Estimating economic damages of non-indigenous invasive weeds on recreation using three analytical approaches

Mark E. Eisworth[1], Wayne S. Johnson[1], Jeanmarie Agapoff[2], Tim D. Darden[1] and Thomas R. Harris[1]
[1] Department of Applied Economics and Statistics/204, University of Nevada, Reno, NV 89557-0105, USA
[2] Economic Research Service, USDA, 1800 M St. NW, Suite 4039, Washington, DC 20036, USA

Summary Economic impacts by alien, invasive weeds to recreation are not well known. The data to estimate such impacts are not easily measured and are scarce. We apply three analytical approaches to limited data and compare results to estimate ranges in which the true economic losses lie. To reflect underlying uncertainty, we develop a range of estimates using low, medium, and high scenario combinations of parameter and variable values. In a case study of alien, invasive weeds on public lands in Nevada, we estimate lost wildlife-related recreation values from $5 to $15 million per year. Using our most conservative findings for all annual recreation losses, we predict that discounted losses over five years would range from $25 to $35 million, depending on actual future expansion rates.

Keywords Alien, invasive weeds, non-indigenous species, non-native species, recreation, economic losses.

INTRODUCTION

Terrestrial and aquatic, alien weeds spread rapidly in riparian ecosystems (Smith *et al.* 1999). They impact fishing, hunting, hiking, wildlife viewing, and water-based recreation by affecting soil quality, water quality and quantity, plant diversity, availability of forage and cover, animal diversity and abundance, including that of fish (Olson 1999, Madsen 1997, Newroth 1985).

Few estimates of economic losses to recreation due to weeds exist, except analyses that 1) are part of studies on reduced grazing, 2) are focused on weed species that have yielded substantial economic impacts, and 3) are helped by good maps or other data collected for other purposes (Leistritz *et al.* 1992, Leitch *et al.* 1996).

Herein, we deal with the common problem of estimating recreational losses from alien invasive weeds for an area when data are scarce or poor quality and estimates are sought by agencies and legislatures to decide how to spend money on invasive weed detection, prevention, and control. For lack of ‘bottom up’ data, our approach analyses aggregated state-level data, employs three analytical approaches and compares results and lastly, acknowledges and reflects uncertainty in the available data by estimating a range of potential recreation losses.

MATERIALS AND METHODS

Data First, we used recreation days per year in Nevada for fishing, hunting and wildlife-watching (US Fish and Wildlife Service 1996). Second, we estimated per-day net economic values (NEV), consumer surplus, for wildlife-related recreation, drawing on an existing meta-analysis (Walsh *et al.* 1990). Multiplying the number of recreation days per year by NEV per day produces an estimate of the NEV per year for each category. Summing values across the three activities values recreation at about $163 million per year in Nevada (Year 2000 dollars), Table 1.

Second, consumer annual expenditures on recreation in Nevada, year 2000 dollars, are given in Table 2 (US Fish and Wildlife Service 1996). These data are useful for an ‘expenditure-based’ approach for measuring recreation impacts.

Third, to estimate infestation rates of alien invasive weeds for this study, we conducted an expert opinion survey of agency land managers. About 87% of Nevada is under agency management. The mean response for the percentage of a typical watershed infested was 47%. Variability among geographic and management units was significant. To reflect such variability and uncertainty in our estimation techniques, we use ‘lower’ (35%) and ‘higher’ (65%) estimates for the statewide

Table 1. Estimated annual net recreation values (consumer surplus) in Nevada[a].

Recreation activity	Recreation days per y[b]	Net economic value per day[c]	Estimated net value per y
Hunting	649,000	$53	$34.4m
Fishing	1,976,000	$43	$85.0m
Wildlife viewing	1,394,000	$31	$43.2m
Totals	4,019,000	NA	$162.6m

[a] Monetary values denote consumer surplus, or net economic values, from recreation uses. Consumer surplus is the amount that recreators are willing to pay for recreation minus all recreation expenditures (therefore a net value).
[b] US Fish and Wildlife Service, 1996.
[c] Source: median values by recreation use type as reported in the Walsh *et al.* (1990) meta-analysis, updated to June 2000 dollars.

mean percent infestation rates along with a 'middle' estimate of about 50% as derived from the survey.

Estimation techniques We developed 'lower,' 'middle' and 'higher' estimates of annual losses from alien invasive weeds. This reflects uncertainty in the analyses, yields a 'bounding exercise,' and produces a likely range of potential losses.

Approach 1: Develop a range of estimates of losses in consumer surplus from wildlife-based recreation.

$$RL = (\theta)(\phi)(\Delta)(CR + RL) \quad (1)$$

where:

θ = fraction of potential wildlife-related recreation use values lost on recreation lands fully (100% cover) infested with alien invasive weeds, $0<\theta<1$.

ϕ = fraction of potential recreation lands that are currently infested with alien invasive weeds, $0<\phi<1$.

Δ = average percent weed cover (÷100) on those recreation lands that are currently infested, $0<\Delta<1$.

CR = current wildlife-related recreation use values.

RL = wildlife-related recreation use losses.

Table 3 summarizes parameter values used herein.

Approach 2: Partial parameter transfer based on research in the upper Great Plains. This approach is similar to approach 1, except that it employs information derived by Leitch *et al.* (1996) on the linkage between infestation rates and recreation activity. Wildlife-related recreation losses are estimated as:

$$RL = (\eta)(\phi)(CR + RL) \quad (2)$$

Where η denotes the average percent reduction in recreation expenditures per 1% increase in weed infestation (scale = from 0% to 100% infestation). If the $\eta = 0.15$, then each 1% increase in weed infestation is calculated to lead to a 0.15% decline in wildlife recreation values, on average, over the range of data. Table 4 summarizes parameter values for this approach.

Approach 3: Use a Nevada input-output model to estimate economic losses to the state's economy. Input-output analysis estimates the direct, indirect, and induced change or 'shock' to an economy. We used IMPLAN Pro™ (Impact Analysis for PLANning model) (Anon. 1999) to estimate impacts by alien weeds on reductions in recreational visitor expenditures and their effect on output and employment, Table 5. Estimates of the three values for η and ϕ are the same as for approach 1. Baseline wildlife-related recreation expenditures (CE) are $599.6 million under each scenario (Row 3), and correspond to total recreation expenditures less 'expenditures for other items' (approx. $625 million minus $25 million, see Table 2), which are subtracted out because they mostly leave the region. Losses in direct recreation expenditures (Row 4) are calculated using equation 3 and the values in Rows 1–3 of Table 5:

$$RE = (\eta)(\phi)(CE + RE) \quad (3)$$

where:

RE = reductions in wildlife-based recreational direct expenditures.

η = the rate at which wildlife recreation expenditures are reduced when land is weed infested.

ϕ = the fraction of potential recreational lands currently alien weed infested.

CE = Current wildlife-based recreational expenditures.

We then estimated the portion of these losses

Table 2. Annual recreation expenditures in Nevada (millions of dollars)[a,b].

Activity	Expenditures per year: Trip-related	Equipment	Other items	Total
Hunting	$22.8	$74.3	$7.2	$104.2
Fishing	$81.2	$142.1	$8.5	$231.8
Wildlife viewing	$94.6	$184.6	$9.4	$288.6
Totals	$198.6	$401.0	$25.1	$624.6

[a] US Fish and Wildlife Service, 1996.
[b] All values have been updated to June 2000 dollars.

Table 3. Parameter values for the recreation use (consumer surplus) loss estimates using only Nevada data (Approach 1).

Variable/ parameter	Scenario estimate: Lower	Middle	Higher
θ	0.50	0.70	0.90
ϕ	0.35	0.50	0.65
Δ	0.10	0.30	0.50
CR	$163m	$163m	$163m

Table 4. Parameter values for the recreation use (consumer surplus) loss estimates using Great Plains partial parameter transfer (Approach 2).

Variable/ parameter	Scenario estimate: Lower	Middle	Higher
η	0.12	0.17	0.22
ϕ	0.35	0.50	0.65
CR	$163m	$163m	$163m

Table 5. Parameters and direct expenditure estimates used as inputs for the expenditure-based (I/O model) loss estimates (Approach 3).

Variable/ parameter	Scenario estimate		
	Lower	Middle	Higher
η	0.12	0.17	0.22
ϕ	0.35	0.50	0.65
CE (expenditures)	$599.6m	$599.6m	$599.6m
RE (direct losses on recreation)	$26.3m	$55.7m	$100m
Estimated nonresident direct losses	$4.47m	$9.47m	$17.0m

attributable to reductions in recreation spending by out-of-state residents as in-state residents respond to infestations either by a) switching to substitute, non-infested recreation sites or b) diverting spending to other forms of entertainment expenditure within the state. We calculated that 17% of the total recreation days in Nevada are by out-of-state visitors. We apply this percentage to the calculated losses in total direct expenditures (Row 4) to derive the estimated nonresident direct expenditure losses (Row 5). The reductions in nonresident direct expenditures were then broken down specifically into retail trade and service sector purchases at 67% and 33%, respectively. We used this ratio from the Great Plains (Bangsund *et al.* 1999), because we lacked primary wildlife-associated recreation expenditure data specific to Nevada. Allocating expenditures between these two sectors estimates the regional economic impacts of how the monies from purchases flow throughout the economy and affect regional employment and income. Finally, purchases made from the retail trade sector were margined at 31.8%, the average retail mark-up of goods purchased from the Bureau of Census Annual Survey of Retail Trade (US Bureau of the Census 2000). The margined figure allows only the impacts of the retail trade purchases rather than total purchases, which would overstate the overall impact on the regional economy.

RESULTS AND DISCUSSION

Loss estimates Tables 6 illustrates estimates using approach 3 (I/O model) of the economic impacts (direct, indirect and induced) of alien weeds to Nevada's economy using the middle scenario assumptions. The middle estimate is $12.4m y^{-1}$. Using the lower and higher scenarios' inputs results in loss estimates of $5.9m y^{-1}$ and $22.3m y^{-1}$, respectively.

Table 7 summarizes the annual recreation loss estimates for each of the three analytical techniques. Lower estimates range from $3 to $7m y^{-1}$, middle from $12 to $19m y^{-1}$, and higher $22 to $67m y^{-1}$. With the exception of the highest estimate, which is a product of the higher linkage parameters, specifically between infestation rate and reductions in recreation, the estimates are comparable across the three estimation approaches. The means provide reasoned estimates of recreational use losses to invasive weeds in Nevada.

Table 6. Middle scenario estimate of the impacts of a weed-induced reduction in recreational expenditures to Nevada's economy (Approach 3).

Expenditure loss ($m)	-$9.47	Retail/service sector split ($m)	Estimated direct impacts ($m)
Retail trade expenditures	67%	-$6.34	-$2.02
Service expenditures	33%	-$3.13	-$3.13
Retail trade margin	31.8%		
Total impacts	**Direct impacts ($m)**	**Indirect/ induced impacts ($m)**	**Total impacts ($m)**
Industry	-$5.14	-$3.60	-$8.74
Labour income	-$2.33	-$1.32	-$3.65
Employment	-85	-44	-129
Economic	-$7.48	-$4.92	-$12.40

Table 7. Summary of annual recreation loss estimates by analytical approach[a].

Approaches	Scenarios (m y^{-1})		
	Lower	Middle	Higher
Approach #1	$2.9	$19.1	$67.2
Approach #2	$7.1	$15.1	$27.1
Approach #3	$5.9	$12.4	$22.3
Mean (across approaches)	$5.3	$15.5	$38.9

[a] Note that Approach 3 measures a different category of economic value (i.e., state-level direct and secondary impacts from changes in expenditures) than Approaches 1 and 2, which measure net economic value, or recreator benefits over and above expenditures.

The width of the range of economic losses may be somewhat overstated because the lower (higher) scenarios use all low (high) parameters jointly. Gaps in knowledge lead to these under and over estimations, particularly regarding infestation rates of individual species within particular ecological systems and management schemes, if managed.

Table 8 presents estimates of the discounted present value of future flows of economic losses (foregone benefits). We predict losses for four alternative average annual rates of expansion for invasive species (5%, 10%, 15%, and 20%) over a time horizon of five years. Conservatively, we use the approximate mean of the lower scenario estimates of recreation losses (\$5 million y^{-1}) to predict foregone benefits over future periods. If any of the other scenario estimates more accurately describe true losses, then our predictions in Table 8 will understate future losses. Conservative estimates of the present value of the future flow of recreation losses range from about \$25 million to about \$35 million over the next five years. Three points deserve mention. The present value stream of foregone benefits depends upon the average annual expansion rate for invasive species. The longer the future time horizon, the greater the uncertainty regarding future expansion rates will be. Uncertainty in future expansion rates is at least as important as uncertainty in current annual recreation losses. Also, uncertainty regarding the expansion rate easily leads to estimates that differ greatly.

Smith *et al.* (1999) examined the growth rates of a variety of invasive weeds in diverse locations around the western United States and found an average expansion rate of 24% per year, with relatively high rates in early years and lower growth rates as an infestation matures. Based on this information, it is likely that the expansion rates in Table 8 are lower than the intrinsic growth rates many Western states will experience without control of alien invasive species. If this is the case, the overall economic impacts may be understated.

Table 8. Future flows of wildlife-related recreation losses using the lower scenario annual loss estimate as the starting point, by expansion rate.

Mean annual expansion rate	Present value streams of future recreation losses [a, b]
	T = 5 y
5%	\$26m
10%	\$28m
15%	\$31m
20%	\$34m

[a] Discount rate = 4%. [b] As the starting point for current annual recreation losses, we use the approximate mean of the lower scenario estimates in Table 9 (\$5 million y^{-1}). For this and other reasons, the present value streams in this table likely understate the true recreation use losses that would accrue over the next five years in the absence of weed management measures.

ACKNOWLEDGMENTS

The US Department of Agriculture Cooperative Extension System's Integrated Pest Management Program provided partial support. We thank Larry Leistritz, North Dakota State University, for sharing information on the economic impacts of leafy spurge.

REFERENCES

Anon. (1999). IMPLAN Professional™, Version 2.0, Social accounting and impact analysis software, Minnesota IMPLAN Group, Inc., 1725 Tower Drive West, Suite 140, Stillwater, MN 55082, USA, www.implan.com.

Bangsund, D.A., Leistritz, F.L. and Leitch, J.A. (1999). Assessing economic impacts of biological control of weeds: the case of leafy spurge in the northern Great Plains of the United States. *J Environ Mgmt*. 56, 35-43.

Leistritz, F.L., Thompson, F. and Leitch, J.A. (1992). Economic impact of leafy spurge in North Dakota. *Weed Science* 40, 275-280.

Leitch, J.A., Leistritz, F.L. and Bangsund, D.A. (1996). Economic effect of leafy spurge in the Upper Great Plains: methods, models, and results. *Impact Assessment* 14, 419-433.

Madsen, J.D. (1997). Methods for management of nonindigenous aquatic plants. *In*: Assessment and management of plant invasions, eds J.O. Luken and J.W. Thieret, pp. 145-171. (NY Springer-Verlag).

Newroth, P.R. (1985). A review of Eurasian water milfoil impacts and management in British Columbia. Proceedings First International Symposium on watermilfoil (*Myriophyllum spicatum*) and related Haloragaceae species. July 23–24, Vancouver, BC, Canada, pp. 139-153.

Olson, B.E. (1999). Impacts of noxious weeds on ecologic and economic systems. *In*: Biology and management of noxious rangeland weeds, eds R.L. Sheley and J.K. Petroff, pp. 4-18. (Oregon State University Press).

Smith, H.A., Johnson, W.S., Shonkwiler, J.S. and Swanson, S.R. (1999). The implications of variable or constant expansion rates in invasive weed infestations. *Weed Science* 47, 62-66.

US Bureau of the Census (2000). Annual benchmark report for retail trade, Jan. 1990 to Dec. 1999. Current Business Reports Series, BR/99-A. Washington, DC.

US Fish and Wildlife Service (1996). 1996 National survey of fishing, hunting and wildlife-associated recreation. USFWS, Washington, DC.

Walsh, R.G., Johnson, D.M. and McKean, J.R. (1990). Non-market values from two decades of research on recreation demand. *In* Advances in Applied Micro-Economics, Vol. 5, eds V.K. Smith and A.N. Link. (JAI Press, Inc.).