Visitor Perceptions and Valuation of Visibility in the Great Gulf Wilderness, New Hampshire

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Abstract—New Hampshire's White Mountain National Forest is well known for its mountain scenery and its diverse outdoor recreational opportunities. Within The Forest are two federally protected Class I wilderness areas, the Great Gulf Wilderness, and the Presidential Dry-River Wilderness. The expansive scenic vistas from these two wilderness areas are commonly impaired by regional haze, largely a byproduct of fossil fuel electric energy production upwind of the region. Consumer choice of electric suppliers, the U.S. Environmental Protection Agency's 1999 regional haze regulations, and other regional emissions reductions programs may work to change visibility in the White Mountain National Forest. This paper characterizes existing visibility conditions in the Great Gulf Wilderness, and outlines the design and preliminary results of an ongoing study of visitor perceptions of visibility. The objective of the study is to understand: a) visibility conditions in the Great Gulf Wilderness, b) the sensitivity of visitors to haze, and c) the economic value of potential visibility changes to visitors.

The Appalachian Mountain Club (AMC) and the White Mountain National Forest (WMNF) have jointly examined regional haze-related visibility impairment and its causes in New Hampshire's Great Gulf Wilderness for over a decade (Hill and others 1996). The Great Gulf Wilderness, located in northern New Hampshire (fig. 1), is one of two federally protected Class I airsheds in the White Mountain National Forest, and one of only seven in the Northeast. The Wilderness lies just north of the summit of Mount Washington, the highest peak in New England (6,288 feet). The approximate quarter-million visitors to the summit of Mount Washington travel by car, mountain train or by foot to see the breathtaking views. Approximately seven million visitor days are logged in the White Mountains annually. On a perfectly clear day, one can see West across the state of Vermont to the Adirondack Mountains in New York State—130 miles distant or east to the Atlantic Ocean. However, on very hazy days, nearby peaks become indistinct, and the scenic vistas from the summit lose clarity, color and contrast. Under these conditions, the closest towns, approximately 7-17 miles distant, may disappear into the haze altogether, seriously degrading the quality of the wilderness experience for some visitors.

In the eastern United States, the annual mean visibility is estimated at 18-40 miles (EPA 1997). Visual range in New England's Class I airsheds (measured in Acadia National Park, ME, Lye Brook Wilderness, VT, Great Gulf Wilderness, NH) is generally about 35 miles compared to about 20 miles in the mid-Atlantic and southern United States (EPA 1998). The poorest mean annual visibility for Class I areas in the United States is 18 miles, recorded in Shenandoah National Park (VA), Mammoth Cave National Park (KY) and Great Smoky Mountains National Park (NC, TN).

As compared to estimated natural conditions, the visibility in the entire Eastern United States is significantly

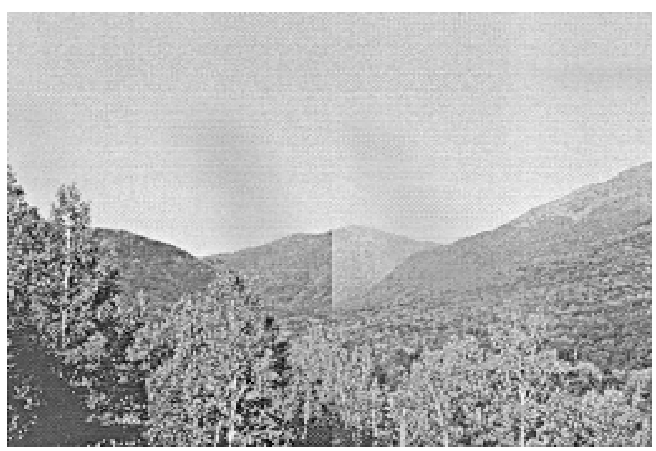

Figure 1—Visibility image, Great Gulf Wilderness as if viewed from visibility camera location at Camp Dodge, Pinkham Notch, NH. Image produced using WinHaze 2.7.0 (Air Quality Specialists Inc.) Image represents natural visibility juxtaposed with the 80th percentile summer time visibility value.

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impaired. One estimate of median natural visibility is given by Trijonis (1982), 60 miles plus or minus 30 miles. EPA (1998) estimates mean natural visibility to be about 80-90 miles, which takes into account natural organic haze in the Southeast. In New England, due to less stagnant atmospheric conditions, average natural visibility may be higher, in the range of 90-120 miles. Thus, comparing current visibility with estimated natural average visibility, current visual range is about one quarter to third of estimated natural visual range in the eastern United States. In addition, current trends in visibility conditions on the haziest days at many eastern Class I airsheds suggest little or no improvement in visibility (Sisler and Damburg 1997) despite national reductions in sulfur dioxide emissions, from 23.2 million tons in 1988 to 20.4 million tons in 1997, as reported by EPA (1998).

Typically, visitors come to the White Mountains of New Hampshire from the Boston, New York and Montreal metropolitan areas for respite from the urban life. Visitors to these areas reasonably expect fresh clean air and crystal clear vistas. In reality, however, some days are as smoggy as the urban areas from which they came. In a three year study of hikers to the summit of Mount Washington, AMC, Harvard School of Public Health, and Brigham and Women's Hospital demonstrated measurable reductions in short-term lung function at levels well below the national ambient air quality standards (Korrick and others 1998). From an early unpublished study of hiker's response to photographs of visibility conditions (Kimball, unpublished data, 1989) it was apparent that the same smog that affects hiker health could further diminish the quality of the wilderness experience, resulting from haze-impaired vistas. This paper focuses on our investigations into regional haze in the Great Gulf Wilderness, its potential effects on visitors and how visitors value visibility in the wilderness area.

To understand how people perceive visual air quality in a wilderness area, the AMC piloted its study in the Great Gulf Wilderness in 1996 based on the Denver visibility study (Ely 1991). The objective of the study was to determine: a) if people could distinguish between a continuum of hazy and clear vistas, b) the acceptability of haze to visitors to a wilderness area, and c) whether people may be willing to pay for cleaner air in these areas. The study was joined and broadened in 1997 by University of New Hampshire and University of Massachusetts economists interested in how visitors and people off-site value visibility in the Great Gulf Wilderness (Porras 1999). The following briefly describes: a) research on the causes of visibility impairment in the Great Gulf Wilderness and b) the design and preliminary results of a wilderness visibility perception/valuation study.

Characterizing Visibility Impairment and Its Causes in the Great Gulf Wilderness, 1988-1998

Section 169 of the Clean Air Act requires federal land managers to protect federal wilderness areas, national parks and national wildlife refuges, designated as Class I, from visibility impairment. As a part of this obligation, a visibility monitoring program was established in the Great Gulf Wilderness in 1985 by the White Mountain National Forest. A camera designed to assess visibility conditions was installed near the Great Gulf Wilderness in 1985 which was subsequently supplemented with AMC air quality monitoring in 1988 under a partnership with the White Mountain National Forest to characterize visual air quality conditions. The AMC's monitoring program and results are briefly outlined below as a context for understanding the preliminary results and significance of the visibility survey.

Visibility Monitoring Methods

The Great Gulf Wilderness monitoring site is located at Camp Dodge in Pinkham Notch, New Hampshire. The site is located in an active AMC volunteer trails management facility adjacent to the Great Gulf Wilderness, a glaciated valley surrounded by the steep headwalls and ravines of the Northern Presidential Range (fig. 2).

From its installation by WMNF in 1985 until its elimination in 1997, the visibility camera was automated to take three daily photographs (at 9:00 AM, noon and 3:00 PM) of the visibility scene "target," Mount Jefferson (5,712 feet). Mount Jefferson is situated along the western border of the Great Gulf wilderness approximately 4.4 miles from the camera. The photographic monitoring was undertaken typically from mid-May until late September/early October. For each of the visibility photographs, systematic estimates of standard visual range (SVR), an empirical measure of visibility generally expressed in kilometers, were

Figure 2—Location map showing AMC and cooperators' four air quality monitoring sites in northern New Hampshire (Pittsburg site: ozone; Camp Dodge site: PM2.5, ozone and full IMPROVE; Mount Washington site: ozone; Lakes of the Clouds site: PM2.5, acid precipitation).

determined using a scanning densitometer (NRC 1993). In 1997 the camera measurements were superceded by a nephelometer (a continuous electronic visibility measurement device based on light scattering).

To determine the causes of visibility impairment, particularly the relationship between visual range and particulate matter aerosols in the Great Gulf, a fine particle monitor ($PM_{2.5}$) was colocated with the visibility camera at Camp Dodge in 1988. Further, in order to explore high elevation air quality conditions a high-elevation fine particle monitor was sited in at the AMC's Lakes of the Clouds Hut in 1990 at 5,050 feet elevation on Mount Washington. From 1988 until 1997, AMC acquired fine particle ($PM_{2.5}$) samples from mid-June through August. Samples were typically collected from 7 AM to 5 PM daily (fewer samples in the first few years of operation)—during the daytime hours when visitors are typically hiking or sightseeing. In 1998, daily, consecutive 24-hour sampling replaced 10-hour daytime sampling in the program following the fine particulate matter monitoring protocol introduced as part of the 1997 $PM_{2.5}$ air quality standards. Fine particle measurements at Camp Dodge use a the Harvard/Turner Impactor (HI) to fractionate the sample, effectively removing all particles larger than 2.5 microns in diameter but collecting the fine particles, less than 2.5 microns, on a pre-weighed Teflo filter inside the HI monitor. Mass per unit volume of air for each filter (in micrograms per cubic meter of air —ug/m^3) were subsequently determined from: 1) the measurement of fine particle mass on a filter, and 2) the measured volume of air pumped across the filter. Following these gravimetric analyses, sulfate mass, aerosol acidity and ammonium concentration (degree of neutralization) were measured from the same filters.

In 1996 WMNF added a full IMPROVE (Interagency Monitoring for Impaired Visual Environments) monitoring site at Camp Dodge. IMPROVE protocol includes coarse and fine particle monitors (PM_{10} and $PM_{2.5}$), and an Optek nephelometer (a visibility monitor that continuously measures light caused by scattering and absorption of particles and gases). In addition to the fine particle and visibility monitoring, AMC and WMNF conduct tropospheric ozone monitoring at the same site.

Visibility Monitoring Results

Figure 3 shows the distribution of daily summer visibility measurements from 1988-1996. These data represent visibility measurements from both photographic and electronic (nephelometer) methods when $PM_{2.5}$ was monitored in that 9 year period (369 days). Note that this does not represent all of the days visibility was monitored—only the days when fine particles measurements are available— and therefore these data only represent the approximate conditions in the wilderness area during the summer months. For these days, the median summertime daily visibility was 15 deciviews (87 km/54 mi.), with a maximum (poorest visibility) of 39 deciviews (8 km/5 mi.).

1988-1998 $PM_{2.5}$ data is summarized in figure 4. For simplicity this box plot combines 10-hour daytime sample data from 1988-1997 with the 24 hour sample data acquired beginning in 1998. Based on these data, $PM_{2.5}$ concentrations in the Wilderness have been measured as high as 86 micrograms per cubic meter of air over 10 hours (86 ug/m^3) in comparison to the 24-hour national standard of 65 ug/m^3. The approximate summer mean for continuous $PM_{2.5}$ monitoring ranges from 9.5-15.0 ug/m^3 (Hill and others 1996) as compared to mean 1996 summer conditions in Boston of 14.4 ug/m^3 (Unpublished data, courtesy Harvard School of Public Health, Boston Edison). Chemical analyses suggest that the dominant particle phase in the fine mass is the partially neutralized form of sulfate, ammonium bisulfate (Hill and others 1996).

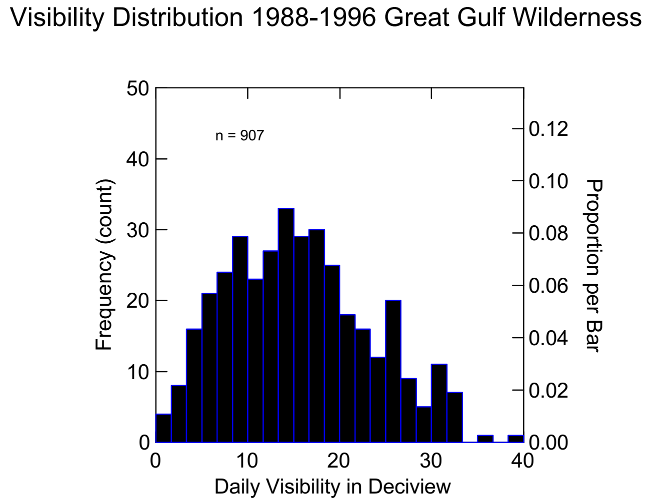

Figure 3—Distribution of average daily visibility measurements 1988-1996.

Figure 5 is a plot of $PM_{2.5}$ versus visibility, where visibility is measured in deciview (for explanation of deciview scale see figure 5 caption). The graph shows a clear cause and effect relationship between the dependant variable, visibility, and the independent variable $PM_{2.5}$. Moreover, the relationship has a positive slope which demonstrates that an increase in fine particulate matter is accompanied by a systematic, although somewhat non-linear, decrease in perceived visibility in the Great Gulf Wilderness (note that changes in deciview of 1-2 increments are approximately "just noticeable" and that the deciview scale is linear to human perception). Correlations between visibility and sulfate also show an even stronger predictable relationship between sulfate compounds in the Great Gulf Wilderness (Hill and others 1996) To summarize, average visibility in the Great Gulf Wilderness is approximately one third of estimated natural conditions, impaired by anthropogenic aerosol particles, which, in turn, are dominated by hygroscopic (moisture-absorbing) sulfate compounds.

Visibility Perception Study: Acceptability Survey

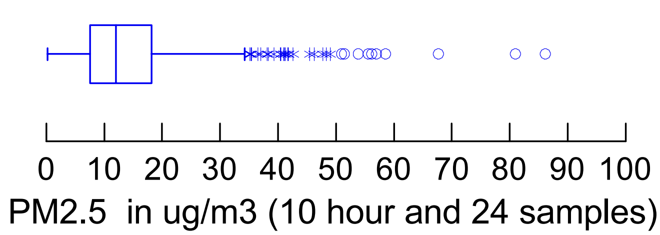

Figure 4—Distribution of PM2.5 Concentrations, Great Gulf Wilderness 1988-1998, combining daytime 10 hour and 24 hour samples.

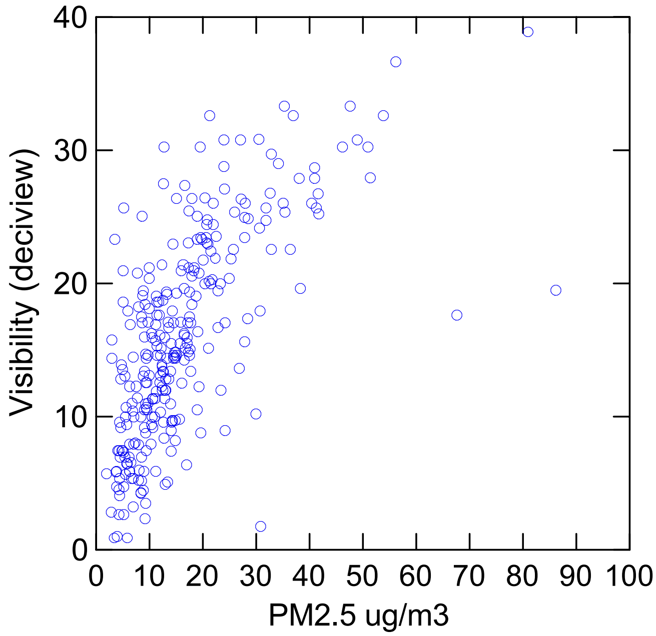

Figure 5—Relationship of visibility in deciview to fine particle mass, Great Gulf Wilderness. For reference, deciview (dv)= 10 ln (bext/0.01 km-1) where bext is the coefficient of light scattering expressed in inverse kilometers (Pitchford and Malm, 1994). (For example, 0 dv = 391 km, 10 dv = 144 km = 53 km , 30 dv = 19 km, 40 dv = 7 km.)

In the 1977 amendments to the Clean Air Act, Congress established a goal of remedying visibility impairment in wilderness areas, national parks and national wildlife refuges federally designated as "Class I." Yet little action was taken in meeting this goal in the first two decades after the goal was established. However, in April 1999, the U.S. Environmental Protection Agency promulgated the "regional haze rule" establishing a flexible timeline for states to implement programs to bring visual air quality in Class I areas back to natural conditions in 60 years. Anticipating the development of these recently published rules in 1995, the AMC designed a pilot visibility perception survey to investigate visitor awareness of haze using photographs of a range of visibility conditions in the Great Gulf Wilderness. If meaningful, the White Mountain National Forest, land manager for the Great Gulf and Presidential Dry River Wilderness areas, could use the results of the survey as guidance in establishing visibility as an "air quality related value" (AQRV). AQRVs are resources sensitive or in some way related to air quality conditions in a Class I airshed. As an AQRV, a threshold of "unacceptable" visibility could be established to screen, for recommended approval or denial, permit applications for new and modified smokestacks in the vicinity of the wilderness areas. As an analogy, ozone and acid deposition are current AQRVs in the Great Gulf Wilderness with established limits called "red line values" (which effectively operate as ozone and acid deposition standards). Exceeding an established AQRV "red line" value, permits for new and modified plants emitting pollutants that cause haze could be recommended for denial by the federal land manager. This study could help determine at what point the red line value might be set.

Visibility Survey Methods

To investigate the sensitivity of visitors to these protected areas, the AMC embarked on a pilot study in 1996 to see if visitors could consistently rate and rank changes in visual air quality. The study was continued with largely the same protocol in 1997 and then modified into a digital format in 1998. The 1996 pilot study was designed to determine by survey:

1) if forest visitors could consistently distinguish, rate and rank photographs of a spectrum of visibility conditions, and
2) if respondents perceived visual range as "unacceptable" at some consistent value when viewing clear to haze-obscured vistas of Mount Jefferson in the Great Gulf Wilderness.

The survey was initially designed after the Denver Visibility Study (Ely and others 1991). In our pilot field study (Harper and others 1997), visitors viewed a suite of 23 photographs of the wilderness scene. They were told that they were participating in a study of "how people perceive visibility conditions in wilderness areas" and that "the photographs in the binder represent a range of conditions in the Great Gulf Wilderness." In addition, participants were advised that "your responses will be used to develop visibility standards in wilderness areas and to assess the economic impact of visibility changes in the area." Participants were asked to "decide if the amount of haze depicted in the photograph would be acceptable or unacceptable under your standard."

The 5 x 7 images of the Great Gulf Wilderness scene were printed, with careful control of contrast, from visibility slides obtained from the White Mountain National Forest. Images were viewed individually by flipping through individual photos mounted on a white background over so that side-by-side was not possible. They were, however, allowed to flip back through. First, as a warm up, participants in the survey rated 5 photos, representing the range of visibility conditions in the following section of the survey, on a scale of 1-5 (where 1 is clear and 5 is most hazy). In the second section of the survey, participants rated a series of 23 photographs on the same scale. Finally, participants were asked to go back through the same suite of 23 photos, and rate each as either "acceptable" or "unacceptable."

The survey was conducted at three sites. The primary site, using a trained interviewer, was located at the Tuckerman Ravine trailhead to the summit of Mount Washington at the AMC's Pinkham Notch Visitor Center, one of the busiest trails in the White Mountain National Forest which logs over 7 million visitor days per year. Mount Washington provided an ideal location for the study because of its near proximity of the wilderness area; the summit is located less than 1 mile north of the Presidential-Dry River Class I Wilderness and about 0.25 mile south of the Great Gulf Wilderness area. A second self-service survey location was established at the summit of Mount Washington in the Mount Washington Observatory. Surveys collected at the summit self-service site presumably represented a broader demographic group, from sightseers that rode up to the summit in cars, trains and on foot. The third site was located at AMC's Cardigan Lodge, the trailhead of a popular hike to the bald summit of Mt. Cardigan in central New Hampshire. These surveys were collected both by staff and as self-service surveys when staff were unavailable at this fairly remote location. In total, approximately 300 useable, valid surveys were collected in the 1996 pilot from the three survey sites. A parallel study was undertaken in 1999 by Porras (1999, unpublished Master's thesis, University of Massachusetts) to examine off-site responses in Amherst Massachusetts, using virtually the same survey design and using the Great Gulf images, as described below.

The design of the survey included pairs of cloudy and cloud-free photos, at the same visibility/visual range levels to estimate the effect of clouds in confounding the perceptions of views. We concluded from the survey results that cloudy images were consistently rated as less acceptable. For example, one pair of photos with the same visibility, one cloudy and one clear at the 44 km visibility level, were tested. On the 1-5 scale, the clear image garnered a mean rating of 2.9 (rated clearer) while the cloudy photo (but with same visibility/visual range) received a mean rating of 4.0 (rated hazier), significant at the 95 percent confidence level. Moreover, the cloudy photograph received a rating of "acceptable" from 15 percent of the respondents, and the cloud-free (clear) photo was acceptable to 71 percent of the respondents. Therefore, subsequently, in the 1997 and 1998 surveys, cloudy images were eliminated to remove the observed bias. Interestingly, this result suggests that natural sky conditions (clouds) may have a negative impact of a viewer's overall rating of a scene as well as uniform haze does. By analogy, this result also raises the question of whether respondents make decisions based on health impacts unconsciously when viewing hazy scenes although we have clearly informed them that the goal of the study was to understand "how people perceive visibility conditions in wilderness areas."

One of the first questions to address was whether respondents could distinguish between photos representing a variety of visibility conditions and then secondly, whether they could accurately rate them, placing them indirectly in order of visual range. Using cloud-free images, 34 percent of participants ranked the images in the correct order, 63 percent ranked all but one image accurately and 88 percent correctly ranked all but two images. In addition, duplicate photographs were also used to assess the precision of the method in the first survey. Three sets of duplicate photos in the series of 23 photographs garnered similar ratings, leading us to conclude that the precision or repeatability of the method was good. Therefore, we conclude that viewers could consistently distinguish between, and accurately rank, photographic images of visibility based on the Great Gulf Wilderness/Mount Jefferson scene. As the Great Gulf scene is characterized by a short viewer to scene distance, this result suggests that, given a longer sight path to the horizon, viewers might be sensitive to smaller decrements in visibility.

In 1998, the survey was redesigned with computer modeled images using the WinHaze Visual Air Quality Modeler (Air Resource Specialists, Fort Collins, Colorado). This allowed us to generate a clear to hazy continuum of cloud-free visibility images of the Great Gulf Wilderness. Also in 1998, automated data collection by embedding scene images in a Microsoft Access database program and by subsequently collecting data using a laptop computer in the field, eliminating paper surveys and photographs.

Results

In general, the study in progress confirms the expected relationship between visibility and perception: As visibility decreases acceptability decreases. 1998 results indicate that half of all respondents (the median) found a visibility of about 20 deciviews (53 km or 33 mi.) or greater, unacceptable for the Great Gulf/Mount Jefferson vista (fig. 6). As noted above, the scene depth of the Mount Jefferson vista, approximately 5 miles is a comparatively short range with respect to many other visibility monitoring sites in Class I areas. This may introduce a bias into the acceptability results, since the image may not represent the distant features which become obscured sooner. In other words, in a scene with greater distance to the scene target being viewed, distant ridgelines would disappear into the haze before haze may even be noticeable in a scene with a shorter distance to the viewing target. This would have the effect of shifting the unacceptability threshold to a greater visual range. From the Great Gulf Wilderness results we have learned that given a short range from viewer to scene, visitors can clearly distinguish between and rank images of a variety of visual air quality conditions. However, to further test the sensitivity of the acceptability question to the scene depth, location and visitor demographics, we are considering a control study at one or more eastern national parks, such as Acadia National Park in Maine, for summer 2000. The objective of the Acadia study would be to see how the longer distance/greater depth in the scene from Cadillac Mountain's summit (12 miles to Blue Hill, the target, and further depth beyond) may affect the acceptability relationship derived from perceptions of the Great Gulf image. Moreover, the visitor demographics in a National Park may be quite different.

Valuation of Visibility in the Great Gulf Wilderness

Methods

Economists have long been interested in placing a value on goods that are not traded in a market setting (see for example, Mitchell and Carson 1989; Cummings Brookshire and Schulze 1986). Examples of such goods include environmental amenities such as clean air and water. In order to make informed policy decisions it is often important to understand the economic value that individuals place on environmental goods. There are two methods used by economists to value these goods, revealed preference and stated preference. Stated preference methods are survey-based and involve asking individuals directly how they value an environmental good (Boxall and others 1996). The most commonly used stated preference method is the contingent valuation method. This method asks respondents directly about their willingness to pay or willingness to accept compensation for a given change in an environmental amenity. Revealed preference methods use observations of mar-

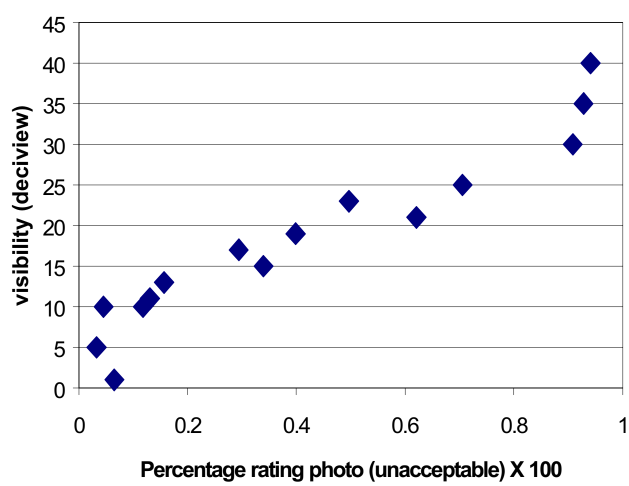

Figure 6—Percentage of respondents to visibility survey rating the Great Gulf scene unacceptable at a given visibility level in deciview.

ket behavior to infer the value that individuals place on environmental goods. For example, we might look at how much individuals will pay to travel to an environmental amenity, or we might examine differences in housing prices to infer the value of proximity to an environmental amenity. The study discussed here uses stated preference methods. While there are advantages to both methods, in this case the stated preference is the most appropriate.

The idea of a stated preference methodology was first proposed by an economist in the 1940s, however it was not put into practice until the mid 1960s with a study of hunters in the Maine woods. (Hunters were asked about the value of their experience, and their answers were then compared with values obtained from a revealed preference methodology.) Improvements on this technique have continued to be made since the mid-1970s. Many studies have focused in on clean air (for example, Brookshire and others 1985). A majority of these studies focused on vistas in the southwestern United States, primarily the Grand Canyon. In these studies, visitors and non-visitors alike were asked to state their willingness to pay to either avoid further visibility degradation or willingness to accept compensation if visibility worsened. In the willingness to pay scenarios, respondents would state their willingness to pay an increased admission fee, contribute to a special fund or pay a higher monthly electric utility bill.

In the current study, we attempt not only to value a change in the visual range, but also to compare two types of stated preference methods. These methods are the contingent valuation method (CVM), which is described above and conjoint analysis (CA). Conjoint analysis has been used widely in marketing research to determine how individuals value different attributes of a good (e.g. Green and Srinivasan, 1990). It has only recently been introduced in the environmental economics literature and this is the first study which has compared conjoint analysis and CVM to examine air quality. The conjoint method asks respondents to rate rather than directly price changes in an environmental amenity; However, the method also allows for the calculation of consumer surplus estimates comparable to the CVM (e.g. Stevens, Barrett and Willis 1997; Mackenzie 1993; Roe and Teisl 1996). In comparing these two methods we hope to gain insight into the individuals decision making process and continue to make progress in improving and refining stated preference methods.

The survey was administered during the summer of 1998 at the Pinkham Notch Visitor center in New Hampshire. Respondents were approached and asked to complete a visual image-based survey. In addition to soliciting information on how visitors value changes in the visual range, this survey collected information on respondents' perception of visual conditions as well as travel and demographic data. Both valuation questions asked respondents to make a trade off between a reduction in their monthly electric bill and degraded visibility. In the CVM question, respondents were asked if they would accept degraded visibility in exchange for a reduction in their monthly electric bill. In the CA question, they were presented two scenarios and asked to rate the two individually. Scenario A was a "status quo" scenario and Scenario B had worsened visibility and a lowered monthly electric bill. In thinking about the format of the question, it was decided that the individual should be assigned the property rights to the clean air, thus giving them the right to exchange that clean air for some monetary compensation; thus the choice of the willingness to accept wording. Also of note is the use of the payment vehicle of an electric bill. A change in electric bill has been employed in earlier visibility studies and had several advantages over other commonly used payment vehicles. Further, with electric utility deregulation upcoming in the New England states, the use of this payment vehicle seemed to be the most realistic.

Results

Under both methods, the preliminary analysis of the data suggest that only 20% of the respondents were willing to accept a lower electric bill if it would result in hazier air. This indicates that respondents' value changes in the visual range more highly than our compensating offer. Econometric analysis was unable to explain the behavior of the respondents in any satisfactory way. There are several possible reasons for our inability to successfully capture respondents' value of a change in the visual range. One possible reason could be sample bias. As stated earlier, the survey was conducted at a major trailhead/ visitor center in the White Mountain National Forest. Simply by their presence at this location we can infer that the respondents will have a high valuation for visibility. It is possible that this particular group is not willing to make a trade-off regarding a change in visibility. A second (and related) possible explanation is limitations within the payment vehicle. The electric bill makes up at the maximum 5.8% of a respondent's income, and on average 3.3%. By limiting the realistic amount we can offer in means of compensation, we may simply not be able to offer a sufficient reduction to induce respondents to make this trade off.

A parallel off-site control study supporting these results was completed by Porras (1999, unpublished Master's thesis, University of Massachusetts) employing both personal and mail-in survey methods, similar questions and the same Great Gulf image created using the WinHaze Visual Air Quality Modeler (Air Resource Specialists, Fort Collins, Colorado). Results show that respondents in the parallel study were also able to rate and rank the images consistently. Visual ranges of 36 miles or less were unacceptable to half or more of the respondents. Based on a total of 60 personally acquired survey observations, using the CVM (contingent method), the off-site study indicated that the average electric bill reduction offer of 20 percent (average $11.16) was insufficient to compensate most (80 percent) of the participants for the reduction in visibility in the White Mountains from 90 miles (cleaner end of annual median summer visibility) to 20 miles (approx. 90th percentile haziest condition, and deemed by most viewers as "unacceptable"). Results were similar using the CA (conjoint) method indicating that respondents could rank the images accurately, that acceptability decreases with increasing haziness and that a threshold level can be determined using this method. Based on the CA method, visual ranges of 50 miles or less are unacceptable to more than half of the viewers of the Great Gulf Wilderness image.

The mail-in survey results, (1,000 sent, 106 CVM, 106 CA= 212 responses) indicated that for an average reduction of visibility to 12 miles (the "viewed" average of 4 images used at 30, 20, 7.3, 4.4 miles), 23 percent of the respondents would accept a 35 percent decrease in their electric bill (average $45.40 reduction) using the CVM method. Using the CA method, the average rating of 3 (where 1 is unacceptable and 10 is acceptable) suggests that respondents would not be willing to accept similarly degraded visibility regardless of the 35 percent reduction in their electric bill (average $25.50 reduction). Eighty-seven percent of the respondents were planning to visit the White Mountains in the future, but if visibility conditions worsened, 64 percent of the CVM respondents stated that they would be less likely to visit, while 36 percent would not change their plans. Similarly for the CA respondents, 68 percent of the 72 percent that said they were planning a visit to the White Mountains would be less likely to visit if conditions worsened.

Future Work

Visibility monitoring and human perception and econometric research was continued in summer 1999 utilizing the computer-aided survey method for the Great Gulf Wilderness. Daily $PM_{2.5}$ and visibility monitoring was continued at both high and lower elevation sites on Mount Washington by AMC and WMNF (IMPROVE). The Great Gulf IMPROVE site is slated to be upgraded to an enhanced site and full annual operation in the near future. Sensitivity to survey question wording may be tested in future surveys (for example, testing willingness to accept versus willingness to pay). Additional data is necessary to make the results more robust. To examine potential differences in response with a different scene image and visitor demographics, a pilot project in Acadia National Park and other locations is under consideration for summer 2000.

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