Experimental and Archaeological Verification of an Index of Retouch for Hafted Bifaces

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The relative amount of retouch on stone tools is central to many archaeological studies linking stone tool assemblages to broader issues of human social and economic land-use strategies. Unfortunately, most retouch measures deal with flake and blade tools and few (if any) have been developed for hafted bifaces and projectile points. This paper introduces a new index for measuring and comparing amount of retouch on hafted bifaces and projectile points that can be applied regardless of size or typological variance. The retouch index is assessed initially with an experimental data set of hafted bifaces that were dulled and resharpened on five occasions. The retouch index is then applied to a hafted biface assemblage made from tool stone that has been sourced by X-Ray Fluorescence (XRF). Results of both assessments show that the hafted biface retouch index (HRI) is effective for determining the amount of retouch and the degree to which the hafted bifaces have been curared.

In the 1970s, Lewis Binford (1973, 1979) introduced the concept of lithic curation in the context of human organization of foraging societies. This concept soon became embedded in what has come to be known as lithic technological organization. Lithic technological organization may be defined as technological strategies that weigh social and economic concerns with respect to environmental conditions (Nelson 1991). Central to this concept is the manner in which lithic tools are designed, reduced, resharpened, recycled, and discarded within foraging life and land-use practices. Following Shott’s (1996) argument, use life of a tool may be defined as simply the service life of a tool, which may or may not be reflected in tool resharpening and reduction characteristics. Tool curation, on the other hand, should be a measure of the relationship between realized and maximum potential tool utility. As such, the degree to which a tool has been re-used via resharpening and reconfiguration may be an expression of the degree to which it has been curared.

Archaeologists from all parts of the globe have recognized the importance of lithic tool curation within this context (Andrefsky 1994; Bamforth 1986; Bettinger 1991; Bleed 1986; Binford 1980, Carr 1994; Kelly 1992; Hiscock and Attenbrow 2003; Rolland and Dibble 1990). Several archaeologists have argued that lithic tool curation can be effectively assessed by measuring the amount of tool retouch or resharpening that has taken place (Blades 2003; Clarkson 2002; Kuhn 1994; Shott 1989; Weedman 2002). I agree that such measures are useful in linking the concept of tool curation.
with human organizational strategies. Unfortunately, most techniques used to measure retouch and tool curation have been developed for flake tools such as scrapers and very few have been developed to measure retouch on bifaces, and even fewer have been developed to measure retouch on hafted bifaces and projectile points.

Some of the early attempts at measuring retouch include Wilmsen's (1970) estimate of retouch based on length of tool, and Barton's (1988) estimate of retouch measuring the length of retouched tool edges. Both techniques are effective measures of retouch on specific tool types, but are influenced by overall tool size, making them difficult to use on diverse tool forms. Several researchers have attempted to account for the effect of tool size by estimating the original blank size of the tool and comparing that estimate to the recovered specimen. Such estimates have looked at the allometric relationship(s) among blank attributes such as platform dimension, weight, width, and thickness to determine the original blank size (Blades 2003; Davis and Shea 1998; Dibble 1997; Dibble and Pelcin 1995; Eren et al. 2005; Shott et al. 2000). Other measures of tool retouch include Shott's (1989) and Morrow's (1997) edge angle to tool linear dimension ratios for scraper retouch. Kuhn's (1990) geometric index using height of retouch and blank thickness has been shown to be particularly effective for assessing retouch on side scrapers (Hiscock and Clarkson 2005). All of these techniques deal with measurement of retouch amount on flake or blade tools.

Clarkson (2002) recently developed a promising technique for measuring retouch on unifacial and bifacial tools. Like the other retouch measures, Clarkson's "index of invasiveness" assumes the tool begins its use life as an unmodified flake, and gradually as the tool undergoes use it also undergoes resharpening and retouching. The measure is based upon the relative proportion and size of flake scars to the unflaked surface of the tool blank. A tool with two completely flaked surfaces would have the highest retouch value and a tool with no flakes removed from its surface would have the lowest retouch value. This is an excellent measure for tools that begin their use life with little or no chipping before they are ready for use. I suggest that we cannot use retouch indices on hafted bifaces that are designed around assumptions of little or no chipping before they are used to perform various tasks. Instead, I propose that we look at retouch measures that are specifically developed for hafted bifacial tools. Hafted bifacial tools have a production and curation cycle different than those of unmodified or slightly modified flake or blank tools.

In this paper I introduce and assess a new technique to measure retouch on hafted bifaces and projectile points. I first review some literature related to hafted biface use life to establish a context for some of the assumptions of the new procedure. The measurement technique is next described and discussed. Experimental replication data on hafted biface use and resharpening are then introduced to evaluate the technique. Finally the technique is applied to an excavated assemblage of hafted bifaces to assess its effectiveness at measuring retouch amount.

The Unique Use Life of Hafted Bifaces

Unlike many other kinds of lithic tools that undergo retouching during the course of use, hafted bifaces have a complex production cycle followed by a use cycle. Hafted bifaces are defined as lithic tools that have been extensively modified by chipping and have two sides or faces that meet to form a single edge that circumscribes the entire specimen. Both faces show evidence of previous flake removals, and some portion of the tool was bound or attached to a handle or haft (Andrefsky 2005). These tools have been called projectile points, arrow heads, spear tips, daggers, bifacial knives, and a number of other names. Most hafted bifaces are produced as a result of multiple steps or stages of production (Andrefsky 2005; Callahan 1979; Whittaker 1994), or production may be viewed as a continuous sequence without discrete steps or stages. In either case the production process ends when the specimen is hafted onto a handle or foreshaft of some type. The hafting process often results in the notching of the specimen to facilitate hafting. As such, hafted bifaces contain a haft element and a bit or blade element and are easily recognized when they are notched. Some hafted bifaces (such as lanceolate forms) do not undergo notching but can be recognized because their haft element is often ground
or dulled to facilitate a wrap or lashing. Haft elements are also sometimes discriminated from blade elements because the blade is resharpened or reshaped in use or through accidental breakage, whereas the haft element undergoes no resharpening (Andrefsky 1997; Flenniken and Wilke 1989; Goodyear 1974; Truncer 1990). This dichotomy results from resharpening the biface while it is hafted. One important aspect of the blade element for these kinds of tools is that the blade begins its use life after being hafted, and hence, the curation cycle for the blade element begins upon initiation of its use life.

Traditionally hafted bifaces have been assumed to function as tips or armatures for projectiles and thrusting lances. However, it is now apparent the hafted bifaces were also effective also as cutting and sawing tools. Ahler's (1971) early functional study of hafted bifaces at Rodgers Shelter revealed that they were used for cutting. Other analyses showed that hafted bifaces performed many tasks in addition to use as piercing tips (Andrefsky 1997; Greiser 1977; Nance 1971). In a recent paper Marvin Kay (1996), using microwear analysis, demonstrated that an early North American lanceolate biface form was hafted, used as a projectile, and also used as a cutting tool interchangeably. Using breakage pattern analysis, Truncer (1990) found that Perkiomen points from the eastern U.S. were likewise multifunctional, used as either projectiles and/or cutting tools. Robert Kelly's novel paper (1988) introduced hafted bifaces as potential sources of raw material for foragers on the move. Not only could hafted bifaces be used as cutting tools or as projectile tips, but they could also be used as cores or sources of raw material if a sharp flake is needed for a particular task. Indeed, hafted bifaces have the potential to accommodate a diversity of needs and tasks. A large side-notched biface hafted to a tapering wooden handle could easily be inserted as a fore shaft into a spear propelled by a throwing board. This same side-notched point could be held in the hand with the fore shaft used as knife handle to saw wood, cut leather, or butcher game. An examination of almost any assemblage of hafted bifaces will show that the blade elements are not necessarily uniform. One side of the blade will often be longer or shorter than the other, or one edge will have a more acute edge angle than the other, or there will be differential evidence of use, dulling, or damage from one side to the next. Irregularities from a bilaterally symmetrical shape can be a clue in assessing the varied use of each tool (e.g., Nowell et al. 2003).

Simple flake tools provide valuable service as cutting and scraping implements, often with little or no retouch (Shott and Sillitoe 2005). As the flake tool edge becomes dull it can be resharpened by the removal of chips from the dulled area. The more a flake tool is used and subsequently retouched the greater the amount of visible resharpening either in the form of total length of edge resharpening (Barton 1988) or total surface area with flakes removed (Clarkson 2002). Hafted bifaces differ in this regard because they begin as tools with extensive flake removals from both surfaces. Retouching of hafted bifaces cannot be simply measured by the amount of edge containing flake removals or the amount of surface being flaked, since by definition hafted biface edges and surfaces are completely flaked. However, it is possible to discriminate between the kinds of chipping evident on hafted biface surfaces and the relative locations of chipping to assess amounts of retouching. For instance, hafted bifaces tend to undergo resharpening on the blade element and not the haft element. As such, we would expect to witness differences between the blade and haft elements during the resharpening process (Hoffman 1985). Additionally, dull edges on hafted bifaces can be resharpened and obliterated fairly easily by the removal of small chips along the dulled edges. This often results in a recognizable "retouch" pattern of flakes over the original chipped surface. The location and type of chipping can be used to assess amount of retouch on hafted bifaces.

**Hafted Biface Retouch Index**

The hafted biface retouch index (HRI) is introduced here as a measure of the extent to which a projectile point or hafted biface has been resharpened or reconfigured. It is assumed that such resharpening or retouching of the hafted biface is an effort on the part of the tool maker/user to realize additional use from the tool. Hence, the HRI may be viewed as a measure of tool curation. This technique computes the overall amount of retouch along the lateral edges of the blade element on hafted bifaces. In this case retouch is defined as sec-
ondary chipping along the edge that is found over the original or previous flake scars. In most cases secondary retouch is applied to the cutting edge in an effort to straighten the cutting surface or to renew the dulled margins. Retouching the cutting edge is a subtractive technique that produces flake scars over the original bifacial blade element surface.

The hafted bifacial retouch index is measured by first applying a piece of masking tape or some other cover to separate the haft element area from the blade element. The blade and haft element locations for a series of different hafted biface styles may be found in Andrefsky (2005:183–185). The haft element is not included in the HRI calculation. The hafted biface is next placed on a sheet of graph paper and the blade element is partitioned into eight segments (four on each side of the bifacial midline). The graph paper can be easily marked to help segregate the four segments of the specimen. Figure 1 shows an example of segment locations for a hafted biface. Only the blade element is evaluated for retouch flake scars. Each segment is assessed with a value based upon the appearance of edge resharpening within the segment. Segments that are dominated by flake scars originating from the bifacial edge and extending to the midline or beyond are given a value of zero. A value of zero is also given to those segments where the original flake scars do not extend to the midline, but instead meet flake scars that originate from the opposite margin. Essentially both cases represent original tool trimming without resharpening and are each given a value of zero. Segments where the entire edge contains resharpening flake scars or flake scars that do not extend to the midline or to flake scars originating from the opposite lateral margin are given a value of one. Segments that contain roughly equal amounts of retouch flake scars and flake scars that extend to the midline are given a value of .5. Both sides of the biface are assessed in this manner for a total of 16 segments. The bifacial retouch index is then calculated as:

$$HRI = \frac{\sum S_i}{n}$$

where HRI is the biface retouch index, $S_i$ is the sum of all section scores, and $n$ is the total number of sections. Figure 2 shows an example of a side-notched hafted biface with a HRI of .5312. In this case the total value of all segments is summed to 8.5. This value is divided by the total number of
segments (16) to arrive at .5312 for the HRI. Since the blade element for hafted bifaces is partitioned into 16 segments and each segment is scored with a standardized value (0, .5, or 1.0), all hafted bifaces can be compared to one another with the HRI regardless of the sizes of various blade elements. This means that hafted bifaces with broken tips or impact fractures can also be included in the analysis with hafted bifaces containing intact blade elements. By dividing the total score of all segments by the number of segments, the HRI values are theoretically standardized from "0" (no retouch) to "1" (completely retouched).

Experimenting with Hafted Biface Resharpening

One way to assess the effectiveness of the HRI for measuring retouch amount is to calculate the retouch index on hafted bifaces where it is known for certain the amount of resharpening that each specimen has undergone. Such information can effectively be gathered from a controlled hafted biface resharpening experiment. An experiment was designed that measured the HRI on a set of replicated hafted bifaces that were dulled and resharpened five times. The experiment began by making seven hafted bifaces from obsidian recovered from the Glass Buttes area of Oregon. All specimens were made by reducing a flake blank initially with hard-hammer percussion and then finishing each specimen with pressure flaking. Four of the bifaces were side-notched forms with different blade element sizes and there was also one corner-notched, one stemmed, and one lanceolate form. Each biface was measured and photographed then hafted onto a wooden foreshaft. All specimens were used to slice leather made from dried deer skin and to saw dried wooden twigs roughly 3 cm in diameter for the preparation of toggle switches for snares. Each hafted biface was resharpened while bound in its haft after it became ineffective for slicing the leather.

Table 1 lists linear dimensions of each replicated biface at the beginning of the experiment and after each resharpening episode. Different individual initial blade element sizes and particular circumstances of dulling and resharpening (for instance unanticipated step fractures) resulted in different "final" forms even though each hafted biface was sharpened the same number of times. Table 1 reveals quite a variety of blade element sizes and shapes. Some blade elements are longer relative to width with roughly parallel sides and others are wider relative to length and more triangular in shape. Although these replicated specimens are...
Table 1. Measurement of Experimentally Replicated and Resharpened Hafted Bifaces.

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not representative of the entire range of hafted biface blade shapes, they provide some variability and allow us to assess how well the HRI copes with variability.

Figure 3 displays the raw data for the HRI for each resharpening event for each specimen. Overall, the trend for each hafted biface shows a greater reduction index value as the hafted biface is progressively resharpened. This pattern is particularly strong in the early “stages” of hafted biface resharpening (through the first two episodes of resharpening). In some cases the retouch index deviates from the progressively greater trend and then resumes the trend. For instance, hafted biface BA05002 has an index value of .593 after the second resharpening episode, and that value drops to .50 after the third resharpening. The index then increases to .875 for the fourth and the fifth resharpen-
Figure 5. HRI values for each replicated and resharpened hafted biface for each resharpening episode. Specimens BA05001, 002, 003, and 004 are side-notched forms. BA05005 is a corner-notched form. BA05006 is a lanceolate form and BA05007 is a stemmed form.

Figure 5 shows the reduction index values for each resharpening episode. This deviation represents several interesting aspects within the resharpening data. Not all bifaces show monotonic variability in HRI as retouch advances. Also the HRI values do not increase at a uniform rate as retouch proceeds. In later stages of retouch the HRI increases slower than during earlier episodes of retouch.

All incidences of IIRI deviations from the expected occur in the later stages of resharpening. One of the reasons this may be occurring is that as the specimens get progressively resharpened, the blade gets progressively narrower. As the blade narrows it is more likely that some resharpening flakes approach the mid-line of the blade, thus decreasing the retouch score in those segments and reducing the resharpening index value. Table 1 confirms this pattern of progressively narrower blade elements. Nonetheless, the resharpening index shows progressively increasing values for all specimens from initial hafting to final resharpening.

As noted in Table 1, blade width gets progressively smaller as each biface is resharpened. This is often expressed as a change in blade cross-section from a lenticular to diamond-shape (cf. Goodyear 1974; Hoffman 1985). A thickness-to-width ratio at the mid-point of the blade can be used as a proxy measure for blade cross-section. The mid-point of the blade is a reliable location to measure cross-section shape because it is away from the haft location. Measurements such as maximum width or thickness taken near the haft element can be skewed because of influences of the haft binding. Another reason the mid-point of the blade is a good location to assess cross-section is because it standardizes the location for this measurement on all hafted bifaces regardless of size. Arbitrarily selecting a location such as four cm from the blade base to take width and/or thickness measurements may exclude some specimens, particularly those that do not have a blade four cm long. All hafted bifaces have a blade midpoint. Since the replicated hafted biface data show a relatively constant value for thickness of the blade element throughout the resharpening cycle, a simple width measurement (as opposed to a thickness/width ratio) can provide the same proxy measure. The experimentally derived width data for individual hafted bifaces was charted and compared to the HRI. With all else being equal we...
would expect the HRI to correlate with the blade width as resharpening progresses. Figure 4 displays a scatter plot of blade element cross section (expressed as width values) against the HRI. There is a strong negative correlation $r^2 = .644$, $HRI = 1.3134 - .0316$ (blade width). An ANOVA using HRI as a dependent variable and blade element cross section as a constant shows a significant relationship between the two ($F = 11.644$, $p < .0005$). These data indicate that as the blade width decreases (presumably because of resharpening), the HRI increases. Stated another way, as the hafted biface cross section changes from lenticular to diamond-shaped, the HRI increases. These data show that the HRI may be an effective proxy measure for assessing retouch amount on hafted bifaces. It is important to note that although blade width correlates with HRI in the experimental assemblage for each specimen, blade width is not a good proxy value for retouch since blade widths vary depending upon the size of the original specimen (see Table 1).

Another way to assess the strength of the HRI is to compare it against the amount of weight loss of each biface during the resharpening cycle. Since retouching each biface is a subtractive process, the weight for each biface gets theoretically lower as retouching progresses. This weight loss can be expressed as a percentage of total weight loss (Clarkson 2002). We would expect the HRI to correlate positively with the percentage of weight loss if it were an accurate indicator of retouch amount. Figure 5 is a scatter plot displaying the percentage of weight loss against the biface retouch index. In this graph the "percentage of weight loss" for each specimen is recorded as a cumulative frequency. As such, weight loss for each specimen begins with zero and ends with 100 percent of the total amount of weight lost for each hafted biface due to resharpening. There is a strong correlation ($r^2 = .688$, $HRI = .3357 + .0052$ [weight loss]) and a significant relationship between increasing percentage weight loss and the HRI ($F = 84.176$, $p < .0005$). Again, this demonstrates that the HRI is a useful proxy measure for amount of retouch on hafted bifaces based upon controlled resharpening experiments.

**An Archaeological Example**

As an example of how HRI might be used in an archaeological context, it was applied to a sample of hafted bifaces recovered from the Birch Creek site (35ML181) in the Owyhee River Canyon of southeastern Oregon. The Birch Creek site was
used by relatively mobile foraging populations sporadically for approximately 4,000 years, from approximately 6,200 B.P. to 2,200 B.P. (Andrefsky et al. 2003). Even though high-quality lithic raw materials are readily found in close proximity to the site in the form of cherts and basalts, obsidian was transported to the site in finished artifact form from a variety of sources. Obsidian source location surveys in the region have isolated several distinct source locations using XRF (Andrefsky et al. 2003; Centola 2004; Lyons et al. 2001). Figure 6 shows the location of the Birch Creek site and several of the obsidian sources in the surrounding area.

Most sources are located to the north of the site approximately 32 to 48 km away. However, several sources are located between 76 and 130 km distance. No obsidian sources were found between 48 and 76 km away from the Birch Creek site. This pattern effectively partitions the sources into those that are near Birch Creek and another group that is relatively far from the site area. There is no difference in obsidian source use over time at the site. In other words, regardless of when the Birch Creek site was occupied, obsidian from both the closer and more distant sources were used and they were used in very similar relative amounts during the 4,000-year span of occupation (Wallace 2004).

It can be argued that obsidian in hafted biface form from relatively close proximity to the site may show less evidence of curation than specimens made from a more distant source. This is particularly true if the hafted bifaces were used as multifunctional tools that included use not only as projectiles, but also as cutting and slicing tools. In such situations, the longer the tool is in use, the greater the possibility for it to become dull and to require resharpening. This particular pattern can be expected for foraging populations that circulate in a wide annual and multi-annual cycle as postulated for the Great Basin (Bettinger and Baumhoff 1982; Jones et al. 2003; Madsen 1994), since access to raw materials at different locations can be anticipated and scheduled.

With these assumptions in mind, a random sample of 28 obsidian hafted bifaces were provenienced using XRF analysis. Eighteen hafted bifaces were from source locations between 32 and 48 km away and ten were from source locations between 76 and 130 km away.
Figure 6. Birch Creek site location in southeastern Oregon along with known obsidian source locations used in the sample study. (Adapted from Andrefsky et al. 2003)
Table 2. HRI Central Tendency Values by Raw Material Source Distances.

<table>
<thead>
<tr>
<th>Source Location</th>
<th>N</th>
<th>Min.</th>
<th>Max.</th>
<th>Median</th>
<th>Mean</th>
<th>St. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Far (76-130 km)</td>
<td>10</td>
<td>.593</td>
<td>.906</td>
<td>.708</td>
<td>.719</td>
<td>.098</td>
</tr>
<tr>
<td>Near (32-48 km)</td>
<td>18</td>
<td>.187</td>
<td>.313</td>
<td>.406</td>
<td>.399</td>
<td>.085</td>
</tr>
</tbody>
</table>

Table 3. Mean HRI Values on Hafted Bifaces with/out Impact Fractures.

<table>
<thead>
<tr>
<th>Impact Fracture</th>
<th>Source Location</th>
<th>Mean HRI</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Near n=9</td>
<td>.413</td>
<td>.102</td>
</tr>
<tr>
<td></td>
<td>Far n=0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>Near n=9</td>
<td>.561</td>
<td>.190</td>
</tr>
<tr>
<td></td>
<td>Far n=10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

130 km distant. Table 2 shows the central tendency data for both source location groups. The mean HRI value for hafted bifaces from near sources is .399 while the mean HRI value for hafted bifaces from far sources is .719. Amazingly, the HRI values show no overlap in the two groups. Figure 7 displays the median and mid-spread of HRI values for each source group, and only the near group contains outlier values. The HRI values reveal strong clustering based on distance from tool-stone sources. These results suggest that the HRI is an effective measure of hafted biface resharpening activity, and can be used to assess the amount of retouch on such tools.

It is interesting to note that the HRI can be measured on hafted biface blade elements regardless of their condition. Since the blade element is partitioned into 8 equal segments on each face it doesn’t matter if the blade tip is sharp, dull, broken, or complete. This reveals another interesting aspect of the hafted bifaces from the Birch Creek site. Since hafted bifaces are often used as projectile tips, they frequently break as a result of impact damage (Flenningen and Raymond 1986; Odell and Cowan 1986). In situations where lithic raw material is relatively easily accessible we might expect that hafted bifaces broken as a result of impact damage would be discarded and replaced with a new projectile tip. In situations where lithic raw material is less abundant or less readily available we might expect to see hafted bifaces with impact damage resharpened and reused instead of being replaced. Of the 28 hafted bifaces from the Birch Creek used in this study nine contain impact fractures. Table 3 lists the mean HRI values and source location for hafted bifaces with and without impact fractures. Those with impact fractures have a mean HRI of .413 and those without impact fractures have a mean HRI of .561. These are not significant differences between HRI values based upon impact damage. However, those with impact damage have a lower mean HRI value and a chi square test of association shows that impact fracture (or lack of fracture) on hafted bifaces is significantly associated with proximity to obsidian sources and the Birch Creek site \((x^2 = 7.368, df = 1, p = .01)\). This suggests that hafted bifaces with impact fractures were discarded and replaced with new projectile tips when obsidian was in close proximity to the site. Presumably hafted bifaces made from distant obsidian sources were also used as projectile tips and were also susceptible to impact damage. However, these appear to have been resharpened and reused instead of being replaced with new hafted bifaces.

Discussion and Conclusion

As noted above the HRI may be most effective for assessing retouch on specimens that do not approach a diamond-shaped cross section. Although there was no significant loss of sensitivity to retouch throughout the resharpening cycle for any hafted biface in the study, the HRI values increased progressively less as hafted bifaces were progressively more resharpened (see Figure 3). The HRI values appear to be influenced by the number of flake scars that reach the mid-line of the biface in each segment. Hafted bifaces with diamond-shaped cross sections would be less effectively assessed for retouch amount using the HRI for this very reason. As a conservative measure, I would suggest that the HRI be used cautiously on hafted bifaces with thickness-to-width blade ratio values of 1.0 or greater.
Figure 3 also shows that regardless of style (lanceolate, stemmed, side notched, corner notched), the HRI works effectively for all types of hafted bifaces. Although four different types of hafted bifaces were used to assess the effectiveness of the HRI, it was not a study objective to determine the effects of shape on the index. However, we know, for instance, that different haft-element dimensions and the overall size of hafted bifaces are important for understanding the breakage patterns of these tools (Couch et al. 1999; Truncer 1990). Certain hafted biface styles may therefore have been primarily used for different tasks. Even though all styles of hafted bifaces showed increasingly greater HRI values as they were progressively resharpened, the values for each resharpening episode were synchronous with each point. For instance, specimen BA05006 (lanceolate type) had the lowest HRI values of any specimen for resharpening episodes 2, 3, 4, and 5. Based upon these pat-
terns I suggest that the HRI would be even more effective at assessing amount of retouch if the population of hafted bifaces were partitioned by type. This would not be an unreasonable exercise particularly in areas such as North America where hafted biface forms are routinely separated into types based upon haft element configurations. We also know that lithic raw material variability may play a role in the efficiency and effectiveness of certain tasks and actions such as cutting, piercing, sawing and scribing (Amick and Mauldin 1997; Bradbury and Franklin 2000). This suggests that it may be important to control for differences in lithic raw material types (such as chert, obsidian, quartzite) as well when using the HRI.

It has been demonstrated time and again that hafted bifaces are effective cutting and sawing tools (cf. Andrefsky 1997; Kay 1996; Truncer 1990). However, it is important to remember that many hafted bifaces and probably most smaller hafted bifaces may have primarily been manufactured as piercing tips for arrows and darts. The data presented above on impact fractures and hafted biface replacement patterns emphasizes this use for some specimens. It is interesting to note that the final shape of the experimentally resharpened hafted bifaces was generally long and narrow. This was because the hafted bifaces were used as cutting tools and their lateral margins were dulled and resharpened several times in much the same way as Goodyear’s (1974) Dalton points were used and resharpened. However, in unsystematic examinations of hafted biface collections before beginning the resharpening experiments, I noticed that many resharpened specimens appear to have blade elements much shorter than other specimens of the same style (based upon haft element configurations). In assemblages where the blade element length gets shorter relative to its width, resharpening is occurring on those hafted bifaces that have been broken as a result of impact damage. These specimens were probably resharpened within their hafts as opposed to being discarded and replaced by another tip. I would expect this kind of technological pattern to occur in situations where it was not easy to replace the specimen with a newly manufactured projectile tip (away from available raw material sources). This would account for the reduced length and width of the blade element. Hafted bifaces used as cutting tools and with no impact damage would retain their blade length more readily than those with impact damage that have been resharpened.

The HRI is introduced here as a technique to measure the amount of retouch on hafted bifacial tools. I suggest that hafted bifaces differ from other kinds of chipped stone tools such as unifaces and unhafted bifaces because their use life begins when their production process ends—when they are hafted onto a shaft or handle. As a result these kinds of lithic tools contain distinct blade and haft elements. The HRI was measured and assessed on both experimentally resharpened specimens and excavated specimens of hafted bifaces. Both populations show that the HRI is an effective measure of retouch. Hafted bifaces just beginning their use lives with no resharpening had a mean HRI value of .246, with no specimens assessed with a HRI greater than .375. Hafted bifaces that were resharpened five times had a mean HRI value of .822 and no specimens had a value less than .718. The mean HRI value for hafted bifaces that had been resharpened two and three times was .603 and .674 respectively, but with greater dispersion around these mean values. These values suggest that HRI may be a relative measure rather than an absolute measure since not all experimentally produced hafted bifaces began their use lives with a value of zero.

Since the HRI is calculated as a ratio of segment scores to number of segments the HRI values theoretically range from zero to 1. This allows all hafted bifaces to be compared to one another for retouch amount regardless of size and style. The HRI can also be used to compare broken specimens to unbroken specimens to determine the extent of retouch. This allows investigators to compare retouch amounts on different hafted biface specimens recovered at the same or differing site locations to help interpret aspects of settlement mobility and human land use as it relates to lithic technological organization.

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References Cited

Ahler, Stanley A.
1971 Project Point Form and Function at Rodger’s Shelter. Missouri. College of Arts and Science, University of Missouri-Columbia and the Missouri Archaeological Society, Columbia, Missouri.

Amick, Daniel S., and Raymond P. Mauldin

Andrefsky, Jr., William
1997 Thoughts on Stone Tool Shape and Inferred Function. Journal of the Middle Atlantic Archaeology 13:125-44.


Andrefsky Jr., William, Lisa Centola, Jason Cowan, and Erin Wallace (editors)

Barlow, Andrew B.

Bettger, Robert L.

Bettger, Robert L., and Martin A. Baumhoff

Binford, Lewis R.


Blades, Brooke S.

Bled, Peter
Bradbury, Andrew P., and Jay D. Franklin

Callahan, Errett

Carr, Philip J.

Centola, Lisa

Clarkson, Chris

Couch, Jeffery S., Tracy A. Stropes, and Adella B. Schroth

Davis, Z. J., and J.J. Shea

Dibble, Harold L.

Dibble, Harold L., and Andrew Pelcin

Eren, Metin I., Manual Dominguez-Rodrigo, Steven L. Kuhn, Daniel S. Adler, Ian Le, Ofer Bar-Yosef

Flemming, J. Jeffrey, and Anan W. Raymond

Flemming, J. Jeffrey, and Phillip J. Wilke

Goodyear, Albert C.

Greiser, Sally T.

Hiscock, Peter, and Val Attenbrow

Hiscock, Peter, and Chris Clarkson
2005 Experimental Evaluation of Kuhn’s Geometric Index of Reduction and the Flat-Flake Problem. Journal of


