DOI: 10.1007/s00267-003-3023-5

Hedonic Analysis of Effects of a Nonnative Invader (*Myriophyllum heterophyllum*) on New Hampshire (USA) Lakefront Properties

JOHN M. HALSTEAD*
JODI MICHAUD
SHANNA HALLAS-BURT
Department of Resource Economics and Development
University of New Hampshire
Durham, New Hampshire 03824 USA

JULIE P. GIBBS
Regional Economist
U.S. Army Corps of Engineers
Fort Worth, Texas USA

ABSTRACT / Introduced species are a major threat to the planet's ecosystems and one of the major causes of species extinction. This study deals with some of the economic impacts of one of these "invaders," variable milfoil. Variable milfoil can clog waterbodies, cause boating and swimming hazards, and crowd out native species. This study analyzed the effects of variable milfoil on shoreline property values at selected New Hampshire lakes. Results indicate that property values on lakes experiencing milfoil infestation may be considerably lower than similar properties on uninfested lakes. Results are highly sensitive to specification (variable selection) of the hedonic equation.

There are an estimated 50,000 nonnative species in the United States today. While many of these introduced species, such as corn and wheat, provide substantial benefit, it has been estimated that others are causing over $100 billion a year in environmental damage (OTA 1993, Pimentel 2002). These foreign invaders include plants, animals, birds, and insects that compete with and prey on native species. Nonnative[1] or introduced species are one of the major threats to many of the world's ecosystems and one of the major causes of species extinction (Smith 1996, Simberloff 1996). In the United States, nearly half of the plant and animal species listed under the Endangered Species Act are at risk because of these foreign invaders (Motavalli 2001, Pimentel and others 1999).

Nonnatives, once introduced into a suitable habitat, thrive without the presence of natural predators and diseases that control populations in their native environments. The absence of predators gives nonnatives an advantage over native species and the ability to take over the systems to which they are introduced, sometimes to the exclusion of native species (McNeely and others 1990).

An estimated 4000–5000 nonnative plant species in the United States are threatening native populations and costing the US economy billions of dollars (Morse and others 1995). Nonnative aquatic plant introductions have numerous and varied effects, including habitat disruption, loss of native plant and animal communities, and reduced fishing and recreation opportunities. One species, variable water milfoil, was first identified in New Hampshire lakes in the late 1960s. It has now spread to at least 36 waterbodies, creating a serious economic and recreational nuisance.

This study deals with some of the economic impacts of this particular exotic aquatic—variable milfoil (*Myriophyllum heterophyllum*). By quantifying some of the impacts of this nonnative species, it is hoped that more informed choices can be made by landowners, lake associations, policymakers, and others involved with the region's waterbodies. It is hypothesized that infestation by nonnatives can greatly reduce the aesthetic and recreational values of lakes. Quantifying the effects of milfoil infestation values will help us understand how infestation affects local economies and how to best take steps to address this problem.

KEY WORDS: Variable milfoil; Hedonics; Nonnative species

Published online October 20, 2003.

*Author to whom correspondence should be addressed, *email:* johnh@christa.unh.edu

[1]In the literature, terms such as "nonnative," "nonindigenous," "alien," "exotic," and "invasive" are often used interchangeably to describe (usually human) introduced species. In this article, the term nonnative will be used as a general term for consistency.

Background

Variable milfoil is believed to have been introduced into US waters by way of discarded aquarium plants into lake waters and is spread by human action and by natural sources. Human action includes the dumping of aquarium waters and plants into waterbodies; importing plants for research; and on boats, motors, trailers, and fishing gear and other aquatic recreational equipment that is used in infested waters and brought to uninfested waters. Natural transport can occur when milfoil attaches to migrating birds and waterfowl.

According to New Hampshire law, "the definition of 'exotic aquatic weeds' includes those species of vascular plants which were not part of New Hampshire's native aquatic flora before 1950, and which are considered nuisance species" (NH Law RSA 487:17, 1981). Introduction to New Hampshire waters was most likely by way of plant fragments attached to boating equipment. Milfoil[2] can live out of water for hours (e.g., on a boat trailer) and will rejuvenate once it is returned to the water (NH-DES 1999). The spread of milfoil by transient boat traffic has increased in recent years, prompting New Hampshire and other states to adopt laws that make it illegal to sell, distribute, import, purchase, propagate, transport or introduce nonnative aquatic weeds into the state (NH Law RSA 487:16-a, 1998).

Once introduced, variable milfoil can grow at explosive rates, rapidly inhabiting shoreline areas, and may not be discovered by state biologists until the plants are well established. Once fragmented by wave action, wind, or boat propellers, small fragments float in the water and form roots, allowing the plant to take hold in shallow waters and colonize another area of the lake. One small fragment can potentially multiply into 250 million new plants within a year's time. Rooted in favorable conditions, milfoil can grow up to 1 inch per day to reach up to 18 feet in length, creating a matlike canopy near the water's surface (NH-DES 1999). This plant can even survive in a more succulent form along the shore when water levels are lowered.

Costs of Milfoil

Left unchecked, variable milfoil tends to clog waterbodies, causing boating and swimming hazards and crowding out native species. In extreme cases, milfoil has been implicated in the drowning of swimmers who became entangled in the long vine-like plants. Fish and fowl that depend on native species for food and shelter find it more difficult to survive in infested waters, resulting in decreased species diversity. A less obvious impact of milfoil infestation is increased nutrient loading. When the plants die, decaying organic matter increases internal loading of phosphorus and nitrogen, reducing the levels of dissolved oxygen necessary for healthy fish habitat.

Many of the damages caused by *M. heterophyllum* are difficult to quantify as they are "nonmarket" in nature. For example, if a nonnative species such as Johnson grass (*Sorghum halepense*) has the effect of reducing crop yields, it is a relatively straightforward matter to monetize control costs and yield losses. For milfoil, however, the effects are less amenable to market valuation, as the aesthetic, ecosystem, and health damages of milfoil do not reveal themselves quite as obviously. Isolating one part of the cost of milfoil—its effect on property values—can help to provide some of the information for full cost accounting of damages of this invader. Armed with this information, lakes associations; state, federal, and local officials; and individuals can make more informed choices as to the efficacy of the control measures available. Thus, this research seeks to explicitly analyze the environmental problem's overlap with community finances.

Management Strategies

Once introduced and fully established, milfoil is virtually impossible to eradicate, and its impacts on the natural native ecology of the system they have been introduced into are almost irreversible. To date, a number of techniques have been used in an effort to control the plant, including the application of herbicides, mechanical harvesting, bottom barriers, hand pulling, and biological controls.

The use of herbicides is the method of choice for small, new infestations, but is rarely effective in treating extensive infestations. Since many lakes are also used as sources for drinking water, chemical use can be more destructive to lake water quality than milfoil plants. While it is often illegal for anyone but state-licensed contractors to put pesticides into a waterbody, such aquatic herbicides are advertised as safe and effective and are readily available to the public via the Internet. A serious concern is that homeowners will use these chemicals in an effort to rid their beaches of the nuisance aquatics, posing health threats and increasing costs associated with the drinking water treatment process.

Mechanical harvesting is widely used and can be thought of as a large aquatic lawnmower. This method covers a large area in a short amount of time, but it is expensive and is not a fully effective method of eradication. The harvester cuts the plant about 5 feet below the water line, leaving the roots and sending fragments into the water column, which can then root to create more plants and a thicker mat of vegetation. Both of

[2]Throughout this article, the term milfoil will be used to refer specifically to variable milfoil.

these methods can be expensive—from $150 to $1500 per lake acre—and can harm species other than the target species (NH-DES 2000).

Other methods include the placement of benthic or bottom barriers—a semipermeable fine mesh screening material to shade and inhibit plant growth. This method is most effective in areas of small infestations, but also impacts all plants under the barrier. Lake drawdowns have also been used to expose the plants, but they are highly resistant to desiccation, and drawdowns also impact nontarget plants. Another control method is manual harvesting or hand-pulling, which is highly labor intensive since effort must be taken not to fragment the plant while pulling. It is also not feasible in lakes that have large areas of infestation. Biological controls involve the introduction of an organism that will inhibit the growth of the target plant without affecting other plants or organisms. New Hampshire biologists are currently investigating aquatic moth larvae as a way to control milfoil. Extensive study is still necessary with the use of "biocontrols," since it is hard to predict their long-term effects. All of these strategies have substantial explicit and external costs.[3]

Previous Research

Literature searches provided a large number of hedonic studies dealing with environmental attributes' effects on property values, but none specifically on invasive species. However, a large number of studies have been conducted examining the relationship between water quality measures and housing prices; these provide appropriate guidance for the proposed study.

Epp and Al-Ani (1979) estimated the relationship between the value of residential properties adjacent to streams and the quality of the water in the streams. The final model used pH as the environmental variable because it was the most commonly understood measure of quality to the homeowners; in estimating pooled data, pH had a significant effect on property values. Wilman (1984) used market data on property rentals to discover the cost of beach pollution. The rental price equation included variables for distance from the beach and debris, a proxy for pollution along with structural and neighborhood characteristics. In all four housing markets studied, she found beach debris to be a significant negative factor in rental prices.

Leggett and Bockstael (2000) examined the effect of changes in water quality on property values, using fecal coliform as a proxy variable. The authors found that reductions in fecal coliform levels could lead to a 2% increase in full market assessed value.

Michaels and others (2000) and Gibbs and others (2002) examined the effects of cultural eutrophication on lakes in market areas throughout Maine and New Hampshire. The focus of the research was the effects of eutrophication on property values. The variable ln(water clarity), which is the natural log of the minimum water clarity (using Secchi disk measurements as the proxy for water quality) for the year the property was purchased, was statistically significant in all market areas for which data were usable, with the expected positive sign in all markets.

Methods

The objective of this study is to determine the effects that infestation of milfoil has on lakefront property values in New Hampshire. It is hypothesized that infestation by nonnatives can greatly reduce the aesthetic and recreational values of lakes. From an economic standpoint, it is useful to estimate the costs of variable milfoil infestation. Quantifying the effects of milfoil infestation values will help understand how infestation affects local economies and how to best take steps to address this problem.

This study applies the hedonic method to information gathered on observed property purchases on selected New Hampshire lakefronts. First proposed by Lancaster (1966) and later expanded upon by Rosen (1974) and Freeman (1974), the hedonic technique essentially breaks market selling prices of goods down into their characteristics or attributes and consequently is able to generate an implicit or shadow price for the attribute. These characteristics—environmental quality, local amenities, house attributes, etc.—can then be "priced" via statistical analysis. Since the theory, assumptions, and practice of the hedonic method have been widely discussed elsewhere (see, e.g., Freeman 1993), they will be discussed only briefly in this article.

Once isolated, information on characteristics of properties purchased is combined with information on the presence or absence of milfoil for the relevant lakes. Property price is then regressed against the independent variables, including the presence or absence of milfoil, to obtain the marginal prices of chief property characteristics. The results can then be used to estimate some of the regional costs associated with the

[3]While most of the information cited in this section is from New Hampshire sources, similar discussions can be found in many of the states dealing with milfoil, which range from Maine to North Dakota. A recent web search found over 2000 entries on variable milfoil, most dealing with individual lake issues.

Table 1. Names and descriptions of variables used in milfoil effects model

Variable name	Description	Mean (SD)	Anticipated effect
HP	Selling price of house (1995 dollars)	170,556.67 (186,255.28)	
AGE	Age of house (years)	35.042 (27.656)	negative
AGESQ	Age of house (years, squared)		positive
SQFT	Square footage of finished living area excluding bathrooms and closets	1144.674 (790.628)	positive
FF	Property abutting the water (feet)	149.319 (133.574)	positive
DIST	Miles to nearest town with population > 9000	12.355 (6.531)	negative
DENS	Housing density (lots/1,000 feet of lake frontage)	8.083 (3.055)	negative
TR	Tax rate in year of purchase	23.539 (6.116)	negative
LKA	Surface area of lake (acres)	2,035.669 (1,953.750)	-
MILFOIL	1 if milfoil present in lake, 0 otherwise	0.389 (0.489)	negative
LKAMIL	LKA * MILFOIL		positive

presence of milfoil. Specifically, the study will use a data set developed for lakes in a housing market area identified in a previous hedonic study (Gibbs and others 2002).

Following previous hedonic studies, the general form of the hedonic price equation used in this study is

$$HP = f(S,L,E)$$

where HP is the home price, S is the structural characteristics, L is the locational characteristics, and E is the environmental characteristics, including presence of variable milfoil. Descriptions and summary statistics of the variables included in the model are listed in Table 1. The structural and locational variables were selected based on a review of variables included in previous hedonic studies and the availability of a parsimonious set of variables that were consistently reported for all property sales. Expanding the general equation 1 to include the described independent variables and incorporating a measure for milfoil infestation, the resulting equation is:

$$HP = \alpha + \beta_1 AGE + \beta_2 AGE^2 + \beta_3 SQFT + \beta_4 FF + \beta_5 DENS + \beta_6 DIST + \beta_7 TR + \beta_8 MILFOIL + \beta_9 LKAMIL + \varepsilon \quad (2)$$

To investigate the possibility of a nonlinear relationship between milfoil and property value, a second form was used:

$$\ln HP = \alpha + \beta_1 AGE + \beta_2 AGE^2 + \beta_3 SQFT + \beta_4 FF + \beta_5 DENS + \beta_6 DIST + \beta_7 TR + \beta_8 MILFOIL + \beta_9 LKAMIL + \varepsilon \quad (3)$$

where lnHP is simply the natural log of housing price in 1995 dollars. Ordinary least squares (OLS) was used to determine the marginal value of the characteristics.

Regarding functional form, the literature does not readily suggest a correct form for the hedonic equation (Rosen 1974, Freeman 1979), although it does recommend several possible forms that can be examined for the best fit. The semilog form is the most popular alternative to the Box-Cox transformation (Mendelsohn 1984, Michaels and Smith 1990, Graves and others 1988, Brown and Pollakowski 1977, Bouwes and Schneider 1979, Murdoch and Thayer 1992, Milon and others 1984, Halstead and others 1997). There are two possible semi-log forms: the log-lin form regresses the log of price on the attributes, which implies that the marginal value of the attribute of interest increase monotonically with the price (Nelson 1978, Garrod and Willis 1992). In contrast, the lin-log form regresses price on the log of the attribute such that the effect of the attribute decreases monotonically with the level of the attribute. In this model, a Box-Cox analysis suggested that a log-lin form appeared preferable to the linear form.

Specification of the Milfoil Variable

Since the literature reveals no clear method for estimating the effect of milfoil on property values, two specifications were explored. First, milfoil was considered in a present-absent (0–1) variable, MILFOIL. While it would have been preferable to have a more refined index of infestation—such as percentage of lake covered, proximity to units included in this study, and eradication attempts—this information simply was not available. The state of New Hampshire does not take annual measurements of milfoil infestation severity, so the only option was to note whether milfoil was present in the lake at the time of house purchase. Second, an interaction term was used to allow for interaction between the size of the lake (LKA) and the presence of milfoil. This was because milfoil on a large lake may affect properties less if it is concentrated in a distant section of the lake, and also because more of a large lake might be uninfested and available for boating, swimming, and other uses compared to a smaller lake.

It was anticipated that the presence of milfoil would lead to a negative effect on property values. However, since milfoil infestation can tend to be a localized phenomenon (at least in the short run), it is possible that homeowners on larger lakes may be less affected by—or perhaps even unaware of—the presence of milfoil in their lake. In addition, potential property buyers may prefer larger lakes. Thus, the interaction term LKAMILFOIL was included in the model. The presence of milfoil in a log linear regression thus has the following effect on HP (since the MILFOIL variable can only take on a value of 1 or 0):

$$\Delta HP = (HP|MILFOLI = 1) - (HP|MILFOIL = 0)$$
$$= e^{a+\beta 1 AGE2 + \beta 2 AGE2 + \beta 3 SQFT + \beta 4 FF + \beta 5 DENS + \beta 6 DIST + \beta 7 TR + \beta 8 + \beta 9 LKA + \epsilon}$$
$$- e^{a + \beta 1 AGE + \beta 2 AGE2 + \beta 3 SQFT + \beta 4 FF + \beta 5 DENS + \beta 6 DIST + \beta 7 TR + \varepsilon}$$
$$= e^{a + \beta 1 AGE + \beta 2 AGE2 + \beta 3 SQFT + \beta 4 AFF + \beta 5 DENS + \beta 6 DIST + \beta 7 TR + \varepsilon}$$
$$*(e^{\beta 8 + \beta 9 LKA} - 1) = HP * (e^{\beta 8 + \beta 9 LKA} - 1) \quad (4)$$

with the mean value of LKA in the market area, in acres, used in this calculation.

Data Collection

Following Freeman (1993), the study uses cross-sectional data for individual sales of lakefront properties, since repeat sales of lakefront properties are infrequent. Lakefront housing sales data were collected for the period between 1990 and 1995, and converted to 1995 dollars for estimation.[4] Information on the selected variables was taken from public assessment and transaction records available in the towns where the properties are located. However, the data available are not consistent across towns with lakefront properties in the study area. This inconsistency in the availability of data restricted the variables available for use in regression analyses. The final data set included 144 usable observations.

Lakes were grouped into markets due to close proximity to each other and the probability that they share common characteristics. The market area selected includes ten lakes in central New Hampshire.[5] These lakes were selected because they are part of the Volunteer Lakes Assessment Program (VLAP), and because previous research on water clarity had provided a detailed data set of housing transactions and characteristics in the area. Information on milfoil infestation was obtained through the New Hampshire Department of Environmental Services (NHDES), which has an active program for management of nonnative invaders.

Results

Results of OLS regressions for both the linear and log-linear models are summarized in Table 2. Breusch-Pagan tests indicated the presence of heteroskedasticity in the equation for the market area. Therefore, *t* statistics and confidence intervals were calculated using White corrected standard errors. All variables that were statistically significant had the expected signs. The models' adjusted R^2 values indicate the overall model is a relatively good fit.

Examining the results of the linear model, the effect of milfoil on property values in the region is

$$-177{,}020.98 + (69.57*2{,}036) = -\$35{,}382.98 \quad (5)$$

Since average property value in the sample is $170,556, this translates to a decline in average property values of about 20.7%.

Turning to the log-linear form milfoil variables and using equation (4), the effect of the presence of milfoil on an average size lake of 2,036 acres is

$$170{,}556.67*(e^{-.0531 - .0003(2{,}036)} - 1) = -\$72{,}908.82 \quad (6)$$

Again considering the average selling price of a house in the area is $170,556.67, this represents a decline of about 42.7%. Thus, the presence of milfoil appears to have a substantial deleterious effect on lakefront housing prices, although the size of this effect is heavily dependent on the functional form chosen (linear versus logarithmic). However, a decline of more than 40% seems unreasonably large, so these results should be interpreted with caution, as discussed below. It is also important to note that while the coefficient on the LKAMIL variable is statistically significant at the 90% level, the MILFOIL variable is not (after heteroskedasticity correction). Thus, one might even argue that the results of the most theoretically and statistically appro-

[4]The specific time period (1990–1995) was initially chosen for consistency with two studies previously done at the University of Maine, so that a pooled data set could later be used to generate second stage hedonic estimates (Michael and others 1996).

[5]The ten lakes are Crystal, Halfmoon, Lee, MerryMeeting, Squam, Suncook, Waukewan, Wicwas, Winnesquam, and Winona.

Table 2. Ordinary least squares results, milfoil effects model. Dependent variable = Ln (1995 Housing price).

Variable	Coefficient Model 1[a]	Model 2	Model 3[a]
Dependent variable = HP	Dependent variable = lnHP	Dependent variable = lnHP	
CONSTANT	193,483.4551**[a]	12.0630***	12.0630***
	(76,032.7310)	(0.2761).27998739	(0.2861)
AGE	−2,551.707569***	−0.0090***	−0.0090***
	(591.4289)	(0.0028)	(0.0024)
AGESQ	26.4701***	0.0001***	0.0001***
	(4.6311)	(0.00002)	(0.00001)
SQFT	39.9857***	0.0002***	0.0002***
	(15.0506)	(0.0001)	(0.0001)
FF	142.8724	0.0003	0.0003
	(205.5223)	(0.0003)	(0.0004)
DIST	6,001.4391**	0.0046	0.0046
	(2,183.0512)	(0.0075)	(0.0079)
DENS	−8,521.5145**	−0.0270	−0.0270*
	(3,736.8471)	(0.01370)	(0.01267)
TR	4,307.868**	−0.0150**	−0.0150*
	(1,547.0208)	(0.0064)	(0.0073)
MILFOIL	−177,020.9827**	−0.2878*	−0.2878
	(64,239.9760)	(0.1679)	(0.2307)
LKAMIL	69.5668***	0.0002**	0.0002**
	(19.8942)	(0.00004)	(0.0001)
Adjusted R^2	0.67582	0.57618	0.57618
N	144	144	144
Breusch-Pagan chi-squared	556.3340, 9 d.f.	-	26.5185, 9 d.f.

[a]Standard errors corrected for heteroskedasticity

[b]*Coefficient statistically significant at 90% level; **coefficient statistically significant at 95% level; ***coefficient statistically significant at 99 % level.

priate model are inconclusive. The wide range of estimates of losses—from effectively zero to about 40% of property value—demonstrates that further research is sorely needed to refine these damage estimates, as discussed later in the article.

It must be noted that these results are extremely sensitive to model specification and functional form. The size of lake and milfoil presence variables in particular were highly correlated. This may be due to more interlake traffic on larger lakes (as noted previously, milfoil "hitchhikes" on boat hulls as one means of moving from lake to lake), or simply because a larger lake simply has a higher probability of infestation. In any case, the issue of collinearity among these variables makes it difficult to select the most appropriate specification.[6]

[6]Model formulations that included a separate value for lake size (LKA) resulted in effects of milfoil ranging from decline of over 50% of property value (linear model) to about a 22% decline in values in the log-linear form (although the milfoil variable was not significant at the 10% level in this model).

Conclusions and Implications

This study indicates that shoreline property value may drop substantially when milfoil is present in a waterbody. These declines are in the range of 20%–40%, although it could also be argued that some of the models yielded inconclusive results. It is our opinion that this wide range of outcomes results from the two-fold problem of inadequately detailed specification of the milfoil variable and collinearity among the key independent variables.

These results have important implications for prevention strategies and attempts to control existing milfoil in waterbodies. Currently, the perceived cost of remedy or prevention often outweighs the benefit to the individual, resulting in the status quo. Using these findings to educate property owners, those in affected communities will have more incentive to invest in either prevention or control. This may help to slow and/or stop the spread of milfoil in New Hampshire waterbodies and may serve as a useful tool in future control and prevention efforts. One such control program that was formed by the New Hampshire Department of Environmental Services in 1988 is Weed Watchers, a volunteer association that monitors waterbodies for the presence of nonnative aquatic weeds. Evidence of declining property values on waterbodies may provide incentive to more lake property owners to become involved in such volunteer programs.

One way that this type of data could be used would be to compare the discounted value of frontage on infested lakes to those which have not had milfoil introduced. This discounted value could then be compared with the cost of remediation and control to determine the net benefits accruing to the lake/homeowners/local governments from control programs.[7]

A final note on the statistical issues involved in estimating the model is appropriate. As with many hedonic property value models, this model proved to be highly sensitive to how variables were entered and which functional form was used. These vagaries are consistent with past research that notes the difficulty in finding the "right" form for the equation (e.g., Cropper and others 1988, Milon and others 1984, Halstead and others, 1997).

While the model results indicated substantial property value declines due to milfoil, it is not at all clear how accurate these estimates are, primarily due to the crude specification of the MILFOIL variable. Future efforts would benefit by obtaining larger data sets, expanding data sets to include properties close to but not abutting the lake, incorporating other "weed-related" factors, and by better specification of the milfoil variable. Specifically, we would recommend that a detailed study include: the percentage of the lake infested with milfoil at the time of purchase, the timing and success of any recent attempts at eradication/control, the distance from each housing unit sampled to the nearest milfoil colony, and the extent of home buyer knowledge of both the degree of infestation in the lake and the nature of milfoil. While obtaining this information would be quite an undertaking, the problem is compounded by the issue that if milfoil truly is a major depressor of property values, the "worst" properties will also be the most difficult to sell. Thus, the final data set may exclude much important information due to these "missing" observations.

Acknowledgments

The authors would like to thank Ju-Chin Huang and two anonymous reviewers for helpful comments. Thanks also for support from the New Hampshire Department of Environmental Services and Amy Smagula. Any remaining errors are those of the authors.

[7]Thanks to an anonymous reviewer for this suggestion.

References

Bouwes, N. W., and R. Schneider. 1979. Procedures in estimating benefits of water quality change. *American Journal of Agricultural Economics* 61:535–539.

Brown, G. M., and H. Pollakowski. 1977. Economic valuation of shoreline. *Review of Economics and Statistics* 59:272–278.

Boyle, K. P., J. Poor, and L. O. Taylor. 1999. Estimating the demand for protecting freshwater lakes from eutrophication. *American Journal of Agricultural Economics* 81(5):1119–1122.

Cropper, M., L. B. Deck, and K. E. McConnell. 1988. On the choice of functional form for hedonic price functions. *Review of Economics and Statistics* 70(4):668–675.

Epp, D., and K. S. Al-Ani. 1979. The effect of water quality on rural nonfarm residential property values. *American Economic Review* August:529–534.

Freeman, A. 1974. On estimating air pollution control benefits from land value studies. *Journal of Environmental Economics and Management* 9(1):74–83.

Freeman, A. M. 1979. The benefits of environmental improvement: Theory and practice. John Hopkins University Press, Resources for the Future, Baltimore.

Freeman, A. M. 1993. Property value models. Measurement of environmental and resource values. Resources for the Future, Washington DC.

Garrod, G. D., and K. G. Willis. 1992. Valuing goods' characteristics: An application of hedonic price method to environmental attributes. *Journal of Environmental Management* 34:59–76.

Gibbs, J. P., J. M. Halstead, K. J. Boyle, and J. -C. Huang. 2002. An hedonic analysis of the effects of lake water clarity on New Hampshire lakefront properties. *Agricultural and Resource Economics Review* 31(1):39–46.

Graves, P., G. C. Murdoch, M. A. Thayer, and D. Waldman. 1988. The robustness of hedonic price equations: Urban air quality. *Land Economics* 64(3):220–233.

Halstead, J. M., R. A. Bouvier, and B. E. Hansen. 1997. On the issue of functional form choice in hedonic price functions: Further evidence. *Environmental Management* 21(5): 759–765.

Lancaster, K. J. 1966. A new approach to consumer theory. *Journal of Political Economy* 124(2):132–157.

Leggett, C. G., and N. E. Bockstael. 2000. Evidence of the Effects of Water Quality on Residential Land prices. *Journal of Environmental Economics and Management* 39(2):121–144.

McNeely, J. A., K. R. Miller, W. V. Reid, R. A. Mittermeier, and T. B. Werner. 1990. Conserving the world's biological diversity. IUCN, Gland, Switzerland; WRI, CI, WWF-US, and the World Bank, Washington, DC.

Mendelsohn, R. 1984. Estimating the structural equations of implicit markets and household production functions. *Review of Economics and Statistics* 66(4):673–677.

Michael, H. J., K. Boyle, and R. Bouchard. 1996. Water quality affects property prices: A case study of selected Maine lakes. Maine Agricultural and Forest Experiment Station, University of Maine, Miscellaneous Report 398.

Michaels, H. J., K. Boyle, and R. Bouchard. 2000. Does the measurement of environmental quality affect implicit prices estimated from hedonic models?. *Land Economics* 76(2):283–298.

Michaels, G., and V. K. Smith. 1990. Market segmentation and valuing amenities with hedonic models: The case of hazardous waste sites. *Journal of Urban Economics* 28:223–242.

Milon, J. W., J. Gressel, and D. Mulkey. 1984. Hedonic amenity valuation and functional form specification. *Land Economics* 60(4):378–387.

Morse, L. E., J. T. Kartesz, and L. S. Kutner. 1995. Native vascular plants. *In* E. T. LaRoe, G. S. Farris, C. E. Puckett, P. D. Doran, and M. J. Mac (eds), *Our living resources: A report to the nation on the distribution, abundance, and health of US plants, animals, and ecosystems.* US Department of the Interior, National Biological Service, Washington, DC.

Motavalli, J. 2001. Here comes trouble: Facing up to the invasive-species onslaught. Appalachian Mountain Club. *Outdoors* 15

Murdoch, J., and M. Thayer. 1992. Hedonic price estimation of variable urban air quality. *Journal of Environmental Economics* 15(2):143–146.

NH-DES (New Hampshire Department of Environmental Services). 1999. Exotic aquatic weed control program: Chronology of events, 1981–1996. Concord, New Hampshire

NH-DES (New Hampshire Department of Environmental Services). 2000. Weed watcher kit 2000. Concord, New Hampshire.

Nelson, J. P. 1978. Residential choice, hedonic prices, and the demand for urban air quality. *Journal of Urban Economics* 5:357–369.

(OTA) Office of Technology Assessment. 1993. Harmful nonindigenous species in the United States. Office of Technology Assessment, US Congress, Washington, DC.

Pimentel, D. 2002. Biological invasions: Economic and environmental costs of alien plant, animal, and microbe species. CRC Press, New York.

Pimentel, D., L. Lach, R. Zuniga, and D. Morrison. 1999. Environmental and economic costs associated with nonindigenous species in the United States. Cornell University, College of Agriculture and Life Sciences, Ithaca, New York.

Rosen, S. 1974. Hedonic prices and implicit markets: Product differentiation in pure competition. *Journal of Political Economy* 81(1):34–55.

Simberloff, D. 1996. Impacts of introduced species in the United States. *Consequences The Nature and Implications of Environmental Change* 2(2):000

Smith, R. L. 1996. Ecology and field biology. HarperCollins, New York.

Wilman, E. 1984. External costs of coastal beach pollution: An hedonic approach. Resources for the Future, Washington, DC.