2007 Study Update, Part 8

The Penetration Enhancing Factors

By
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This last 2007 Update presents an overview of the penetration enhancing factors; what they are, their importance and the degree of affect each has on your hunting arrow's terminal performance.

Penetration is paramount

In his article *Hunting Arrows*, published in Ye Sylvan Archer in 1943, Fred Bear wrote, "a deer can be killed with most any combination if no heavy bones are struck but what is needed is something that will crash through where the going is tough." In *Hunting the Hard Way*, referring to the success or failure of any given hit, Howard Hill wrote; "all else being equal, penetration is the name of the game."

Howard Hill designed his "3 to 1 ratio" broadhead with a single goal in mind; maximum penetration on every hit. And it was better penetration, not wider-cut, that Fred had in mind when designing his original Razorhead. Around the campfire, circa 1960, I heard Fred state; "The bleeder blade's job is to open a larger hole in the skin and meat and reduce drag on the shaft to increase arrow penetration. They're thin and brittle so they'll shatter when they hit bone, allowing the arrow to penetrate like any good single blade."

Both Fred and Howard recognized that penetration was the *essential requirement* of every lethal hit; vital areas had to be reached before any arrow could work. They realized the deeper their arrow penetrated the more damage it did, and the more areas it reached the better and faster it worked. Each also knew that, despite their remarkable skills, they were still vulnerable to their shots resulting in less than perfect hits; times when success would depend totally on their arrow's ability to penetrate whatever it encountered.

Since they could not forecast the shot they would be offered, how the animal would react, or precisely what their arrow might be asked to do; both Fred and Howard knew it was important to be prepared for the worst that might happen, and they did everything they knew to do to assure that their arrow would penetrate every time, regardless of the hit. These two bowhunting greats would agree that a sharp broadhead is mandatory, yet both realized even broadhead sharpness becomes irrelevant whenever arrow penetration is lacking. In hunting - on any hit with any arrow of any type – when arrow penetration falls short, absolutely nothing else about the hit matters.

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Rating the penetration factors

At the outset of the 2007 Updates it was noted that data now has clearer definition. Let's consider what it indicates about the penetration enhancing factors.

The following rankings are dynamic. Importance of each factor shifts under certain conditions. For example, arrow mass above the heavy bone threshold isn't very important on a shot impacting only soft tissues, but becomes very important when the shot impacts heavy bone. Taken individually, each factor boosts your arrow's penetration-potential; omitting or diminishing each reduces arrow penetration - at least under some conditions.

It's impossible to anticipate what each hit will be, and impossible to know beforehand which penetration factors will become most important. Maximizing successful hits requires incorporation of as many penetration-enhancing factors as possible.

The Factors

Structural Integrity of the entire arrow system is the most important factor. It applies to every aspect of the arrow, from the broadhead's tip and edge strength to the nock. Even a *tiny* tip-bend results in an average penetration loss of 14%.

The key function structural integrity plays has been stressed through-out. Hopefully no further discussion of 'why' is needed. As for a sharp broadhead, structural integrity should be a 'given' requirement for every hunting arrow. It is a 'must have' arrow design feature, without which no other factor can be relied upon.

Arrow flight is number two in importance. It's the 'enabler' for other factors, delivering more usable-force on target and permitting each additional factor to work at full efficiency. Poor flight squanders arrow force.

You should spare neither effort nor expense in achieving absolutely perfect arrow flight. Even with every other factor in place, without good arrow flight you'll still have poor arrow performance. However, ignore the other design features and all you end up with a perfect flying arrow that still performs poorly on some hits, negating the perfect-flight advantage.

Extreme FOC comes in at number three. Extreme FOC is Study-defined as 19% or greater FOC, measured using the AMO Standard method. (The AMO Standard Formula is presented in the Prologue to the 2007 Updates.) First notable FOC gains are manifest at that level. Between 12% and 19% is Study-defined as 'High FOC'. At or below 12% is defined as 'Normal FOC'.

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Until completion of light-draw testing Extreme FOC's effect could not be accurately placed. In addition to its own effect, Extreme FOC does more than any other defined feature except flight-quality to maximize the effect other factors offer.

All Extreme FOC tests show (or, as with the barrier and measurement constrained 82# bow; imply) very, very high penetration gain. This effect can now be quantified; at least for high-performance arrows having most other penetration-enhancing features. It ranges from approximately 40% to upwards of 60%.

Mechanical advantage (MA) of the broadhead ranks as number four. The degree of gain varies, depending on which broadheads are compared. Broadhead MA ranks this high because it has a more pronounced influence on the outcome-penetration of a perfectly flying and structurally secure arrow than any other factor except Extreme FOC.

Given the chance to apply its advantage, and regardless of other arrow-design features, higher MA increases the 'work' your arrow does with whatever 'useful force' is available. Its advantage is applicable to all arrows, of all designs. However, the more efficient the rest of your arrow is the more penetration-gain higher broadhead MA yields.

Shaft-diameter to ferrule-diameter ratio is number five. It shows an average 10% penetration-gain when the shaft is at least 5% smaller than the broadhead's ferrule diameter; compared to a case where shaft and broadhead ferrule have equal diameter. When shaft diameter exceeds that of the broadhead's ferrule, penetration is *decreased* by an average of 30%; compared to a case where shaft and broadhead ferrule have equal diameter. That means a 40% difference in tissue penetration when a shaft having a favorable ratio is compared to one with an unfavorable ratio.

Shaft-diameter to ferrule-diameter ratio is applicable to all arrows. Regardless of the other design factors present or absent, you should avoid use of arrows having a shaft diameter greater than that of your broadhead's ferrule. Ideally, your arrow's shaft should be *at least* 5% smaller in diameter than your broadhead's ferrule.

Arrow mass is number six on the list. Don't confuse 'mass' with 'size' or 'bulk'. Arrow mass is closely related to arrow weight, but isn't exactly the same. Mass reflects how much *matter* is in the arrow, and weight refers to how hard gravity pulls on that matter. When talking about force or energy, arrow mass is the correct term to use, rather than arrow weight. However, as long as your hunting is confined to planet earth it's ok to *think* of 'mass' as *implying* 'weight'.

Greater arrow mass increases bow efficiency, absorbing more of the bow's stored energy when fired. That means more arrow force. But there's more. When all else is equal, an

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arrow's tissue penetration is directly proportional to its momentum. Don't confuse this to mean two different arrows will penetrate equally just because they have equal momentum. How much of the arrow's momentum comes from its mass, and how much its velocity, is also a factor; as is the efficiency with which your broadhead applies the arrow's momentum.

Momentum *belongs* to the arrow; it is a property of the arrow, carried within it. It is derived from the arrow's forward motion and mass. As an arrow slows during penetration velocity is shed, but its mass remains constant. At equal impact force, the heavier your arrow the longer it takes to stop. The result is deeper tissue penetration. That's part of Newton's First Law of Motion, and its relevance is consistently demonstrated throughout real-tissue testing.

Arrow-mass advantage is available and applicable to all arrows, of all designs. You should use the greatest arrow mass (heaviest arrow) acceptable trajectory allows. Even with every other penetration-maximizing factor in place, greater arrow mass still equates to more usable-force, and more outcome-penetration.

Edge finish places number seven. A smooth, beard-shaving sharp, honed and stropped edge works best. Its advantage is most pronounced in fibrous tissues. In these it shows a 26% advantage over a smoothly-filed sharp edge and a 60%-plus advantage over 'Hill type' serrated edges. It's an advantage available for all broadhead designs, for all arrows.

Shaft profile is number eight. Tapered shafts show an 8% penetration advantage over parallel shafts, and 15% over barrel-taper shafts. Parallel shafts show a 7% advantage over barrel-tapered ones. This is applicable to all arrows and shaft materials, on all hits.

Broadhead/arrow silhouette ranks number nine. Any rough or irregular surface increases arrow drag in all tissues. Its effect is more pronounced during bone penetration. The 'less bumpy' your arrow and broadhead's silhouette the more effortlessly it passes through tissues. Additional 'slickness' helps too.

Shaft finish has a demonstrated penetration-effect, but the degree has not been quantified. Though one finish can be compared to another the Study has no method to define the frictional coefficient of each in a blood-suffused tissue environment. Your arrow shaft's finish should be as smooth and 'slick' as possible.

A Teflon™ broadhead finish offers advantages. When comparing the same broadhead with and without Teflon™ finish, coated heads averaged 12% more penetration on soft tissue hits. There *appears* to be no effect on bone penetration. The only commercially available Teflon™ coated broadhead I know of is the Eclipse. Its Teflon™ finish is excellent. I wish there were more.

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Slicker finishes aside, the crucial element is to have as few 'ups, downs, bumps and lumps' along the arrow's profile as possible. That, of course, excludes the one step-down your arrow *should* have; immediately rearward of your broadhead's ferrule.

Type of edge bevel comes in at number ten. When broadheads identical in all aspects except edge-bevel are tested side by side on identical arrows, single-bevel versions demonstrate sizable penetration-increases in 100% of cases involving bone impact. The gain varies by broadhead profile, but ranges from 14% to 58%. Single-bevel broadheads *may* show a penetration advantage in soft tissue too. Data is *suggestive* of that.

On shots impacting bone, edge bevel jumps well forward on the list of important factors; immediately behind mass-weight above the heavy bone threshold. Single-bevels cause arrow rotation during penetration, applying torque to bones as they pass through. Their use has *consistently demonstrated* a high frequency of *massive* bone splits, especially in the long-bones. Throughout the Study, not a single large bone-split has been observed with any double-bevel broadhead.

Most hits involve bone impact of one type or another. There is no down-side to using single-bevel broadheads on any type hit. There is a demonstrated up-side when bone is hit. (See "*Why Single-Bevel Broadheads*"; and also 2005 Update, Part 1 and 2007 Update, Part 4.)

It also appears *possible* single-bevel broadheads *may* have some beneficial flight-effect on arrows.

Tip design is eleven. Tip design's greatest importance is on shots impacting bone. The Tanto tip shows the best performance. Tested side-by-side with identical broadheads on identical setups, it averages a lower damage rate than any other design tested (See 2005 Update, Part 1). It shows the best outcome penetration in bone, averaging 110.0% better than the worst-performer tested (concave) and 27.5% over then second-best performer (round).

Of all tip profiles, the Tanto demonstrates the lowest tendency to skid off bones on angular impacts. Data *suggests* that a needle tip *might* do as well or better at retarding bone-skids, were it not for their high damage rate. 'Needle tip' should not be equated to conical or pyramidal tips that come to a sharp point. It *appears* these often initiate some bone-skids.

Arrow-mass (weight) above the heavy bone threshold ranks number twelve. As noted, it is placed this low only because it has little significance on shots impacting only soft tissues. On any heavy bone impact this factor will jump to very near the head of all factors; excepting only structural integrity and, *perhaps*, quality of arrow flight (See 2005 Update, Part

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6). To date, Extreme FOC has demonstrated no effect on the heavy bone threshold.

From a personal standpoint, I will not hunt with an arrow below this threshold. Bone impacts of one type or another occur on *most* hits, and bad hits can occur at any time.

Regardless of the arrow setup or broadhead and tip design you use, there is a marked difference in the frequency of penetrating heavy bone when total arrow mass is below this threshold. The threshold is at, or very near, 650 grains of total arrow mass. For any given broadhead, its persistence appears little affected by sizable increases in impact force.

Arrow force derived from the bow comes at the end. Any bow, be it compound, recurve or longbow, is capable of imparting only a set amount of energy to an arrow of a given mass, producing only a finite amount of arrow force. Modest arrow-force gain can be obtained through use of higher-mass arrows, increasing bow efficiency. However, any substantial gain in arrow force from your bow requires either obtaining a more efficient bow or increasing draw-weight.

As demonstrated by the 54# bow, the penetration gain obtainable by increasing draw weight pales in comparison to that achieved through better arrow design. Increasing draw weight offers you a *potential* for better terminal arrow performance, but that potential is all too easily squandered by a poor-performing arrow. Maximizing arrow performance reaps far richer rewards than does increasing draw weight. Increasing draw weight while ignoring your arrow's design features offers only a very modest gain in terminal performance.

Other factors also affect arrow efficiency, but are difficult to quantify. Quality of broadhead steel is a factor; the longer it holds its 'pre-hit' level sharpness as it penetrates, the more efficiently it cuts. Total length of cutting edge is a factor in creating hemorrhage. The blade's angle of attack affects how easily and cleanly it slices tissues. Angle of the edge bevel is a factor, both for its mechanical advantage and the depth of slice achieved at a given degree of tissue tension. There are more.

Does it make enough difference to matter?

Total up just the well-quantified penetration-enhancing factors above. They indicate from 90% to almost 200% penetration increase; depending on whether low or high increase amounts are used. That's the increase data says they deliver over a setup lacking these features. This is allowing for total structurally-integrity and perfect flight with both arrows.

Those increases do not include some factors with a high degree of effect, but whose effect can't be quantified because

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of variables; such as the arrow-mass difference, differing broadhead MA, or shaft silhouette and finish differences.

Does it sound impossible; tripling penetration by changing arrow design? That's what a 200% *increase* implies; three times as much. Again, consider the implications; an arrow that penetrates fifteen inches instead of five, or thirty inches instead of ten. This is the type of gain indicated between an arrow fully penetration-maximized and one lacking these factors. The most startling thing is, if you fully maximize your arrow's penetration potential and compare it to one with *none* of the features the indicated 200% increase is actually too low!

One more item to ponder; the increases we're talking about were demonstrated under test conditions equating to a worst-case scenario when hunting most animals. Each of these shots involves a heavy bone. A single rib on a mature buffalo bull is as thick as the scapular flat of most zebra or elk, and presents a more curved surface to the arrow's impact.

Perhaps the easiest way to illustrate the difference between a common arrow setup and one maximizing performance is through the following photos.

Photo 1

Photo 1 shows two shots on a young buffalo bull, taken during 2004 testing. This is a significantly smaller animal than the ones used in testing the penetration-enhanced arrows; shown below. The arrows have mass weights of 785 and 790 grains. Both show perfect flight. Neither shows structural failure. Other than one (yellow fletched) being a tapered carbon shaft, neither has any of the remaining penetration-enhancing factors.

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Both arrows have 'normal' FOC and broadheads of moderate mechanical advantage (1.43); the Wensel Woodsman, with the tip modified to a pyramid profile. It should be noted that the Woodsman has demonstrated only slightly less penetration than *double-beveled* wide-cut single-blade broadheads having corresponding amounts of MA, such as the Magnus I and Zwickey Delta. Consider, too, that the MA *would* be worse with many other broadheads.

Both broadheads have hair-shaving-sharp double-beveled edges with a micro-serrated edge finish. Both have shaft diameters within 1% of the ferrule's diameter; equal diameter. This too could be far worse, with a shaft-diameter larger than the ferrule.

Both shots were broadside, from twenty yards. They are from the 82# longbow. One shot failed to penetrate the entrance-rib; the second (tapered shaft) penetrated the rib, but barely entered the first lung. Penetrations were 3.375" and 7.5".

[The 82# bow shown is the slowest of my three bows of that draw weight - not one of high-efficiency - and is the 'heavy bow' used throughout the buffalo testing. I have chronographed high-efficiency bows in the mid-sixty pound range that equal its velocity with the same arrow mass.]

Photo 2

This is the same 82# bow. Shooting distance is the same, but the shot is quartering from the rear at 20 degrees, and on a much larger-bodied bull. Arrow mass is 815 grains. This arrow also has perfect flight. It incorporates most penetration maximizing features, but lacks Extreme FOC.

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The broadhead is the Modified Grizzly, with a very high mechanical advantage of 3.25. The tapered hickory shaft has a smooth silhouette and *very slick* finish. Shaft diameter to ferrule diameter ratio is favorable; 11.5% smaller. The broadhead's long, low-angle single-bevel edge was honed (six-thousand grit Japanese water-stone) and stropped; beard-shaving sharp. It has a cut-on-impact Tanto profile tip.

This arrow passed through the entrance rib, traversed the thorax, and imbedded deeply into the off-side rib. This setup monotonously delivered the same performance, shot after shot. Penetration here is 18.5". That's 147% more penetration that the yellow-fletched tapered-shaft arrow in Photo 1; and 448% more than the white-fletched one … and, don't forget, this shot encountered the off-side rib penetration-barrier. Performance shown provides a good indicator of the penetration gain achievable with normal and high FOC arrows, through incorporation of the penetration-enhancing features other than Extreme FOC.

Photo 3

The two shots in Photo 3 are from the same 82# bow, and from the same distance and shooting angle as those shown in Photo 1. These are Internally Footed Extreme FOC arrows. Arrow mass is 790 grains. The buffalo is larger in body size than the one in Photo 1; a body-match to the bull in Photo 2. These Extreme FOC arrows incorporate all the penetration enhancing features except a tapered shaft and Teflon™ broadhead finish.

These penetration-enhanced arrows traversed the thorax, penetrated the off-side rib(s), and provided an exit wound; as did *all* their additional shots. For back of the shoulder shots this setup averaged 22.5" of *measurable* penetration. That's six and two-thirds times as much penetration as Photo 1's

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white-fletched shot (a 566% increase … *plus the amount of penetration that couldn't be measured*). It's fully three times the penetration of Photo 1's tapered-shaft arrow (a 200% increase … *plus that un-measurable amount*). They also show 22% more penetration than the shot in Photo 2; again, plus that amount of penetration not measurable. (*Measurable penetration* is study-defined as: the depth of the wound through tissues, excluding any arrow protrusion.)

It is worth reiterating that a whopping 38.94 foot-pounds of kinetic energy was all required for these penetration-enhanced Extreme FOC arrows to unfailingly accomplished total penetration on massive-bodied, trophy size bulls. According to kinetic-energy proponents that's enough *energy* to hunt deer-size game … nothing bigger. It falls short of their minimum-adequate kinetic energy for elk, black bear or boar, and represents only 60% their minimum-adequate for buffalo. How does kinetic energy explain the outcome? It can't. Momentum's impulse mechanics does.

Each shot with these penetration-enhanced arrows provided an exit wound on trophy size bulls. Consider what they accomplished to get there. They penetrated a full inch of extremely tough and fibrous hide; about three inches of meat, sinew and fascia; a half-inch of very solid bone; over a foot of lung; a second half-inch of bone; three more inches of fascia, sinew and meat; and then another inch of that incredibly tough and fibrous skin!

Considerations

Among the above arrows, which would you say makes the better choice to hunt a buffalo with? If your shot inadvertently hit the spine on a deer, elk, moose or bear which arrow setup would give you the greatest confidence in bringing the animal down? Which arrow setup would you prefer to be using when that 'tight to the shoulder' shot on a big boar accidentally ends up hitting shoulder or leg bone, behind a couple inches of shielding gristle? How about on a shot where a deer wheels-around, and your arrow solidly impacts the pelvic girdle; or the head of the femur, right at the hip's ball joint … or ends up a 'Texas heart shot' requiring near body-length penetration to traverse the chest cavity?

I've had those exact hits happen more than once while hunting, and many on animals larger than whitetail or mule deer. On each I was using arrows penetration-enhanced to the best of my ability. I lost no animal on those poorly-placed hits - not one. When hits end up badly placed, regardless of the reason they did so, it's the arrow's ability to penetrate which matters most. If none of your shots have ever ended up badly placed, you definitely aren't getting in enough hunting!

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Pause for a moment. Think back. Consider the performance shown by the 54 and 70 pound longbows, as well as these from the 82# bow. Every *structurally-secure*, penetration-enhanced Extreme FOC arrow with a mass-weight above the heavy-bone-threshold penetrated the buffalo rib(s). In just the current (2007) round of testing this represents the outcome on 91 consecutive hits with such arrows, without a single failure to penetrate the buffalo's rib. Though they had to penetrate a heavy, half-inch thick bone, even the (structurally intact) penetration-enhanced Extreme FOC arrows from the relatively inefficient 54# straight-end longbow averaged over 14 ½" of penetration - with *none* showing less that a foot of penetration.

Now think of every shot you've heard about that resulted in a non-recovered animal. Contemplate the arrow penetration you've witnessed in videos. Then consider …

The thickness of a single buffalo rib exceeds the scapular-flat thickness of most commonly hunted game; deer, boar and black bear. In fact, on all these it would equal the combined thickness of scapular flat *and* the underlying rib(s). It approximates the very thickest portion of a bull elk's scapular-flat. The combined thickness of *two* buffalo ribs roughly equals the scapular-flat and underlying rib thickness on all commonly hunted *big* animals - including elk, moose, and the big bears.

So, do these bone-thickness comparisons mean that the ability to penetrate a single buffalo rib represents *more* bone penetration that you'll *ever* need on the smaller commonly hunted animals, such as a whitetail? No. Take a moment to consider the flip-side.

For those who think buffalo testing is not applicable to lighter big game such as deer, consider that the scapular ridge on a mature whitetail buck can easily be an inch thick. The head of the scapula on most any mature whitetail, does included, is often an inch or more in thickness - and the head of the humerus (the shoulder's ball joint) on virtually *any* shooting-size whitetail will be 1" to as much a 2-1/4" thick. Even a moderately steep angular impact on a deer's scapula or elk's rib can require that your broadhead penetrate a half-inch or more of bone before reaching anything vital – and it has to do so without skidding of the bone.

Game animals are not 'targets' at the shooting range. Whenever we shoot one, our purpose is to kill; and kill as quickly and humanely as possible. A 'bad hit' on a target only results in a poor score. Every single bad hit that results in a non-recovered animal has far greater implications; from both a practical and moral standpoint, as well as for our sport as a whole.

I've heard many maintain that they have never, ever had any such hits; and have never had any problems with arrow

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penetration on any of the 'common game'. If they've done much hunting, that's difficult for me to comprehend. I'm neither a bad shot nor a great shot, but I've had a fair number of poorly placed hits. Sometimes the animal moved and sometimes I simply muffed the shot.

Among bowhunters I've guided, none of whom I would call bad shots, with most being far more accurate than I, I'd say that around one-third of their hits were poorly placed. Beyond that, on the African hunts, where opportunities at multiple animals during one hunt are the norm, I can't remember a single hunter who didn't make *at least* one marginal or poor hit during his hunt … but, despite their demonstrated accuracy on targets, I can think of some who didn't make a single 'perfectly placed' hit! (I must also note that these weren't setup shots from blinds at water troughs or feeders, at multitudinous masses of game-farm animals. They were hunts in wild places for truly wild animals; ones whose day to day survival depended on fast reactions to ever-present dangers – animals every bit as evasive as the coyote-country whitetails of Texas that I grew up hunting.)

On those hunts, virtually every non-recovered bow-shot animal was a result of insufficient arrow penetration. This determination is not based solely on the penetration observed at time of arrow impact. I was able to verify insufficient penetration as the cause on most, after the wounded animal was dispatched with a rifle, either during follow-up or subsequently by the game scouts.

Three times I've seen arrows stopped on nearly broadside shots by the entrance-side ribs of modest size pigs – with two of those bouncing back. All three of those shots were with high-poundage bows (the lightest-draw being a 65# compound), but with poorly selected arrow setups. One PH I was co-guiding with, Ben Bronkhorst, also had a client's arrow bounce back from a warthog's rib. The arrow swapped ends and passed between himself and the client. That was on a shot from 15 feet. The very light weight carbon arrow, from a 70# compound, tipped with a light-weight multi-blade broadhead hit only a rib on entrance. Total penetration, measured against the blood and tissue on the broadhead was a mere 22 millimeters (0.87").

I've also seen arrows stopped by whitetail and impala ribs, scapulas, shoulder bones, hip bones, leg bones and spines. My collection of broadheads recovered by meat processors from rifle killed deer is steadily growing. There's no question that someone, somewhere is definitely having penetration problems, even on whitetails!

On any big game animal, just on the off chance that you're unfortunate enough to make a 'bad hit', wouldn't knowing your arrow was structurally secure and fully penetration-maximized make you a bit more certain about the likely outcome? Regardless of how light your bow's draw, using

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such arrows does result in a higher recovery rate whenever hits are less than perfect … and every shred of data; every study of bowhunting's wound-loss rate; indicates that such hits are a common occurrence.

Scapular-flat thickness of the largest Zebra stallion taken during the Study's entire 25 years; 5/8". The killing shot; with a penetration-enhanced arrow having a high MA single-bevel broadhead; split this heavy scapula.

What a penetration-enhanced arrow can do to the scapula of a record-class wildebeest bull. It was the killing shot. Note: (1) bone thickness; (2) the massive split caused by the Modified Grizzly's single bevel; (3) large bone flakes

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splintered off and; (4) point of arrow-entry into the bone (blue arrow). Maximizing penetration-potential provided the force required to do this damage, with enough retained momentum to give a near pass-through. The arrow fell free of the exit wound as the animal reacted. Is no arrow a bone breaker?

Comments

When a hunter must kill to survive, he uses whatever he has available, and kills in any manner he can. That is as it should be. Today's bowhunter does not hunt of necessity, he hunts by choice. Within the limits of law and his physical ability, equipment selection is of his choosing.

It is never wise to hunt with a setup which *requires* a near-perfect hit in order to be reliably lethal, yet many seem to consider such a setup as representing 'adequate'; which they generally qualify by adding, "as long as you do your part and put it in the right place." To be adequate your setup should be capable of killing cleanly and humanely on as many of the hits *likely* to occur as possible; not just on near-perfect hits. If the overwhelming statistics from bowhunting surveys are to be believed, at least one hit in every two is poorly placed enough to result in a wounded and not recovered animal. Certainly, not all those will die from a slowly-lethal wound, but some will. What is the acceptable wound-loss rate; and to whom is that rate acceptable? The arrow you choose to use can make a difference.

Next year (2008) marks a half century since my first big game bow-kill. Personal experience as both hunter and guide has convinced me of several things: (1) Hitting an animal and making a killing hit are two entirely different things. (2) No matter how skilled the hunter and how hard he tries, he's going to make marginal and poor hits from time to time. (3) Depth of penetration is a far bigger factor in consistent arrow lethality than cut width or volume. (4) If the arrow penetrates sufficiently, a solid body hit almost anywhere with *any* truly sharp broadhead will yield a lethal hit and recoverable animal. (5) When the broadhead is sharp and the arrow penetrates sufficiently, successful recovery of a poor or marginally hit animal frequently depends upon how you manage the follow-up after the hit. (6) Pass-through hits alarm animals less, resulting in a shorter run after the hit. (7) Pass-through hits result in faster hemorrhage, shorter collapse times and better blood trails. (8) The degree of blood trail present primarily depends on the location of entrance and exit wounds, and what the arrow hits during penetration. (9) The arrow you hunt with is infinitely more important to making clean kills than is the type or draw

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weight of bow you use. (10) Howard was absolutely correct; with equally placed hits, arrow lethality depends primarily on penetration.

It took a long time to learn what was needed to turn hits, even the bad ones I sometimes made, into successful kills. Some of the animals I hit and failed to recover during those early years still haunt me. Excluding small game, using the best penetrating arrow I could assemble, and having it truly sharp - along with careful management after the hit - has allowed me to achieve what is now a 26 year long cumulative wound-loss rate well below 1% (0.66%, to be specific).

That rate reflects four non-recovered large animals since starting to keep kill-records over a quarter-century ago. None of those can be attributed to a lack of arrow performance. One was purloined by other hunters and three simply went where I and my shattered knees could no longer follow. Despite that I'm looking to improve on arrow penetration. Why? Because some of the bad-hit kills I made still had marginal penetration, requiring difficult follow-ups. Lady Luck smiled several times, but there were anxious moments; times when I would have given a lot for just a couple more inches of penetration. I've never lost an animal because my arrow penetrated too much - nor has anyone.

So, that being said, what arrow do you think is in my hunting quiver at the moment? It's the Internally Footed Extreme FOC arrows shown here. Why? Because they are the best penetrating arrow I have available, giving me the greatest chance to recover every animal I hit. Do I think they are the best arrow possible? No, but they'll do until I find a better one … and I'm on the track of it right now.

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