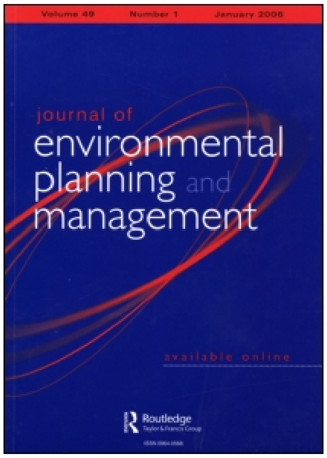

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Connie P. Ozawa [a]; J. Alan Yeakley [b]
[a] School of Urban Studies and Planning, Portland State University, Portland, OR, USA
[b] Environmental Sciences Program, Portland State University, Portland, OR, USA

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Performance of Management Strategies in the Protection of Riparian Vegetation in Three Oregon Cities

CONNIE P. OZAWA* & J. ALAN YEAKLEY**
*School of Urban Studies and Planning, Portland State University, Portland, OR, USA
**Environmental Sciences Program, Portland State University, Portland, OR, USA

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ABSTRACT *The destruction of riparian vegetation in urban areas signals the loss of valuable ecosystem services. This paper documents the extent of riparian vegetation loss during a period of rapid development (1990–2002) in three Oregon cities with distinctive, local management strategies. Findings show that loss has occurred in all three cities, but this loss has been curtailed by implementation of protective policies. Moreover, more than half the losses in each city were due to a few large development projects, rather than a large number of smaller ones. The paper concludes that management strategies do limit destructive actions by small projects and that large losses are potentially avoidable with targeted attention to large-scale projects.*

Introduction

Steady population growth has been absorbed over the past several decades by the sprawling of cities and suburbs into the hinterlands. This pattern of growth has imposed unprecedented pressures on natural ecosystems and highlights a need to reconsider the treatment of environmental resources within urban areas (Platt *et al*., 1994; Daily, 1997; Grimm *et al*., 2000; Groffman *et al*., 2003; Hession *et al*., 2004). One resource directly threatened by urban expansion is riparian vegetation. The vegetation along stream corridors serves a myriad of ecosystem functions. Riparian vegetation preserves water quality by filtering pollutants from runoff, offers flood protection and stream bank stability, and benefits aquatic organisms by providing woody debris that increases stream habitat and shade that moderates stream water temperatures. The vegetation also provides habitat for terrestrial fauna, provides a sink for CO_2, filters atmospheric pollutants in rainfall and cools air temperatures.

Studies have concluded that minimal buffer widths necessary to maintain stream water quality, native vegetation and faunal habitat range from at least 20 m to as

Correspondence Address: Connie P. Ozawa, School of Urban Studies and Planning, Portland State University, PO Box 751, Portland, OR 97207, USA. Email: ozawac@pdx.edu

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much as 200 m (Lowrance *et al.*, 1984; Castelle *et al.*, 1994; Naiman & Décamps, 1997; O'Neill & Yeakley, 2000; Hennings & Edge, 2003; Miltner *et al.*, 2004). Varying ecological functions require varying minimal widths; maintenance of wildlife habitat generally requires greater widths in comparison to maintenance of water quality functions (Naiman *et al.*, 2005). Wildlife requirements may call for large buffers; for example, Hennings & Edge (2003) found that at least 50–100 m riparian widths were required for maintenance of most native bird habitat characteristics, with as much as 450 m required for optimal habitat.

As urban land uses expand, preservation of ecosystem functions of small streams and their associated riparian buffers often are given lower priority than socially-defined demands for residential, industrial and commercial uses, and roads. Streams often fragment land holdings. Hence, historically, in the absence of regulatory instructions to do otherwise, land owners have cleared vegetation and filled or piped what might have appeared to be inconsequential streams. Riparian areas are often severely compromised by encroaching development, and in older sections of many US cities, riparian vegetation and streams have been removed altogether, with culverts and ditches replacing former stream channels. For example, in the Rock Creek watershed in Maryland, more than half of the stream network was eliminated during urbanization (Meyer *et al.*, 2003). Alternatively, while streamside parcels may be spared structures or hardscaping treatment, urban residents often tame stream edges. Highly maintained lawns and parklands can pose an increased threat to environmental quality due to fertilizer and pesticide runoff into urban streams (Kaufman & Gray, 2003). Generally, riparian vegetation in cities exists in an ever-diminishing mosaic, the structure of which is typically either shrinking or maintaining shape in response to a complex of human development patterns and regulatory safeguards.

How cities across the US have responded to the need to protect vegetated stream corridors has varied, and is shaped indirectly by policy at the state and federal levels. From the federal level, the 1987 amendments to the Clean Water Act set forth more stringent water quality goals, particularly around non-point pollution sources and stormwater controls for municipalities of 250 000 population or greater (United States Clean Water Act). In the state of Oregon, riparian vegetation is further protected by the 1973 state land use law that established the Land Conservation and Development Commission (LCDC) (Knaap & Nelson, 1992; Abbott *et al.*, 1994). LCDC set forth 19 goals to guide development in the state, three of which concern riparian areas: Goal 5 specifically addresses the need to protect urban natural and scenic resources; Goal 6 speaks to the quality of air, water and land; and Goal 7 requires the protection of life and property from natural disasters and hazards. Responsibility for addressing these goals in urban areas is assigned to the cities, which are required to prepare comprehensive land use plans that consider the 19 goals.

The recent and highly visible resurgence of private property rights advocates across the US may deter urban managers across the country from attempting to prescribe what home owners may or may not do with vegetation in their own backyards. Indeed, landowner opposition forced the City of Portland to put efforts to expand its environmental zones, which impose constraints on development, on the back burner in 2001 (Ozawa & Yeakley, 2004).

Given the essential ecological functionality and multiple benefits of riparian vegetation and the increasing mobilization of property rights advocates, urban resource managers must carefully consider alternative strategies. Civic environmentalism and other collaborative and partnership watershed-based approaches have received considerable acclaim in the literature lately, but whether co-operation of this type yields on-the-ground benefits system-wide or how long it can be sustained is yet to be shown (John, 1994; Durant *et al.*, 2004).

This paper reports on an investigation of the performance of local development policies that protect riparian vegetation in three cities in the Portland OR metropolitan area, a region whose voters have consistently supported the protection of environmental resources (Ozawa & Yeakley, 2004; Metro, 2007). Specifically, the extent of vegetation loss along stream corridors between the years 1990 – 2002, a period of rapid population growth in these cities, is documented and examined. The fundamental question driving this investigation was whether management strategies correlate with different on-the-ground losses of riparian vegetation. Three questions were asked. First, what has been the extent of vegetation loss along stream corridors during the recent wave of development? Second, have different local management approaches resulted in varied rates or patterns of loss? Finally, what are the major, particularly anthropogenic, causes of vegetation loss? The intention was to clarify the dynamics of riparian vegetation loss on the ground and with respect to management issues to better equip urban resource managers and policy makers in all urbanizing areas to craft effective policies for the future.

Overall Research Approach: Background and Methods

The first step in this project was to identify cities with distinctive local management strategies undergoing arguably comparable conditions of population growth and urbanization. As noted earlier, local management of riparian areas is influenced indirectly by federal and state policies. In the Portland metropolitan region, an additional layer of government has been added through the 1979 establishment of Metro, a regionally-elected organization with land use planning authority (Seltzer, 2004). In the 1990s, Metro began to prepare a series of regional functional plans, including titles that address water quality, erosion control, flood hazard management and fish and wildlife habitat protection, as noted in the paragraph below (Furfey *et al.*, 1997). Cities within the Metro region are expected to comply with functional plan guidelines.

The presence of Metro, a regional planning authority with limited, but some, influence on city-level policies (Seltzer, 2004; Irazabal, 2005), required a choice of Oregon cities that were either all within or all outside Metro's jurisdiction to avoid an incongruent layer of policy. As the primary city in the state of Oregon and with a reputation for innovative environmental and land-use management, it was important to include the City of Portland. Two additional cities in the metropolitan region were selected based on their comparable growth rates during the 1990s, and similar population densities, socio-economic status of the population and distance from Portland. Most importantly, Hillsboro and Oregon City were mentioned repeatedly by local resource managers and planners who were interviewed as representatives of two clearly different management approaches.

Figure 1 shows the location of the three study cities and their streams. It should be noted that the apparent lack of streams on Portland's eastside is the result of ambitious efforts to construct culverts and fill streams in the city's earlier history. In 2002, the streamside lengths of Hillsboro, Oregon City and Portland were approximately 65 km, 32 km and 454 km, respectively.

As shown in Table 1, all three cities experienced considerable growth between 1990–2002 in both population and number of housing units. The growth rates in Hillsboro and Oregon City were similarly high, close to doubling during the study period; although Portland's rates were not as high, they were yet significant for an older central city. The median price of housing and the per capita money income figures suggest that the socio-economic status of the residents in these three cities was comparable.

In addition, as displayed in Figure 2, construction occurred at a strong and slightly increasing pace in all cities during the study period.

The three cities varied relatively proportionally in land area and population. The City of Hillsboro stretched over nearly 57 km^2 (22 square miles), Oregon City included 21 km^2 (8 square miles), and the City of Portland covered 347 km^2 (134 square miles). Therefore, Hillsboro had 2.7 times the population in about 2.5 times the area than Oregon City, and Portland dwarfed Hillsboro by more than six times in land area and more than seven times in population. The population densities were about 1300 persons/km^2 in Hillsboro and Oregon City, and 1550 persons/km^2 in Portland.

Profiling Management Strategies

The cities of Hillsboro and Oregon City are similar in many respects, as noted above. However, their approaches to the protection of natural resources and riparian

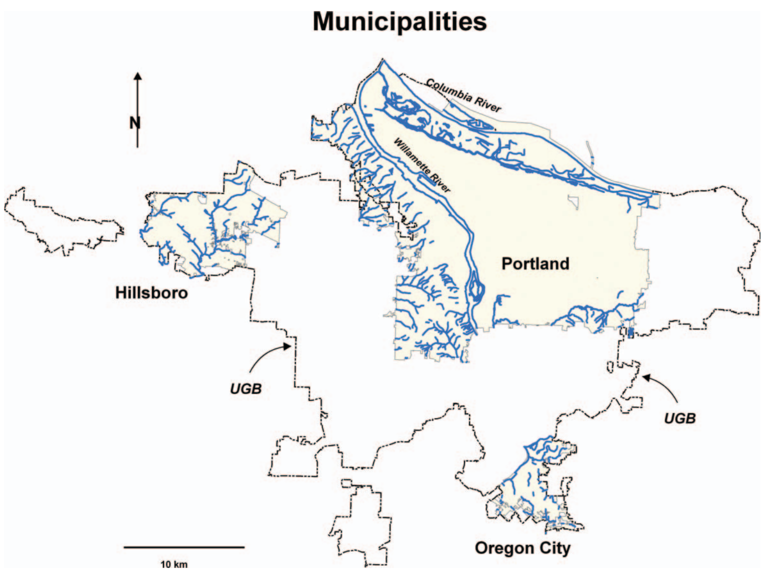

Figure 1. Map of study cities in the Portland metropolitan region. The three study cities are identified and permanent streams shown for each city (UGB = urban growth boundary).

Table 1. Population and housing units, 1990 – 2002

	Population[a]			Number of housing units			Median price of housing	Per capita money income[b]
City	**1990**	**2002**	**Change**	**1990**	**2002**	**Change**	**2002**	**1999**
Hillsboro	37 598	74 840	+99%	13 347	27 192	+104%	$163 200	$21 680
Oregon City	14 698	27 270	+86%	5675	10 165	+79%	$161 900	$19 870
Portland	438 802	538 180	+27%	198 319	237 269	+20%	$154 700	$22 643

Notes: [a]Population data are from the Population Research Center, Portland State University, *2004 Oregon Population Report*. Available at http://www.pdx.edu/prc/annualorpopulation.html (accessed 6 October 2005).
[b]US Census, Quick Facts. Available at http://quickfacts.census.gov/qfd/states/41000.html. Figure for state overall is $20 940.
Source: Oregon Economic and Community Development Department. Available at http://info.econ.state.or.us:591/profile.htm (accessed 6 October 2005).

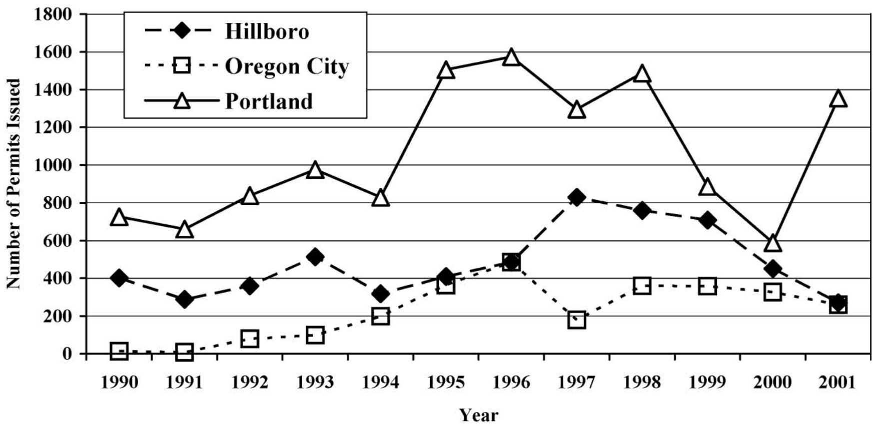

Figure 2. Building Permits by City, 1990 – 2001. *Source:* Ozawa & Yeakley (2004), p. 274. Based on data from Metro RLIS lite.

buffers in particular were quite different. Oregon City and Portland adopted a series of overlay districts to address specific environmental features enforced by city planners. The City of Hillsboro, in contrast, relied on a variety of mechanisms and partnered with technical staff working at the wastewater and stormwater services provider. This section describes in broad terms the distinct strategies implemented by the three cities.

Until 2003, the City of Hillsboro achieved resource protection through a jigsaw puzzle of approaches. The City adopted a 'regulated floodplain district' map in 1980, which required erosion controls along streams. A partial inventory of 'significant natural resource areas', completed in 1991, afforded special consideration to natural features thereby identified. These controls flagged a portion of riparian corridors for special design considerations but did not prohibit outright development or removal of vegetation. A potential avenue of protection was provided through the Planned

Unit Development (PUD) Overlay District, adopted in 1983, which allowed exceptions to setbacks, density and minimum lot size to allow development while avoiding the destruction of sensitive resources (City of Hillsboro, 2006). Finally, as of 2000, development permit applications on parcels abutting streams or within 61 m (200 ft) of a 'sensitive area' were referred for review to the Washington County water services provider, now called Clean Water Services (CWS), which implements programs to meet federal water quality standards. Regulations in place forbid structures or construction within 7.62 m (25 ft) of stream banks, but exceptions would allow developers to encroach within 4.57 m (15 ft), depending on slope draining area and resource quality. In other words, the implementation of the buffer was somewhat flexible and depended on site conditions. This approach may be characterized as essentially relying on 'distance-from-stream' as the first determinant of riparian resource protection.

In contrast, Oregon City pursued resource protection through the creation of a number of single-purpose overlay districts that address specific environmental conditions such as flood management (established in 1980 in accordance with the Federal Emergency Management Act (FEMA) flood maps), steep (greater than 25%) slopes (established in 1984) and water resources (established in 1993). Development permit applicants were instructed to check the zoning maps to ascertain whether their property fell within any of these single-purpose overlay districts. If it did, the applicant was required to demonstrate the extent to which the specified resources would be affected and how such impacts would be mitigated. The overlay districts did not forbid incursions into vegetated stream corridors but they did identify situations when they ought to be avoided and encouraged avoidance or mitigation of adverse impacts. Mitigation plans were usually prepared by the applicant and reviewed by Oregon City planning staff.

In the early 1990s, Oregon City conducted a partial inventory of natural resources to comply with Metro's effort to develop a regional functional plan for fish and wildlife habitat protection to address Goal 5 of the state land use law, as mentioned earlier. A major step forward occurred in 1999 when the city revised its overlay districts to conform to Metro's 1998 water quality and flood management maps. Riparian areas from that point on were protected primarily through the Water Quality Resource Area (WQRA) Overlay District, which stipulates vegetated buffers from 15.24 to 60.06 m (50 to 200 ft), except in the case of intermittent streams with slopes less than 25% and which drain less than 40.47 ha (100 acres). Under these circumstances, a 4.57 m (15 ft) buffer was acceptable (City of Oregon City).

The City of Portland similarly utilized a system of overlay districts, but this system was intentionally integrative in its approach to resource protection. Beginning in the early 1980s, the City created stream setback regulations in the zoning code and, concurrently, a city-wide water features map. In the late 1980s and extending into the mid-1990s, the City began to prepare comprehensive natural resource inventories and protection plans. The inventories were based on review of aerial photographs, topography maps, habitat data from the Oregon Department of Fish and Wildlife (ODFW) and on-site visual analyses. The inventories and protection plans took into consideration key resource features such as streams, wetlands, and steep slopes, and wildlife habitat, as indicated by plant diversity, canopy cover, and the availability of food, water and vegetative cover. These inventories and protection plans were embodied in new environmental overlay zones (e-zones). New development, including expansion of existing structures, land divisions and topographical alterations proposed on land located within the e-zones, were required to undergo special review to ensure the avoidance or mitigation of adverse impacts. The e-zones were further divided into two sub-categories. The environmental protection zone, or 'p-zones', afforded the highest level of resource preservation and near-stream areas are more likely to be designated as p-zone. New development was essentially prohibited unless the project would provide a public benefit that outweighed the expected adverse environmental impact, or unless one could provide access to or through the property without encroaching on the p-zone. 'C-zones' or 'conservation zones' allowed construction but imposed limits on the amount of area disturbed, requirements for the replacement of vegetation, special construction conditions and other such guidelines. Subsequent code amendments also established standards for disturbance and other aspects of development. Opportunities for public review of applications were mandatory in both cases. By 2002, Portland had applied environmental overlay zones to nearly 7689 ha (19 000 acres) of urban land, including local streams, wetlands and portions of the Willamette and Columbia rivers within city limits.

A classification of the approaches of these three cities as increasingly or decreasingly 'stringent' is premature, but the approaches are distinctive. Hillsboro's strategy focused heavily on water features, referred development proposals routinely to water quality specialists, and regulated primarily on the basis of distances from the stream. Oregon City's single-purpose overlay districts revolved around specific attributes such as flooding, steep slopes or water quality. Responsibility for identifying vulnerable resources and proposing mitigation was vested with the developer and reviewed by general land use planning staff. The City of Portland's e-zones were developed with explicit consideration of a range of indicators of habitat quality for aquatic and non-aquatic species, and prescribed explicit requirements for development and mitigation within the two grades of environmental zones.

Methodology for Determining On-the-ground Losses

Aerial photographs of the study cities at three points in time, 1990, 1997 and 2002, were digitized, orthorectified and analyzed using ERDAS and ArcGIS software. It was decided to study the 1990s due to the relatively rapid growth in comparison to the 1980s which were a period of relatively sluggish growth and lower development pressure in the Portland metropolitan area. The 1990 photographs were gray scale at 0.30 m resolution; the 1997 photographs were color at 1.22 m resolution; the 2002 photographs were color at 0.30 m resolution. The 1997 photographs (x and y coordinates), previously orthorectified by Metro, and USGS digital elevation maps (z coordinates) were used as a basis to orthorectify the 1990 and 2002 photos using ERDAS Imagine 8.3 software. Stream locations and city boundaries were obtained from the Metro RLIS database (Metro, 2002). A banding analysis was conducted to measure vegetation coverage in four riparian vegetation classes for all permanent streams and wetland features at eight buffer widths from streams (7.5 m, 15 m, 22.5 m, 30 m, 45 m, 61 m, 100 m and 200 m). From those buffer widths, three distances (7.5 m, 15 m, 100 m) were chosen to represent the range of responses reported here (see Findings for further regulatory reasons for these selections). The four vegetation classes analyzed were based on a two-by-two classification, adjacent vs. all, and woody vs. unmanaged. The 'adjacent' classification included all woody and unmanaged vegetation cover adjacent to stream within the buffer width, with adjacency determined by a 5 m separation distance (Schuft *et al.*, 1999). The 'all' classification included all cover of a given vegetation class (either 'woody' or 'unmanaged') within a given buffer width, regardless of separation distance from other similar cover. These determinations produced the following four classifications:

- Adjacent woody: included trees and shrubs, within 5 m distance of a stream and/or other adjacent woody cover.
- Adjacent unmanaged: included adjacent woody, plus unmanaged herbaceous plants within 5 m distance of a stream and/or other unmanaged adjacent vegetation cover.
- All woody: included adjacent woody plus non-adjacent trees and shrubs.
- All unmanaged: included adjacent unmanaged, plus non-adjacent trees and shrubs.

These vegetative classes were selected based on their varied importance relevant to different ecological functions of riparian vegetation, and the ability to recognize them using the aerial photographs. It is important to note that the streams in these three cities, while located in a climatically similar region (i.e. modified west coast marine climate classification), varied significantly in terms of soils and topography, both within cities and among cities (Price, 1987). In addition, the study was unable to account for invasive plant species in these determinations; the primary riparian plant invaders in this region are Himalayan blackberry (*Rubus armeniacus*), reed canarygrass (*Phalaris arundinacea*), English ivy (*Helix hedera*) (O'Neill & Yeakley 2000), all of which are under-storey plants. It is probable that some sparse woody designations included Himalayan blackberry (Caplan & Yeakley 2006), but for the most part these invasive plants were either under tree canopy (particularly English ivy) or in the unmanaged vegetation category. Given the variation in these landscape and vegetative factors, the authors felt it was important to analyze streams exhaustively (rather than as a subset or sample) for each city investigated.

Vegetation patch edge determination followed methods from Schuft *et al.* (1999), and was based on a separation distance of at least 5 m (approximating the crown width of a mature woody tree/large shrub). A consistent viewing scale of 1:1500 was maintained while digitizing. Quality assurance steps included: (a) cross-correlation of alignment of streamline locations provided by Metro with USGS quadrangle maps and Metro contour maps; (b) snapping streamlines to city lines when streams formed jurisdictional boundaries; (c) truncating shadows from photos where determination was possible; (d) field checks and corrections made accordingly for several dozen features that were ambiguous at viewing scale; and (e) cross-checking digitizing interpretations for a randomized 10% of the total stream length, between two observers, with a resulting error $<3\%$. In addition, 1997 and 2002 changes were interpreted while referring directly to 1990 digitized vegetation polygons to minimize interpretation error among years. The analysis was conducted exhaustively for all streams in the three study municipalities (rather than based on a sample or subset of the streams) to account for all landscape changes in riparian buffers in these cities from 1990 to 2002. Further information on image analysis, GIS and QA/QC methods were provided in Yeakley *et al*. (2006).

This research should be prefaced with a brief mention of a few caveats. First, the methods here do not account for the lag between policy acceptance, project approval and project implementation dates. This period may range from weeks to several years, and the length of time may be quite idiosyncratic. The consequence of this lag is that the efficacy of policies may take some time to show on the ground. The methodology does not address this incongruity. Second, the study has relied on a 'snapshot in time' approach to estimating on-the-ground vegetation losses and does not distinguish between what might be permanent or temporary losses. For example, a construction project may be required to restore vegetation destroyed during construction and the aerial photograph may capture the period of denudation before restoration. In a sense, this would overestimate actual losses in such a case.

Third, the study chose to examine only *losses* in vegetative cover. During this time period, intentional efforts to restore streamside vegetation have occurred. These efforts have been led by local governments as well as by community groups and would be an important piece of the urban ecosystem puzzle to fill. However, this project chose to focus exclusively on understanding the extent and character of losses that occurred under specified management regimes.

Finally, in presenting preliminary findings to local audiences, the presence of 2023-ha Forest Park within Portland's city boundaries raised concerns about the effect of public parks on riparian vegetative buffers. Consequently, in addition to data files showing 'all lands' within city jurisdictions, files were constructed showing city lands with and without public parklands. The rate of loss in buffers in all cities changed only slightly with the exclusion of public parklands in the analysis. The percentage of riparian vegetation loss increased in every buffer in every city when parklands were taken out of the calculation. However, the change was less than 1% except at the 100 m buffer in Hillsboro and Portland, where the change was just over 1%. Further, the relative ordering of the magnitudes of loss remained the same among the cities for each buffer width, whether or not parkland was included. Therefore, separate analysis excluding parkland was not considered warranted.

Findings: Riparian Vegetation Area Losses

A primary objective of this research was to document the extent to which losses in riparian vegetation within certain distances from streams occurred over the 12-year period, 1990–2002. The findings were quite startling. All three cities lost considerable vegetative cover in all four classes along stream corridors. Table 2 shows the losses in the all-unmanaged class in each city at the 7.5 m, 15 m and 100 m buffers. The 'all unmanaged vegetation' class is the most inclusive of the four studied and includes all trees, shrubs and grasses regardless of proximity to other standing vegetation. The 7.5 m buffer essentially reflects current regulatory standards. Although regulations in no city address the 15 m buffer specifically, losses are reported to provide a sense of losses that might have been avoided with a modest expansion of resource protection. The largest buffer (100 m) is presented as a proxy

Table 2. Hectares of all unmanaged vegetation cover lost, 1990 – 2002

	7.5 m				**15 m**				**100 m**			
	1990	**2002**	**Loss (ha)**	**% loss**	**1990**	**2002**	**Loss (ha)**	**% loss**	**1990**	**2002**	**Loss (ha)**	**% loss**
Hillsboro	71.2	68.9	2.4	3.4	135.0	129.7	5.3	3.9	548.2	446.5	101.7	18.6
Oregon City	27.7	25.2	2.5	9.0	54.2	48.9	5.3	9.8	256.2	211.4	44.8	17.5
Portland	292.6	283.2	9.4	3.2	563.7	544.5	19.2	3.4	2,774.9	2,566.6	208.2	7.5

to reflect development activity overall. This proxy is particularly appropriate in Hillsboro, where no regulations aimed to protect water quality hamper development beyond 66 m. In Portland and Oregon City, e-zones and overlay districts may have restricted development, but were likely to cover only limited areas at this distance from streams. In all three cities, the high percentage loss may be viewed as a rough reflection of development pressure during the period 1990 – 2002.

Table 3 displays the proportion of vegetative coverage in each buffer in 1990, and the percentage points lost in the cover of 'all unmanaged vegetation' class between 1990 and 2002. It is important to note that the amount of vegetation loss does not correlate with the amount of existing coverage. That is, although a greater percentage of riparian buffer was covered in vegetation in Hillsboro than Oregon City in 1990, this relative abundance did not result in a squandering or de-valuing of the resource. A comparison of the all-unmanaged vegetation lost between 1990 and 2002 in the three cities shows that Portland lost a smaller percentage of its streamside vegetation, or experienced a lower rate of loss, at every distance from the stream (7.5 m, 15 m and 100 m) compared to the other two cities. Oregon City lost 1990 vegetative cover at more than double the rate of loss as Hillsboro at the 7.5 m and 15 m distance and at nearly triple the rate as Portland. Hillsboro shows loss rates comparable to Portland in the 7.5 m and 15 m buffers, and a sharply increased rate of loss at the 100 m width (reflecting a higher overall development rate).

Findings: Analysis of Oregon City's Overlay Districts

Evaluating the effectiveness of a management strategy is a complicated task. This study set out to examine the extent to which on-the-ground losses of vegetation differ in cities with distinct management strategies. As indicated above, the rates and patterns of losses did vary from one jurisdiction to another. The investigation is too coarse to be able to attribute these differences to differential effectiveness of the management strategies, but it does set a baseline for such an investigation.

One way such an investigation might proceed is to ask whether losses in a jurisdiction would have been higher without a management strategy in place? Oregon City provides an opportunity to illustrate this type of analysis.

This section asks if losses in the vegetative cover in near-stream areas occurred at the same rate as losses in the near-stream area in the city overall. Table 4 displays the relevant data. For example, the percentage of land covered with unmanaged vegetation within the 7.5 m buffer in the FEMA flood maps in 1990 was 6.6%. This

Table 3. All unmanaged vegetation cover, 1990 – 2002

	7.5 m			15 m			100 m		
	% cover		Loss in	% cover		Loss in	% cover		Loss in
	1990	2002	% cover	1990	2002	% cover	1990	2002	% cover
Hillsboro	77.5	74.9	2.6	74.3	71.4	2.9	48.4	39.4	9.0
Oregon City	66.1	60.1	6.0	65.1	58.8	6.3	46.8	38.6	8.2
Portland	58.8	56.9	1.9	58.1	56.1	2.0	47.0	43.5	3.5

Table 4. All unmanaged vegetation coverage areas and losses in Oregon City overlay districts compared with total buffer area losses

	7.5 m				15 m				100 m			
Distance from Stream	**1990**	**2002**	**Loss (ha)**	**% loss**	**1990**	**2002**	**Loss (ha)**	**% loss**	**1990**	**2002**	**Loss (ha)**	**% loss**
Flood Maps (FEMA 1980)	6.6	6.5	0.1	1.5	12.5	12.2	0.3	2.4	30.9	28.7	2.2	7.1
Steep Slopes (1984)	3.4	3.3	0.1	2.9	7.8	7.6	0.2	2.6	60.2	55.9	4.3	7.1
Water Resources (1993)	14.3	13.3	1.0	7.0	26.8	24.6	2.2	8.2	53.7	49.0	4.7	8.8
Metro WQRA (1999)	21.1	19.5	1.6	7.6	37.1	34.2	2.9	7.8	71.5	66.8	4.7	6.6
Total buffer	27.7	25.2	2.5	9.0	54.2	48.9	5.3	9.8	256.2	211.4	44.8	17.5

coverage decreased by about 0.1 ha by 2002, representing a 1.5% loss rate. Comparing this loss rate to the loss rate in the 7.5 m buffer in the city overall, it is found that it is considerably less than the 9% loss of vegetative cover in the 7.5 m buffer in the city as a whole.

This pattern showing lower loss rates in the overlay districts is consistent across all the overlay districts. The percentage loss of vegetation in the various overlay districts ranged from 1.5 (FEMA) to 7.6 (MetroWQRA) compared to the 9.0% loss rate in the city overall at the 7.5 m buffer. Not surprisingly, loss rates are substantially lower in the FEMA and Steep Slopes overlay districts. It might be assumed that the physical features of the site would be highly discouraging to development, and that the overlay district regulation is not the single force behind the property owner's decision not to build in those areas. Nonetheless, it might also be expected that development policies that signal extra concern and precautions in areas with sensitive resources might influence a property owner's behavior. It would be difficult to tease the influences apart without much closer examination on a case-by-case basis, but it is reassuring to see that little loss has occurred over the 12-year period in the first two overlay districts, which were in effect for some time before the baseline data point.

The Water Resources and Metro WQRA overlay districts show less significant but still lower loss rates. In these two cases, it should be noted that these districts did not take effect until the mid- to late-1990s. In fact, one of the largest, single losses for the city was caused by a project that had been permitted before the 1999 Metro WQRA Overlay District regulations were put in place. Therefore, the losses indicated in Table 4 may actually overstate losses that occurred with the Title 3 overlay district in effect.

In summary, this analysis is encouraging with regard to Oregon City's management strategy. That is, although this analysis does not provide conclusive support of the effectiveness of this approach in protecting riparian resources, the figures are consistent with expectations.

Findings: Analysis of Major Losses

Overall losses in vegetative cover are important in terms of assessing the cumulative impacts to riparian resources and the ecosystem functions they serve. From a management perspective, it is critical to understand *why* they occurred. The final question framing this inquiry suggested an examination of the areas of greatest vegetation loss. Two questions were posed: first, what proportion of total losses was attributed to discrete projects that incurred the greatest areas of loss? Second, what types of development activities were associated with these large losses?

This analysis focused on the 7.5 m buffers. Figure 3 shows the percentage of vegetation losses by parcels in descending order of magnitude that account for 90% of the total losses in each city. These graphs show that more than half the vegetation losses in the 7.5 m buffers can be attributed to a relatively few projects: in Hillsboro, only six projects (of a total of 117) caused more than half the total loss; in Oregon City, only four projects (of a total of 138) were responsible, and in Portland, nine projects (out of a total of more than 450) caused more than half the vegetation lost in the 7.5 m buffer area. These graphs also suggest that the remaining half of the

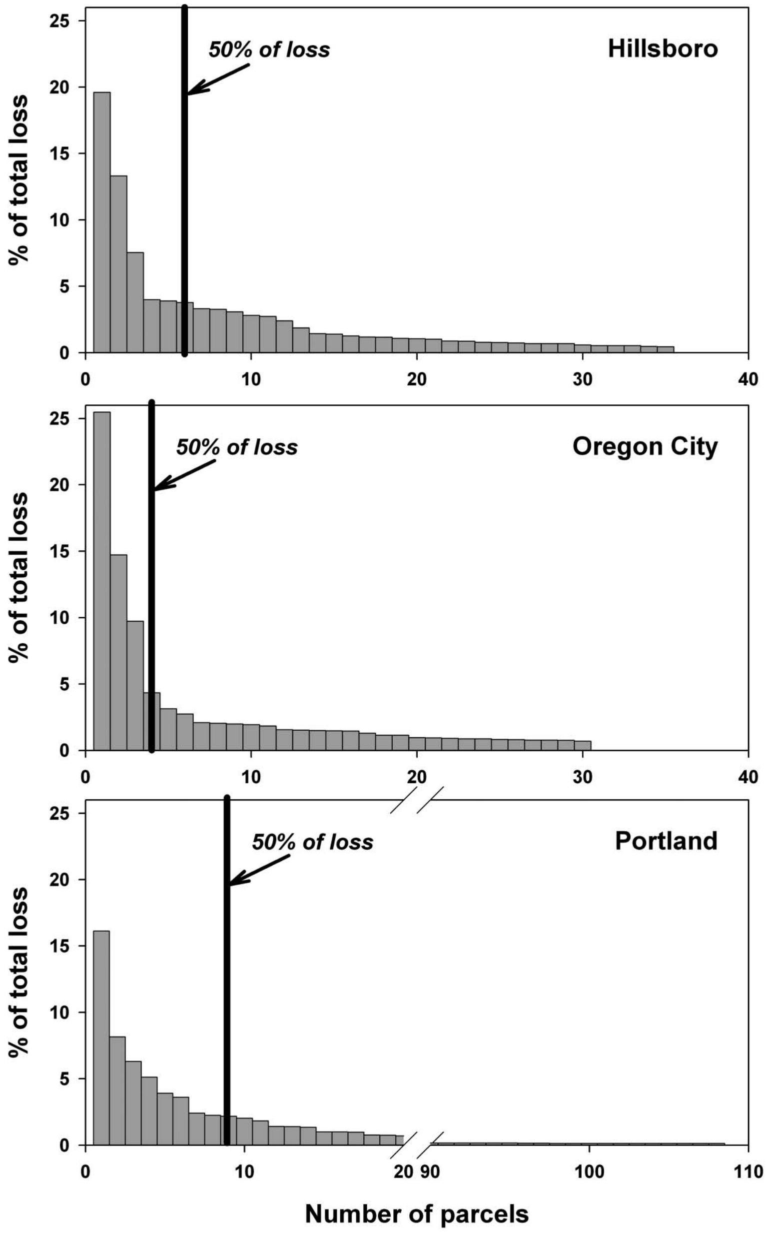

Figure 3. Distribution of losses in all unmanaged vegetation (in 7.5 m buffers) by parcel in descending order of magnitude of parcels, accounting for 90% of total losses in each city.

vegetation losses occurred as relatively small losses distributed fairly evenly over a large number of parcels.

Table 5 lists the project types associated with the 10 largest areas of unmanaged vegetation coverage loss in the three cities, the area of loss by project and the percentage of the city's total loss contributed by these projects.

Table 5. Ten largest losses in all unmanaged vegetation at 7.5 m buffer, by city

	Project type	Loss (ha)	% of total loss
Hillsboro			
1	Industrial manufacturing campus	0.38	19.6
2	Port of Portland (Hillsboro airport)	0.26	13.3
3	Single family homeowner	0.14	7.5
4	Public park	0.08	4.0
5	Industrial manufacturing campus	0.07	3.9
6	Public park	0.07	3.8
7	Residential subdivision	0.06	3.3
8	Industrial office park	0.06	3.1
9	Public park	0.05	2.8
10	Industrial manufacturing campus	0.05	2.7
Total of 10 largest losses		1.22	66.0
All other		1.18	34.0
Total		2.4	100.0
Oregon City			
1	Residential subdivision	0.50	25.5
2	Commercial shopping center	0.29	14.7
3	Residential subdivision	0.19	9.7
4	Public school	0.09	4.3
5	Residential subdivision	0.06	3.1
6	SF homeowner	0.05	2.7
7	Residential subdivision	0.04	2.1
8	Single family homeowner	0.04	2.0
9	Single family homeowner	0.04	2.0
10	Single family homeowner	0.04	1.9
Total of 10 largest losses			
All other			32.0
Total			100.0
Portland			
1	Public transit station	1.28	16.1
2	Industrial (gravel mining)	0.65	8.1
3	Residential subdivision	0.50	6.3
4	Municipal wastewater treatment plant	0.41	5.1
5	Commercial development	0.31	3.9
6	Port of Portland (Columbia River shoreline)	0.29	3.6
7	Cemetery expansion	0.19	2.4
8	Port of Portland (Portland airport)	0.18	2.2
9	Country club and golf course	0.17	2.2
10	Residential subdivision	0.16	2.0
Total of 10 largest losses			
All other			48.1
Total			100.0

A couple of points are worth noting. First, only three of the loss areas in Hillsboro and Oregon City are greater than one-tenth of a hectare. (In Portland, 14 sites incurred losses of 0.10 ha or greater.) The causes of the largest losses among the three cities included residential subdivision developments, a commercial shopping center, industrial developments, airport improvements and the siting of a public transit station. The remaining sites account for losses smaller than 0.10 ha, dropping down to 0.05 ha rather quickly, especially in Hillsboro and Oregon City. While these intermediate losses are yet sizable (0.05 ha is equal to 500 m^2, or loss of the full 7.5 m buffer for a stretch of nearly 67 m), they are associated with a wide range of development projects. The smallest losses (right side of the distributions in Figure 3) were often associated with single-family residences.

Discussion

Loss in vegetation along riparian corridors has been occurring at an alarming rate in the Portland metropolitan region over the recent decade or so. Past efforts to protect riparian vegetation have been driven primarily by concerns about water quality, flood control and other natural hazards. Losses ranging from nearly 2–6% in the study cities in the 7.5 m buffer over the 12-year period represent threats to these objectives. Habitat protection suggests a much broader definition of protected areas, encompassing wider buffers to provide wildlife shelter and forage resources. Slightly greater loss rates in the 15 m buffer width suggest similarly a diminishing habitat quality for wildlife in these urban areas.

Patterns of loss varied among the three study cities. Absolute losses were highest in the City of Portland. Although the higher losses (9.4 ha in the 7.5 m buffer width and 19.2 ha in the 15 m buffer), might be regarded as minor in the context of the city's much greater stream lengths (nearly seven times greater than Hillsboro and 14 times more than Oregon City), these are nonetheless resources lost. Given the regional significance of ecosystem resources due to their embedded and interconnected nature, absolute losses constitute an important metric to consider.

On the other hand, loss rates in the City of Portland were notably lower than in the other two cities in every buffer width examined, and Oregon City loss rates were consistently higher. Comparison of the outcome performance of any two management strategies is challenging due to a myriad of potential factors including topographical differences, historical patterns of existing development, as well as the differences in the timing of policy revisions relative to the data collection, program funding levels or dramatic changes in human resources. Moreover, development permits are often approved several years before ground breaking occurs; consequently, although more stringent resource protection rules may be on the books, it may take many more years before their impact is seen on the ground.

What is evident from this analysis is that resource management interventions in these three cities have made a difference. All cities incurred substantially higher losses of vegetation in the 100 m buffer, which is generally unregulated, compared to the 7.5 m buffer, where development guidelines impose the strictest precautions regarding resource destruction. The analysis of Oregon City overlay districts similarly suggests that regulatory investments pay off.

Finally, examination of major losses reveals important information. First, in all three cities, a large percentage of the overall loss was caused by a handful of projects. In Portland, a closer examination of these projects helps to explain the large absolute acreage destroyed, and suggests that the city's ongoing management approach may be performing better than the numbers indicate. Of the two largest losses, one was caused by a mining operation that is no longer in business. The second large loss was due to the construction of a light rail station on a line going to the Portland International Airport, which represents, it might be argued, an extraordinary event. It might also be argued that the transit station was a clear case in which a public good (the riparian vegetation) was sacrificed for another public good (the transit line), although the rail line was built as part of a public-private development partnership, which may raise questions for some. The second largest loss in Hillsboro was due to improvements at the local airport, which is owned and operated by the Port of Portland as part of a regional aviation system. Remaining large losses in the study cities were due to large, private development projects including a manufacturing site in Hillsboro, a commercial and residential project in Oregon City, and residential subdivisions in all three cities.

These findings raise several interesting policy questions. Were the exemptions made after a careful weighing of direct and indirect benefits and costs? Were the exemptions granted for a greater public good? Or, could the losses have been avoided by modifications to site designs or slight reductions in project scale?

While trying to second guess planners or decision makers is not necessarily fruitful, it is useful to look at current conditions and imagine what else might have been possible in order to gain insights for future decisions. In several cases, it would appear that alternative site designs could have preserved riparian vegetation. In one project, large sections of the 7.5 m and 15 m vegetative buffers were destroyed to create a surface parking lot and roads on a large industrial manufacturing site. Mitigation on site was offered through the construction of a wetland, complete with watering devices to ensure wetland plant survival due to an incomplete wetland hydrologic design. It can be speculated that the monies spent on the mitigation might have covered the costs of a small parking structure, thereby preserving the hydrological and riparian features in their natural state. In a second case, a first-order stream was filled and paved to build, yet again, a surface parking lot, this time for a shopping center. The footprint of the lot probably could have been reduced through a more creative design. However, parking needs at the shopping center might also have been accommodated through a shared parking arrangement with the neighboring church, which was built concurrently on a parcel adjacent to the commercial center. Hours of high demand for parking in shopping centers and churches would seem to be complementary. Finally, in the cases of residential subdivision projects, a greater project and site design flexibility would be expected than in the case of construction of a single home on a single parcel.

This analysis also suggests that large developments tend to present greater threats to riparian areas. It is beyond the scope of this investigation, but an obvious next step to better understand how losses occur in cities would be a closer examination of how decisions around these projects were made. In the US, local planning decisions are made by planning commissions and city councils, who receive the recommendations of planning staff. Exceptions to rules can and do occur with a single vote.

Conclusion

This research has shown that substantial losses in riparian vegetation in three study cities in the Portland, OR, metropolitan region occurred over the period 1990–2002.

Losses of 1990 vegetative cover in near stream buffers (7.5 m) ranged from slightly over 3% in the cities of Hillsboro and Portland to 9% in Oregon City. Clearly, such a rate of loss in the ecological functions served by riparian vegetation is cause for concern and must be attenuated.

Regulatory strategies in place to curb the destruction of this important resource appeared to have had a positive effect. Cities employ a range of management approaches. The City of Hillsboro employed a straightforward 'distance from stream' approach to trigger special attention to development proposals to ensure the protection of water quality. The rate of loss of near stream vegetative cover was significantly lower than loss rates at greater distances. The City of Portland with integrative, environmental overlay zones similarly demonstrated lower loss rates in areas closer to streams. Oregon City had the highest loss rates of the three study cities. However, an analysis of its single-purpose overlay districts show lower rates of resource depletion than in the city overall. Therefore, the management approaches of all three cities showed positive effects.

The final question of this research was to gain insight regarding major anthropogenic causes of riparian vegetation loss. Interestingly, in all three cities, a substantial proportion of the losses in near-stream areas were attributable to a few discrete projects. Like the 'point source' water polluters curtailed under the NPDES system, perhaps a more watchful eye and more rigorous standards on actions of large developers is a next important step toward slowing the pace of the degradation of urban natural resources.

What urban resource managers can learn from this work is the sobering fact that riparian vegetation in cities is diminishing steadily even in a region of the US that has implemented local controls to protect environmental resources. Preserving natural systems calls for aggressive action, but propitiously it may in fact require less action than commonly assumed. Despite the prevalence of small property owners in urban areas, this research has suggested that destruction of land-based natural resources in growing urban areas may be primarily due to a relatively few large, and rather mundane, projects, namely residential subdivisions and parking lots. Moreover, in the wake of property rights initiatives such as Oregon's 2004 Measure 37, which requires public agencies to compensate land owners for economic losses due to restrictions on the use of their land, resource managers are being called upon to think differently about how to protect natural resources. Creative attention to the design of projects inspired with a commitment to preserve the existing state of natural resources may offer a pathway forward and produce higher retention rates of a precious resource than the recent past has shown. This awareness and consequent intentional behaviors along with the restoration of streams and riparian buffers that is ongoing in many urban areas can work together to improve the future of urban ecosystems.

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