30-meter buffers on smaller streams. Installation costs can vary widely and include site preparation, plants and other materials, labor, and ongoing maintenance. Estimated costs, including both buffer installation costs and land rental payments, average $4,695 per acre for rural areas and $10,543 per acre for urban areas. Additional upfront costs include $6,307 per acre for fencing around buffers in grazing areas (about 8 percent of buffers in the study area) and $12,333 per acre for bank stabilization and other instream habitat improvement activities (61 percent of urban buffers, 33 percent of agricultural buffers, and 10 percent of forest buffers). Ongoing rental payments are estimated to be $128 per acre per year for rural lands and $240 per acre per year for urban lands. All costs are in 2008 dollars. Table 3 shows upper and lower bounds for BMP costs estimates.

**Table 3.** Estimated per-acre costs (2008 USD) associated with 15-year buffer restoration best management practices in the Willamette Basin, Oregon. (Source: Michie 2010)

| BMP | Average Cost | Lower Bound | Upper Bound |
|---|---|---|---|
| Rural Planting | 4,695 | 3,964 | 5,426 |
| Urban Planting | 10,543 | 8,962 | 12,124 |
| Instream Habitat | 12,333 | 10,483 | 12,183 |
| Fencing | 6,307 | 5,362 | 7,254 |

### *VI. Other case-study cost estimates*

The majority of buffer cost estimates in the literature focus on agricultural or commercial forestry lands rather than urban development and may not be directly applicable to the Great Bay watershed. However, they do provide some information on the lower bound of costs or the upper bound of landowner participation in voluntary programs (Roberts et al. 2009). Table 4 summarizes information from four studies, two of which utilize survey data on landowner willingness to accept (WTA) payment to voluntarily forego production activities (Kline et al. 2000; Yu and Belcher 2011); the other two estimate the cost to landowners of mandatory buffer policies (Nakao and Sohngen 2000; Roberts et al. 2009). Interestingly, Kline et al. (2009) show WTA varies from $38 per acre to $137 per acre depending on landowner objectives, with the lowest payments required for landowners with recreational objectives and the highest payments required for landowners with production objectives.

**Table 4.** Comparison of estimated costs of buffer management.

| Study | Location | Buffer Width | Costs Included | Annual Cost Estimate |
|---|---|---|---|---|
| Kline et al. 2000 | Pacific Northwest | 200-foot | opportunity costs of timber harvest | $128-$137 per acre for landowners with timber objectives;<br>$54-$69 per acre for landowners with timber and non-timber objectives;<br>$38-$57 per acre for landowners with recreation objectives |
| Nakao and Sohngen 2000 | Maumee River Basin, Ohio | 50-foot to 150-foot | opportunity costs of crop production | $61-$110 per acre |
| Roberts et al. 2009 | Harpeth River Watershed, Tennessee | 150-foot | installation, maintenance, livestock exclusion, and opportunity costs of crop and grazing production | $78-$118 per acre for cropland;<br>$52-$351 per acre for pasture;<br>$1.3 million regionally |
| Yu and Belcher 2011 | Prairie Pothole Region, Saskatchewan (Canada) | ten-meter | opportunity costs of crop production | $30 per acre |

**III. What lessons can we learn from existing benefit-cost analyses?**

Benefit-cost analyses (BCAs) are often used to guide management decisions or policy making. The most comprehensive economic analysis of buffer management will include a comparison of economic values for all benefits and all costs. If net benefits are positive (i.e., total benefits exceed total costs), then a buffer program or policy is deemed economically efficient because society as a whole can be made better off. While political feasibility and social justice issues are also concerns for buffer management, they are not the focus of this literature review but will be discussed briefly in the policy section.

Only five riparian buffer BCA case studies were identified in the literature (Table 5). In all five, benefits were evaluated for hypothetical buffer programs using survey methods rather than reporting actual benefits achieved through an existing program. While there were mixed results in terms of net benefits, the general consensus from these studies is that the total market and non-market benefits generated from riparian buffer zones outweigh their costs. Unfortunately, none of the studies included *all* benefits and *all* costs, so drawing formal conclusions is not possible. Of the five studies, the most relevant for the Great Bay watershed is the case study highlighted below.

***i. Case study: Canaan-Washademoak Watershed, New Brunswick, Canada***

The Canaan River and Lake Washademoak watershed in southern New Brunswick includes 91 tributaries and 12 major subwatersheds across an area of 2,160 square-kilometers. Land use is predominantly forest but also includes agriculture and residential development, with recent trends towards more commercial (service sector) and residential development for commuters and seasonal (recreational) residents. In a recent benefit-cost analysis, Trenholm et al. (2013) investigated the net social benefits of providing water filtration, fish and wildlife habitat, and forest scenery ecosystem services through the establishment and maintenance of riparian buffers in the watershed.

To estimate benefits from improved ecosystem services, a contingent valuation survey was mailed to three groups of residents: (1) households owning property in riparian areas of the watershed, (2) households owning non-riparian property within the watershed, and (3) households living outside the watershed in southern New Brunswick. Survey respondents were asked to evaluate four hypothetical buffer programs that varied over buffer size (30 meters versus 60 meters), the type of land protected (forest only versus forest, agriculture, and residential), the magnitude of the expected level of improvement in ecosystem services (slight, moderate, or large), and the level of payment (increase in annual income taxes over ten years). Estimated annual household willingness to pay (WTP) for buffer enhancement programs ranged dramatically from -$4.13 to $42.28 (2007 Canadian Dollars (CDN)) across the four buffer programs and four statistical methods (a total of 16 sensitivity analyses). Total WTP ranged from -$1.4 million to $110 million (2007 CDN). Only one of 16 analyses resulted in negative values, indicating a general positive WTP for buffer enhancement programs.

Costs for the two buffer scenarios (30-meter and 60-meter) were limited to the opportunity costs of foregone productivity. Forest opportunity costs were estimated using a net present value wood supply model that was developed and calibrated to the region. Agricultural opportunity costs were estimated using regional agricultural land rental values. Residential opportunity costs were estimated using regional assessed property values. Total opportunity costs (calculated by multiplying per-acre opportunity costs for each land-use type by its area within the buffer) ranged from $1.3 million to $5.4 million (2007 CDN) for 30-meter buffer scenarios and from $2.2 million to $10.4 million (2007 CDN) for 60-meter buffer scenarios.

A total of 32 different benefit-cost sensitivity analyses were conducted, and results were mixed. Half the 16 most conservative (i.e., low-benefit and high-cost) net present value calculations, ranging from -$17 million to $36 million (2007 CDN), resulted in negative net benefits. In contrast, all 16 of the least conservative (i.e., high-benefit and low-cost) calculations produced positive net benefits ranging from $8 million to $119 million (2007 CDN). Unfortunately, like all the others, this study did not include all benefits and all costs, so results are inconclusive. The inclusion of other costs (e.g., restoration, maintenance, monitoring, and enforcement costs) would likely decrease the number of positive net benefit calculations further, while the inclusion of other benefits (e.g., tourism from outside southern New Brunswick) would also change the overall results.

### *ii. Cost-effectiveness as an alternative to benefit-cost analysis*

Some benefit-cost analyses use biophysical rather than economic metrics to measure benefits (Balana et al. 2012, Qiu and Dosskey 2012, Tiwari et al. 2016, Yang and Weersink 2004). These cost-effectiveness studies typically assess the economic costs associated with different ecological outcomes and either (1) identify the minimum cost of achieving a particular ecological goal, or (2) identify the best ecological outcome that can be achieved within a fixed budget. These types of analyses have been used for spatial targeting of buffer conservation and restoration efforts as well as determining variable buffer widths, although none have been conducted in urbanizing regions. A similar process could be used by New Hampshire resource managers and decision makers to assist in targeting buffer conservation efforts in the Great Bay watershed, although the modeling efforts require expertise and can be quite expensive.

**Table 5.** Comparison of benefit-cost analyses from existing literature.

| Study | Location | Buffer Action | Benefits and Costs* | Net Benefits |
|---|---|---|---|---|
| Amigues et al. 2002 | south-central France | preservation of 50-meter buffer along 70 kilometers of Garonne River | WTP = \$7-\$10 per person<br>$NPV_{benefits}$ = \$7.4-\$14.0 million<br>Costs = \$294-\$447 per hectare<br>$NPV_{costs}$ = \$1.6-\$2.4 million | \$5-\$12.4 million |
| Holmes et al. 2004 | western North Carolina | restoration (planting trees and grasses) along six miles of Little Tennessee River | WTP = \$4.54 per household per mile for full six miles<br>$NPV_{benefits}$ = \$2.84 million<br>Costs = \$30,202 per mile<br>$NPV_{costs}$ = \$0.18 million | \$2.56 million for full six-mile restoration<br><br>\$184K for 2 miles<br>\$281K for 4 miles |
| Loomis et al. 2000 | Colorado | restoration of buffer strips along 45 miles of Platte River | WTP = \$252 household†<br>$NPV_{benefits}$ = \$19-\$70 million<br>$NPV_{water\ leasing}$ = \$1.13 million<br>$NPV_{easement\ costs}$ = \$12.3 million<br><br>†includes leaving more water in river and restricting land uses in addition to buffers | \$5.7-\$56.7 million |
| Thomas and Blakemore 2007 | Wales (UK) | improvement of fish habitat (fencing and restricted land use) along Wye River | WTP = £38-49 per angler<br>$NPV_{benefits}$ = £318K – 1.5 million<br>$NPV_{cost\ 2.7\ km\ fence}$ = £17,200<br>$NPV_{cost\ 20\ km\ fence}$ = £127,400<br>$NPV_{cost\ full\ program}$ = £1.1 million | -£782K-£400K depending on timing of benefits and improvement program |
| Trenholm et al. 2013 | New Brunswick (Canada) | four buffer programs in Canaan-Washademoak watershed | WTP = -4.13-42.28 CDN<br>$NPV_{benefits}$ = -1.4-110 million<br>$NPV_{costs}$ = 1.3-10.4 million | -17-119 million (2007 CDN) depending on buffer scenario |

*All willingness to pay (WTP) values are per year. NPV stands for Net Present Value—essentially, all costs and benefits have been converted from future values to current (present) values.

## C. What are the economic aspects of buffer-related policy options?

Protection, restoration, and ongoing management of buffers in the Great Bay watershed has the potential to protect and improve water quality, wildlife habitat, and other ecosystem services. However, buffers, like many other small natural features with ecological roles extending beyond their area, face particular management challenges but also present unique opportunities (Gonzalez et al. 2017, Hunter et al. 2017). Their relatively small size and lack of detailed information about their benefits can lead to perceptions of insignificance by landowners, policymakers, and the public. In addition, a spatial mismatch often exists between those who reap the benefits of conservation and those who incur the costs. However, conservation does not typically require foregoing productive land uses across the entire land parcel, so some production remains viable.

A variety of buffer management approaches have potential, but it is important to assess not only the total benefits and costs, but also their distribution. In situations where society has decided that public rights to environmental quality and ecosystem service provision overrule the private property rights of individual landowners, the cost burden of managing buffers falls on the landowner, while non-excludable benefits spill over parcel boundaries to nearby residents and the public at large. In situations where the private property rights of individual landowners are favored over society's rights to ecosystem service provisioning, the cost burden of managing buffers falls on those who receive value from the ecosystem services and are often borne by government agencies or nonprofits. The discussion of buffer management policies begins with the three most common approaches (buffer regulations, fee-simple purchase, and conservation easements) and continues through to less common approaches that may have future potential. The goal of any policy or group of policies is to balance public and private needs. A combination of policies may make sense in some communities or watersheds of the Great Bay ecosystem.

**I. Land-use regulations**

Land-use regulations such as vegetated buffer strips limit the type and intensity of activities allowed within a set distance from a water body's edge and are typically established across a relatively large region (e.g., community, watershed, or entire state). There are a number of advantages to untargeted land-use regulations. All affected landowners are treated the same, so there is no need to negotiate specific contracts. Changes to existing regulations can occur without consulting landowners. Furthermore, the regulator does not need to know the exact value of the ecosystem services provided or landowner opportunity costs to devise policy, and no coordination of activities among landowners is required. Essentially, there are minimal transaction and management costs. However, because buffers and their ecosystem service benefits are not evenly distributed across the landscape, a typical landscape-wide regulation might not target a specific environmental problem very well, and extremely large opportunity costs could make the policy politically infeasible. Treating all buffers the same may be perceived as equitable among affected landowners but could be highly inefficient if the provisioning of ecosystem services or the opportunity costs are variable across space. In addition, buffers might not actually be equitable. Consider the impact on three waterfront landowners: one owns a one-acre rectangular parcel with 150 feet of waterfront, one owns a one-acre rectangular parcel with 250 feet of waterfront, and one owns a half-acre parcel with 150 feet of waterfront. A 50-foot buffer regulation would result in a restriction on 17, 29, and 33 percent of the total parcel, respectively. Hardly an equitable outcome. In summary, untargeted land-use regulations, while administratively straightforward, could create large costs for little benefit. Although there are several ways to target land-use regulations while reducing overall opportunity costs, increases in regulatory flexibility to address ecological heterogeneity often creates higher administrative costs. That is, a tradeoff exists between the opportunity costs to landowners and the transaction and management costs to the regulator, and it may be unclear which approach minimizes the total cost burden to society.

**II. Fee simple purchase**

The extreme and arguably most common approach to conservation for which beneficiaries incur all costs involves the outright purchase of land by a town, state, government agency, or nonprofit organization (e.g., a land trust), that often permanently protects the land in a natural state. From an ecological perspective, this approach can be highly successful. However, this approach can also be extremely expensive and is likely inefficient for the management of buffers that may be able to coexist on parcels with productive land uses. In addition, finding enough waterfront landowners willing to sell their entire parcel is highly unlikely in urbanizing regions like the Great Bay watershed.

**III. Conservation easements**

Conservation easements are voluntary agreements that transfer control of one or more (but not all) rights to a government agency or land trust, typically in perpetuity. The landowner retains ownership and may continue to use the land in other less harmful ways depending on which use rights remain intact. Contracts may include a description of the property and its current ecological condition, limits on current and future use, land management requirements, conservation agency or land trust access rights, public access rights, demonstration of unencumbered ownership, remedies for breach of contract, limitations on liability of the conservation agent, statement of transferability of restrictions to future owners, and transaction details (Boyd et al. 1999). There are two broad categories of easements: purchased and donated. With purchased easements, payments are typically made to landowners for the purchase of development rights, but may also target water, mining, or grazing rights. Purchased easements can also be targeted to specific properties (e.g., those with buffers) that provide a large amount of good quality ecosystem services. Payments typically reflect opportunity costs, which are calculated as the difference between private “highest and best” land-use values with and without restrictions on that use. Donated easements are essentially charitable land donations. Several potential tax benefits exist as financial incentives for the donation of conservation easements (Sundberg 2013). The Internal Revenue Service allows federal income tax deduction of charitable contributions of land. The specific rules change periodically, depending on the political climate, but the donated conservation easements must provide a public benefit and be in perpetuity. The federal government also allows federal estate tax and gift tax deductions for the portion of a property with an easement. Several states also allow income tax deductions for donated easements. While New Hampshire does not have a state income tax and thus cannot offer an income tax deduction as an economic incentive to increase buffer conservation, it is worth noting the mixed results among those states that do offer state deductions. Sundberg (2011) found that the development of a state tax credit for conservation easements does not guarantee that a significant number of easements will actually be donated. States that offer more credits (i.e., a higher total cap or no cap at all) are more likely to have a higher level of donated easements, but these programs are also more likely to have built-in assurances or controls such as listing the specific conservation values coming from each parcel, narrowing the scope of conservation values that qualify an easement for participation in the program, and certifying that the conservation values actually exist.

The use of easements as a conservation tool in the United States has grown dramatically over the past 20 years, both in terms of quantity of lands conserved and as a percentage of total conservation, with much variation across states (Fishburn et al. 2009a, 2009b). A recent group of studies examining conservation easements held by The Nature Conservancy, the largest private land conservation organization, revealed that overall easements are achieving stated goals of identifying biological targets and selected lands adjacent to other protected areas (Kiesecker et al. 2007, Rissman et al. 2007). However, while monitoring of the land to meet legal contract requirements takes place (e.g., making sure land has not been developed), biological monitoring is not occurring (Kiesecker et al. 2007) and 56 percent of the sampled easements allowed some additional buildings (Rissman et al. 2007).

Conservation easements are less costly than outright purchase but may still be expensive depending on the use rights that are given up and the potential for landowners to behave strategically (Lennox and Armsworth 2013). Donated easements do not incur any acquisition costs but may be of lesser quality. Easements are particularly effective in situations where lots of alternative land parcels are available for development (i.e., the supply of undeveloped parcels is large) and when landowner values for conservation are relatively homogeneous throughout the area; in contrast, fee simple purchase may be a better strategy when land supply is tightly constrained (Armsworth and Sanchirico 2008). Land trusts tend to be more interested in holding easements rather than purchasing land outright (i.e., full ownership) when transaction and management costs are low and gains from landowner specialization (e.g., if some productive activities such as farming, forestry, or grazing remain unrestricted) are high (Parker 2004).

Local communities and land trusts can create programs that generate funds to purchase easements. There is evidence from two studies in Ohio that public willingness to pay to support conservation easements in riparian corridors is positive and ranges from $16.80 to $29.16 per household per year in the Grand River Watershed (Blaine and Smith 2006) and from $32.28 to $36.48 per household per year in Cuyahoga County (Blaine and Lichtkoppler 2004). However, it is also important to understand the factors that influence landowners' willingness to sell an easement. A recent survey of forest landowners in southern Vermont and western Massachusetts suggests that more than half of the respondents would not participate in any type of conservation easement program despite being offered full payment for the foregone opportunity costs of their land (LeVert et al. 2009). A payment at the high end of the land value range would likely attract 47 percent of all landowners in the sample, with differences among the subgroups from the two states (51 percent of the Massachusetts sample versus 33 percent of the Vermont sample) likely due to alternative use opportunities being greater in southern Vermont where skiing and other recreational opportunities are present. Interestingly, 63 percent of the respondents from Massachusetts and 75 percent of the respondents from Vermont had never considered granting a conservation easement prior to receiving the survey, suggesting that targeted landowner education may increase the amount of conservation easements in the future. Brenner et al. (2013) identified several key factors that predict landowner willingness to grant conservation easements, including participation in environmental organizations, recreational land-use activities, wild food gathering, and size of land holdings, all of which were more important than economic returns to productive land uses.

Local communities may have concerns regarding the impact of conservation easements on property tax revenues and associated tax rates (King and Anderson 2004). If a large number of acres are removed from the tax rolls, one of two things will happen in the short run. If tax rates remain the same, then less tax revenues are generated and the community will need to cut services. If the community maintains the level of services, then tax rates need to rise. In the long run, however, the additional conservation land could make existing residential land and remaining undeveloped land more valuable, with a corresponding higher assessed value and thus more tax revenues generated. For example, Chamblee et al. (2011) found a 46 percent price premium on land adjacent to conservation land in Buncombe County, North Carolina, with additional positive price effects for nearby properties that declined as distance from the conserved property increased. In contrast, Anderson and Weinhold (2008) found a negative price effect (47 percent reduction) on vacant land parcels with strict no-development easements and no price effect on parcels that already contained a single residence in three southern Wisconsin counties. The net effect is an empirical question recently tested by King and Anderson (2004) using a case study of Vermont, which showed that conservation easements over the period 1990-1999 led to a short-term increase in the property tax rate (needed to maintain services as required by Vermont state law), but that this increase only lasted for two years and then tax rates fell such that the long-run effect on property tax rates was neutral or negative.

**IV. Impact fees**

Impact fees are payments from landowners to a government agency for permitted development or other intensive land use that causes ecological damage. For example, an impact fee could be charged for removing or degrading vegetation within a riparian buffer of a designated width. The regulator could set a simple one-size-fits-all fee, thereby lowering transaction and management costs; however, this could result in fees that severely under- or overvalue benefits and lead to increased litigation. Instead, the regulator could attempt to set the fee equal to the value of the ecosystem services lost via the development of land management activity. Such a system would ensure that landowners pay for their exact damage; however, the cost of determining which ecosystem services will be damaged by an activity and the controversy and uncertainty of measuring the level of damage in monetary terms are likely to be quite high (Ruckelshaus et al. 2015).

**V. Payments for ecosystem services**

Targeted payments for ecosystem services (PES) can be made to landowners as incentives to: (1) engage in some activity or group of activities (e.g., installing vegetated buffers) that maintain, restore, or improve the provision of one or more ecosystem services; (2) reduce the intensity of active land uses (e.g., building fewer homes); or (3) cease productive land use altogether. Payments can be monetary or in-kind and can come from government agencies, nonprofit organizations, or the direct beneficiaries (Engel et al. 2008, Engel 2016). Payments can also come in the form of tax credits or deductions. For example, several states (including all six New England states) have programs that offer property tax reductions for current use assessed values, with a great deal of variation in the method used to determine the actual reduction, the criteria for participation, and the penalty for altering the land use to a more intensive (e.g., developed) use (Sundberg 2014). New Hampshire's Current Use Taxation Program allows property taxation at lower "traditional use" values rather than the real estate market value (typically developed land use) for ten or more acres of agriculture, forestry, or wildlands. A similar tax credit program for buffer areas might provide good incentives to waterfront landowners in the Great Bay watershed.

PES schemes do have some drawbacks, however. The transaction and management costs can be quite high, and it can be extremely difficult to select the best participants from a group of applicants (Sorice et al. 2011). For example, landowners are more knowledgeable of opportunity costs than regulators and, therefore, can extract payments that are much higher than their minimum willingness to accept (Lennox and Armsworth 2013). In addition, the offering of payments may weaken the landowner's sense of a moral obligation, resulting in less conservation than is possible because recipients might have accepted smaller payments leaving funds for extra conservation elsewhere. Further, to maximize gains in social welfare, PES schemes have to set payments equal to the value of benefits procured, but determining their values can be challenging.

**VI. Assessment of buffer-related policy options**

The efficacy of alternative buffer management policies is case-dependent and influenced by the specific ecosystem services of interest, the level of connectivity required to provide the targeted services, and the magnitude and distribution of benefits and costs. Buffers, in general, provide a wide variety of ecosystem services; however, an individual buffer in a specific location may be most valued for its provision of one kind of service. Identification of the specific ecosystem service of interest is important because it determines the spatial extent of the landscape that managers or regulators need to worry about, the uses of that landscape that are impairing the ability of the buffer to provide its services, and how many landowners need to be involved in the conservation effort. If the number of landowners needed for conservation success is low and buffers providing high-quality ecosystem services can be targeted, then incentive-based approaches (e.g., land purchases, easements, and payments for ecosystem services) are simpler. If many landowners need to be involved, then simple and non targeted approaches (e.g., buffer regulations and public education) may work better.

The magnitude and distribution of costs also affect the efficacy of buffer policies. Relevant costs include opportunity costs, transaction (information, contracting, coordination) costs, management (administrative, monitoring, enforcement) costs, and, in some cases, acquisition costs. Large-scale land purchases are not likely to be cost-effective for managing buffers due to the high costs associated with purchasing land outright. In comparison, economic incentives that reduce land-use intensity rather than eliminating all land uses cost less and are much more likely to fall within organizations' conservation budgets. Community attitudes towards conservation can influence the dominant property rights regime that ultimately determines who incurs what cost. Sharing the cost burden among landowners and the rest of society may result in higher total costs but may provide more equitable (and perhaps more politically feasible) alternatives.

## D. Summary and Conclusions

This review synthesized existing literature on the economic benefits and costs of buffer management and policies in order to provide information that facilitates the best possible decision making today and to identify critical gaps in our current knowledge that would allow for better decision making in the future.

This review found that studies investigating the effect of vegetated buffers on housing prices produced mixed results, likely due to two opposing effects of buffers on property values. Improved ecosystem service provisioning may increase prices for adjacent and nearby properties. In contrast, lost development potential and degraded scenic views may reduce prices. In comparison, the general consensus of relevant literature is that higher property values are associated with better water quality. In addition, these positive effects, which can be as high as a 30 percent increase in property value, extend far beyond waterfront properties. In addition, while this literature review is mainly focused on economic values of households living within close proximity of the focal resource, it is worth noting that additional benefits of buffer-related ecosystem services accrue to visiting recreationists and other tourists.

To address distributional issues between those who incur the costs of buffer management and those who reap the benefits, societies can establish policies, programs, or institutions that align the interests of private landowners with social interests. In some cases, this involves governments regulating landowner behavior (e.g., establishing buffer rules), forcing landowners to bear management and opportunity costs. In other cases, government agencies or nonprofits offer incentives to landowners to facilitate provisioning of the socially efficient amount of buffer-provided ecosystem services.

Untargeted buffer regulations, while administratively straightforward, could generate large costs for landowners. Although there are several ways to target land-use regulations and reduce overall opportunity costs, increases in regulatory flexibility to address ecological heterogeneity often create higher administrative costs. That is, a tradeoff exists between the opportunity costs to landowners and the transaction and management costs to the regulator, and it may be unclear which approach minimizes the total cost burden to society.

In comparison, targeted payments for ecosystem services can be made to landowners as incentives to: engage in some activity or group of activities (e.g., installing vegetated buffers) that maintain, restore, or improve the provision of one or more ecosystem services; reduce the intensity of active land uses (e.g., building fewer homes); or cease destructive land use altogether. Payments can be monetary or in-kind and can come from government agencies, nonprofit organizations (e.g., land trusts), or the direct beneficiaries. Purchased conservation easements are one way of targeting critical buffers. Payments can also come in the form of tax credits or deductions. For example, several states have programs that allow property taxation at lower “traditional use” values rather than the real estate market value. A similar tax credit program for buffer areas might provide good incentives to waterfront landowners in the Great Bay watershed.

The efficacy of alternative buffer management policies is case-dependent and influenced by the specific ecosystem services of interest, the level of connectivity required to provide the targeted services, and the magnitude and distribution of benefits and costs. If the number of landowners needed for conservation success is low and buffers providing high-quality ecosystem services can be easily targeted, then incentive-based approaches (e.g., easements and payments for ecosystem services) may work better. If many landowners need to be involved, then simple and untargeted approaches (e.g., buffer regulations and public education) may be more appropriate. Economic incentives that reduce land-use intensity rather than eliminating all land uses cost less and are much more likely to fall within organizations’ conservation budgets. Community attitudes towards conservation can influence the dominant property rights regime that ultimately determines who incurs what cost. Sharing the cost burden among landowners and the rest of society may result in higher total costs but may provide more equitable (and perhaps more politically feasible) alternatives.

Several gaps in our current understanding of the economics of buffer management were uncovered. First, while there is substantial literature covering the effects of water quality on property values, there are very few empirical analysis of the effects of the physical buffer itself. Anecdotal evidence provided mixed results, suggesting that some waterfront landowners enjoy the privacy of a densely vegetated buffer while others prefer an unobstructed view of the water body. Second, only two case studies of New Hampshire residents could be found and both of these were conducted using lakefront property sales data from the early 1990s. As a result, the Great Bay Estuary Project is forced to extrapolate willingness to pay values from other diverse locations. Third, no studies comparing a full set of benefits and costs associated with buffer management could be located, and existing benefit-cost analyses were highly inconclusive. Finally, no studies that compared the economic and ecological outcomes of buffer regulations to outcomes of other buffer policies were found. This has ramifications for the efficiency of long-term buffer planning and management.

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