Quantification of Ram Horn Shape in Soay Sheep

13-November-2005 Gevan R. Marrs – Woodland Creek Farm©

Background

One of the notable features of Soay sheep is the attractive spiral horns that most rams develop with age. Breeders whose flocks graze where the sheep can be seen by passers-by remark that often people stop and stare in wonder at the appearance of mature rams. Many ewes of course also have horns, but these are always much smaller and will therefore not be the focus of this article. Similarly, smaller ram horns from scurred rams, or wethers, will also not be discussed here. Breeders often discuss rams horns in terms like wide or narrow, good or poor clearance, wide or narrow angle, tight or loose spiral, etc. (See Figures 1 and 2 for examples). In general, almost everyone wants to avoid the one extreme—horns that grow into the neck or jaw, endangering the animals health. Not everyone agrees that "wider horns" are an important breeding objective, but even to maintain diversity it would be useful to better understand whether and by how much the basics causes of differences in horn geometry are genetic or environmental.

While the general nature of the horn descriptions commonly used is fairly clear, if we desire to track more uniformly the horn geometry, and in particular have consistency among observers and on the same sheep as they change over time, and produce offspring, it would seem desirable to have an agreed-upon methodology to quantify key horn geometry measures. Such observations could be the measure(s) used in pedigree databases that would then potentially allow deduction of genetic contributions (or lack thereof). Additionally, if measures can be developed that show good correlation between juvenile and mature patterns, decisions on breeding or culling of young rams can be made with much better outcome.

Figure 1. Horns that might be described as heavy, but narrow, tight, or small clearance. (Fedan)

Figure 2. Horns with good clearance, but asymmetrical. (Max)

Some candidate horn measures

A basic difficulty in quantifying Soay sheep rams horns is that they are actually a quite complex shape in 3-dimensional space. The horns taper in girth from the skull to the tip, but they also spiral in varying diameter and are translated inboard or outboard to varying degrees as they pass through the spirals. In addition, there may be a twist of some sort. They are far more complex than a simple corkscrew, which is just a coil extended at a constant pitch. They are even more complicated that the classic “golden series” spiral (most commonly illustrated by a cross-section through the centerline of a chambered nautilus shell), as that has no lateral translation of the spiral, and no twist. Given that they seem to fit no simple pattern precisely, the following list of empirical measurements might be considered as candidates:

1. Width of horns.
2. Clearance from neck or jaw.
3. Basal angle – angle formed inside horns where they join the top of the skull.
4. Second angle – roughly, the angle formed between the first and second year’s horn growth.
5. Diameter of spiral- Loose or tight curl
6. Basal circumference – Heavy or light horns.
7. Intra-annual Ridges – frequency, prominence.
8. Horn Length – outside curve
9. Symmetry – difference in clearance or tips compared to a central line.
10. Tip twist angle – the twist of blade-shaped tips – top twisted outward, inward, or vertical.
11. Tip angle from animal centerline – diverging or converging.
12. Cross-section shape- oval, triangular, rounded-rectangular, square.

Objective

The goal of a good horn measurement technique would be one that is **repeatable** by different individuals measuring; it would be relatively **simple** and **quick** to perform; and hopefully measurements of younger rams would give a **reliable indication of the mature** ram horn pattern. The candidate measurements listed above will be discussed in order of declining fit with the stated objectives. For ease of illustration, many of the measures will be shown using the preserved skull of the departed Max (shown above when alive.)

Width and Clearance

Clearance—defined here as the gap between some part (usually at the lower portion of the first curl) of the inner side of the horns and either the jaw or neck—is one of the most commonly mentioned traits in Soay sheep rams horns. Avoiding narrow horns with tight clearance—as this is generally considered less attractive and can actually inhibit chewing and thus the animal’s survival—is presumably an unstated but underlying goal behind statements about “lines that produce very wide horns”.

Since there is relatively little variation between different rams in horn thickness at a given location in the horn spiral, the overall width outside the horns, at the bottom of the curl, will be very closely related to clearance. Therefore, these two measures are addressed together here—likely measuring one will suffice to characterize both. Figures 3 and 4 show, with Max’s skull, the approximate definition of the width and clearance measurements, respectively.

A difficulty of the width measurements is that there is invariably some angle between the horns, at any measurement point (see Figure 3), making the choice of any standard location (save for the tips) somewhat arbitrary and thus not likely to be repeatable between different observers. The measurement at the tips is probably the least important of any of the width measures. Therefore, it seems that width by itself is not a good candidate measure, and we should focus directly on the measure of more concern—clearance.

Clearance could be measured against several reference points—upper jaw, lower jaw, or neck. The clearance from the neck is not a fixed distance, thus would be difficult to measure repeatably. Although the lower jaw moves laterally to some degree, a normal closed position, as would be typical exhibited if an animal were restrained for examination, should be highly repeatable. The clearance from the horn to the upper jaw is certainly fixed, so should be highly repeatable, but is probably not different from the lower jaw clearance. Rather than measuring clearance along some standard angle from, say, normal to the medial plane through the skull, it is more easily measured and more relevant to simply measure the *minimum* distance from inner horn surface to either upper or lower jaw.

Figure 3. Potential width measures.

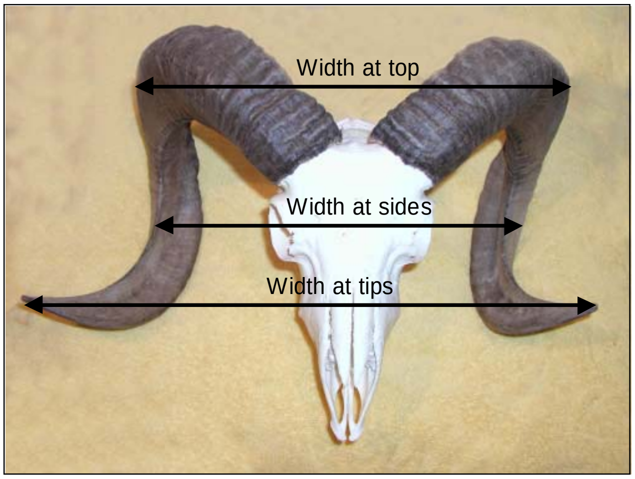
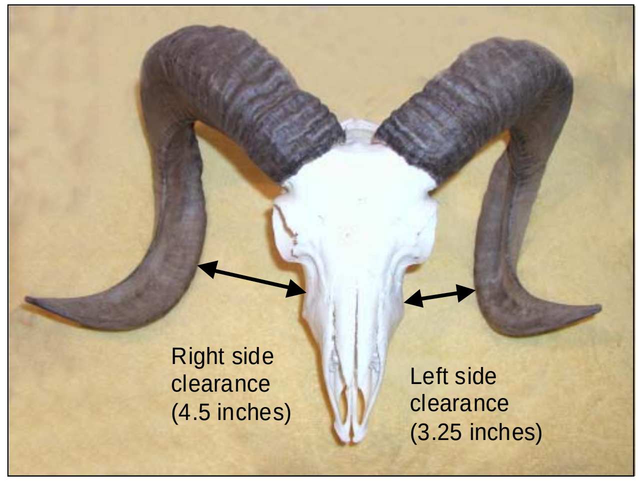


Figure 4. Potential clearance measure.



Conceptually this is like determining what diameter sphere could be placed between the horn and jaw. While direct captive measurements would be most accurate, for broad classification purposes most observers could probably estimate visually, without restraining the animal, the clearance to within 1 inch classes by reference to familiar spheres of known diameter. For example, some candidates classes and reference spheres might be as follows:

General clearance description	Clearance Range	Common sphere for middle of range
Touching	zero	-
Very Tight	¼ to 1 inch	marble
Tight	1 to 2 inches	Ping-pong ball (1.5 inch diam)
Medium	2 to 3 inches	Baseball (~3 inches)
Loose	3 to 4 inches	Softball (~4 inches)
Wide	4 to 5 inches	Cantaloupe? (~5 inches)
Very Wide	over 5 inches	soccer ball (~7 inches)

Given the importance of clearance, and the relative ease with which is can be measured directly, on captive animals, or estimated fairly accurately from a distance, it would seem to be a very strong contender for one of the few important measurements. The main drawback is that is not measurable until the horn growth is sufficient to come close to the reference of the jaw. This would typically occur in the fall of the ram's 2nd year. So while this directly measures an important aspect of horn geometry once it has been expressed, it doesn't allow assessment in younger rams. Accordingly, it seems to be necessary, but not sufficient to meet our goals in quantifying horn geometry.

Basal Angle

One of the earliest expressions of horn geometry—one that is fairly well expressed at about 6 months in ram lambs—is the included angle that the horns make as they emerge from the skull. I have been told by several experienced breeders that this angle is not always highly reliable in predicting what clearance will be as the ram ages and the horns continue to spiral past the jaw. Still, it is one of the few early measures we could make, and until some reliable, precise measurement system is used to track a number of rams from infancy through the age of 4 to 5 years, when horn growth essentially stops, we cannot say how reliable or unreliable the measure might be. Accordingly, considerable attention will be devoted to this measure here.

Figures 5-8 show, for example, the general comparison of 4 of our young rams. In this early attempt to quantify basal angle, ‘heads-on’ photographs were taken while the rams were grazing, and the angle inscribed and measured from the resulting photo.

Figure 5. **Basalt** horn angle at 6 months.

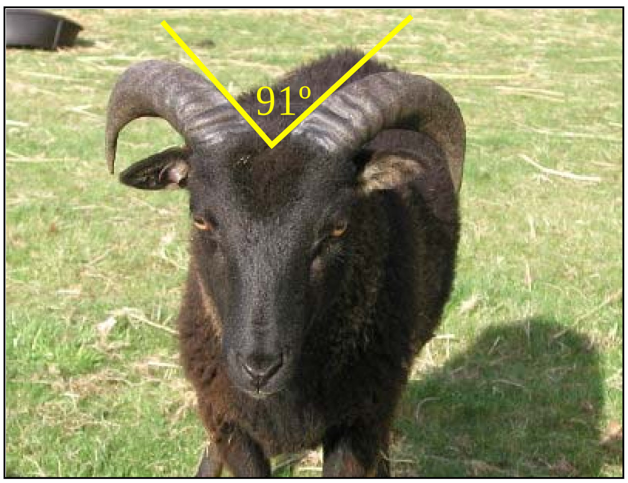


Figure 6. **Dagger** horn angle at 5 months.

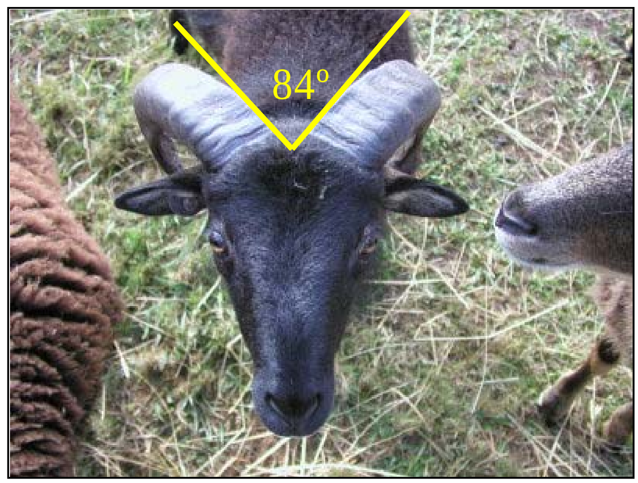


Figure 7. **Rocky** horn angle at 4 months.

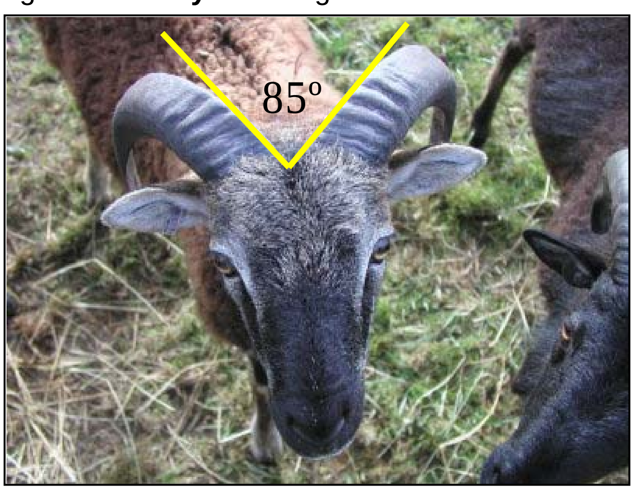
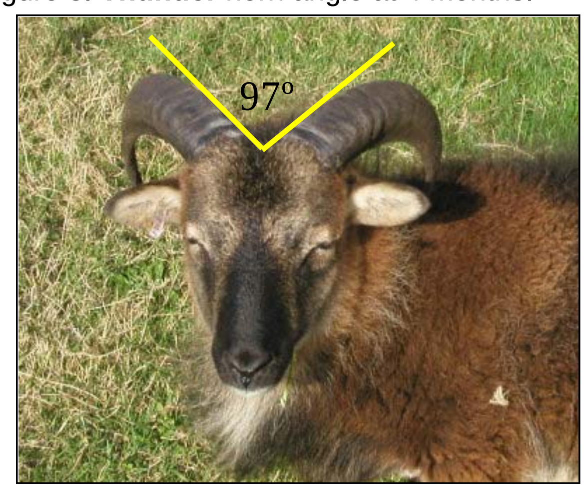


Figure 8. **Thunder** horn angle at 4 months.



Careful study of these photos will reveal several potential weaknesses of this approach. For one thing, the basal angle is clearly not capturing the effect of the tips beyond the basal angle. Note that in Basalt above, the horn tips are diverging, while in Dagger they are converging, and in Rocky the tips are fairly straight, but the basal angles are not greatly different. Note too that some judgement is required in placing the reference lines against the horn angles, since, at least in the plane of the photograph, they actually curve continuously inward or outward. This would mean that not every observer would get the same measurement, which misses one of our goals. A second, less obvious problem is that the *apparent* angle, as measured in the plane of the photograph, is actually affected significantly by the vertical angle of the photo with respect to the head. This can best be shown by comparison photos of another ram, Juniper, at 16 months (Figures 9 and 10).

Figure 9. Juniper at 16 months, **grazing**, camera roughly **45º Up** from plane of face.

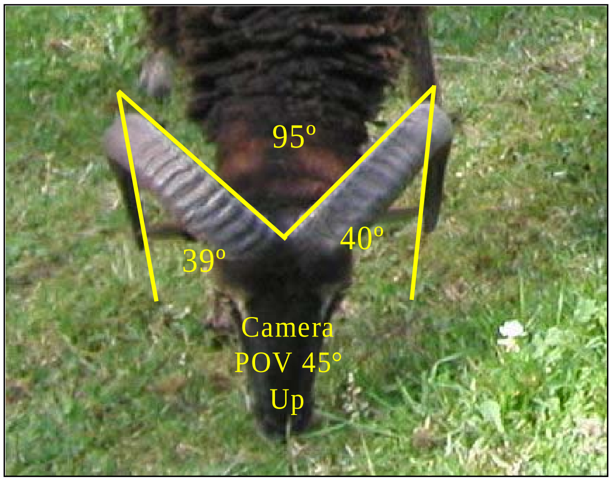
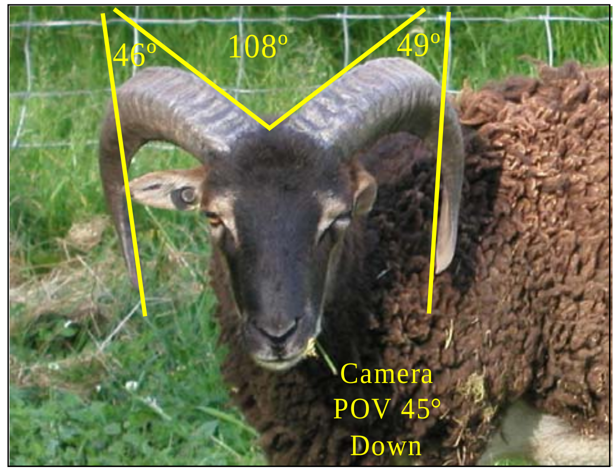


Figure 10. Juniper at 16 months, **alert**, camera roughly **45º Down** from plane of face.



The reason for the different apparent angle in the plane of the photo follows from simple geometry. This can best be illustrated by a simple demonstration one can perform. First draw a simplified horn pattern—one of constant divergence, that is, a "V"—on a planar surface (say, a 3x5 index card). Let's say the example "V" is 90º. If one scribes horizontal parallel lines at equal intervals, for example, on ½ inch spacing, then when the camera/viewing angle is normal[1] (90º) to the plane of the card, the angle will appear to be 90º. If, however, the card is tilted either forward *or* backward at the top of the card, then the *apparent* spacing of the horizontal lines decreases from the viewer's position. Since the width of the "V" in the horizontal direction doesn't change, but the vertical *appears* to be shorter, then in both cases, the angle that would be measured on a photograph taken from the observers POV (Point of View) would show a *larger* angle than the normal POV. It can be shown by experiment or trigonometry that the **minimum angle for such a simple case is when the POV is normal** to the plane of the "V".

While this would work in the simple case of horns growing in a plane, in fact the real world is more complex as the horns always spiral, thus, defining exactly where the reference plane should be gives some room for differences between observers. There is, however, one candidate for a reference plane that should be highly repeatable. I call it the "Nose Plane", and it would be practically defined by placing a flat rigid sheet (say a piece of plywood) so it rests on the nose and the two horns. It can best be shown by illustration (Figure 11). You can see that at least for Max (and for the other rams I have access to) the nose plane comes pretty close to being a tangent to the horn spiral as it exits the skull. Being normal to a tangent at any point of the horn spiral would be a repeatable POV, so this seems like a reasonable reference plane. Shifting to study of Max's skull, Figure 12 shows three candidate photographer points of view. What I call **45º Up** (camera up from nose plane) is what one would typically obtain from a **grazing** ram. The **45º Down** angle would be when the animal is **alert** (almost alarmed) and staring at the photographer. The repeatable, minimum angle POV is the **90º** view, often obtained when the subject is **relaxed** and neither alert nor grazing.

[1] It should be mentioned that for this section it will always be assumed that the observer's horizontal point of view will be along the centerline of the animal, thus will always be 90º to the central axis of the head / skull.

Figure 11. Max at 4 years. A repeatable "Nose Plane" would be defined by a rigid sheet laid upon the nose and horns.

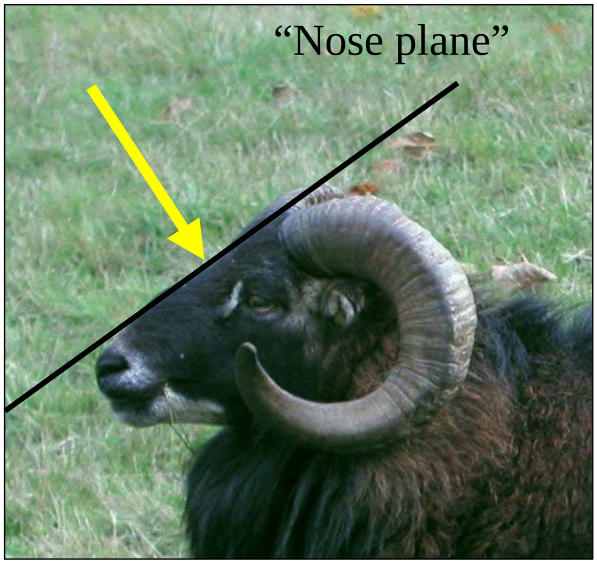
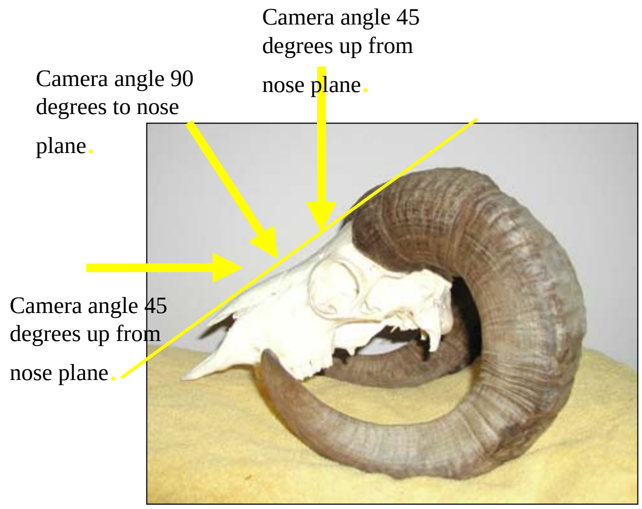


Figure 12. Max's skull, death after 4 years horn growth. Three POV angles that might be readily obtained by a standing photographer observing a live animal from a distance.



Second (Year) Angle

When a ram with a typical second year's horn growth is observed normal to the nose plane, there is a second angle (beyond the basal angle) that could be measured. This is shown in Figure 13 for Max's skull and in Figure 14 for Fedan. Note that it is difficult with some horns (Max in particular) to decide whether the angle is formed by the inner or outer surface of the horns, and depending upon the twist, these two may be quite different. On some with small clearance, like Fedan, some judgement is required to define the second angle, as it is not shown explicitly in the photograph. Additionally, the sensitivity of the appearance of the second angle in the photo to the normality to the nose plane makes this second angle measurement one which would likely not be very repeatable with the same observer, much less between observers. While it does not seem to be a good candidate for one of the critical few key measurements, it may well be a good way to quantify the development of horn patterns on a single ram over his lifetime. It does, to a fair extent, merely reinforce the more directly assessed clearance aspect.

Figure 13. Max's second angles.

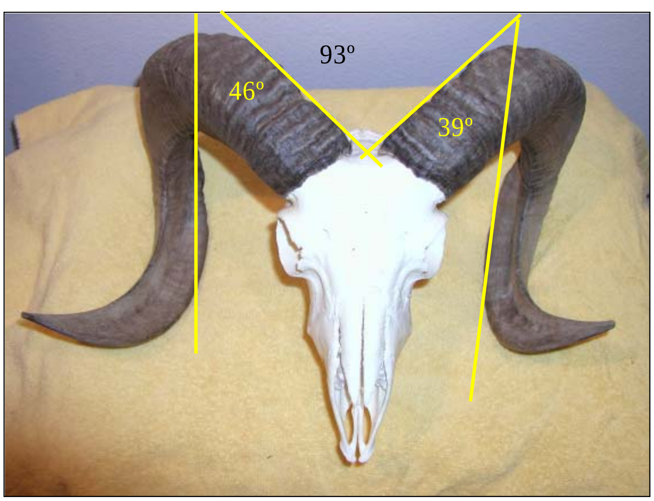
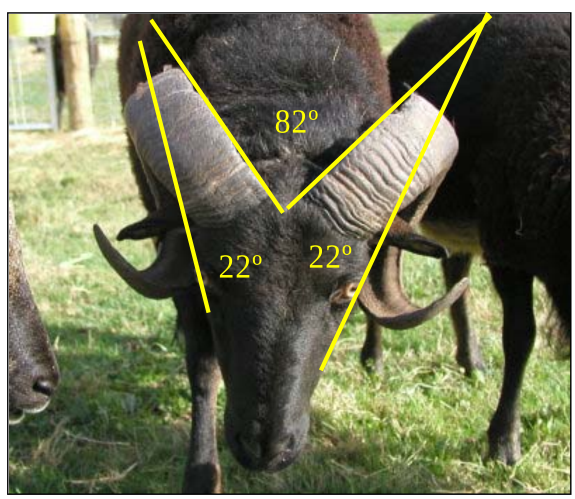


Figure 14. Fedan's second angles.



Diameter of spiral

Given the range of spirals as shown in all types of sheep (see Figures 15 and 16), the range of variation in spiral diameter one can observe in Soay sheep, either in person or via internet photographs, is quite narrow. Variation in spiral diameter is, in my brief experience, rarely mentioned as an important trait, and thus I suggest it is not among the critical few measurements.

Figure 15. A very tight spiral in horned Dorset.

Figure 16. A very large diameter spiral in Mouflon.

Basal circumference

Hunting organizations utilize horn diameter measurements (along with spiral length) to suggest the “massiveness” of trophy bighorn sheep. While it would be quite easy to measure the basal diameter, or circumference, of the horns, this would only be relevant when compared to the rams age, and as such it is likely that a subjective assessment of simply heavy or light would suffice, and in fact it is probably not among the few measurements worth trying to maintain (although some might disagree with this view).

Intra-annual ridges

Many, but not all, rams have a distinct ridge at the junction of each annual growth increment, but some additionally have noticeable patterns of ridges between these annual ridges. Others have virtually smooth horns with no ridges. Again, if worth mention at all, a brief description such as smooth, small ridges, or large ridges should suffice.

Horn length

A standard convention for measuring horn length has been used by big game hunting associations for years. The distance outside the curve from base to tip is measured with a flexible tape. Each horn can be measured separately. While this measure is easy to accomplish, and repeated measurements on the same ram would quantify horn growth rates, it does not seem to be a critical measure for the key aspects that concern most breeders (width or clearance).

Combined length, angles, and symmetry

As I studied Max's skull and horns for this work, I became aware that, at least with a skull, one could make a 'map' of a rams horns in one plane by 'unrolling' the horn spiral onto a flat surface and measuring simultaneously the length, width, and any asymmetry. Imagine the skull as shown in Figure 12, but inverted so that the nose plane rests on the table surface. With a sheet of paper on the table one could trace either or both the inner and outer surfaces of the horns onto the paper as one rolls the horns and records the horn location as the tangent of the spiral intercepts the paper. This is actually a fairly difficult process, even with a skull, so an alternative that results in nearly the same record was devised. If one wraps a flexible measuring tape around the outside curve of a rams horns, one can measure the total length from base to tip. If, in addition, measurements of distance between inner surfaces, and from a centerline, are added at intervals, a full mapping of the horn pattern may be constructed, including length, angles, and symmetry. This was accomplished with Max's skull by marking masking tape at 2-inch intervals, then wrapping the tape around the outside of each horn's spiral (See Figures 17 and 18).

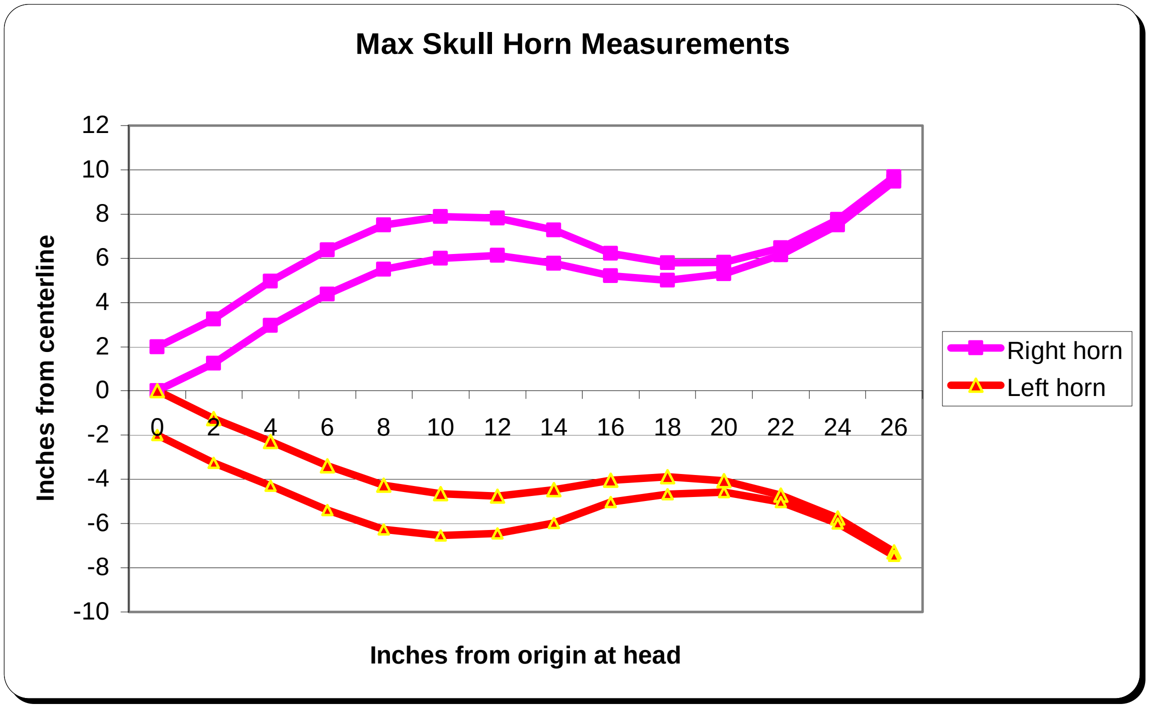
Figure 17. Reference tape on Max's horns. Marks every 2 inches.

Figure 18. Example: Width is 4.25 inches from centerline on left and 5 inches from centerline on right for a total of 9.25 inches wide at 16 inches from base.

These measurements can then be transferred to a flat surface (that is, plotted), and for Max this results in the "horn map" shown in Figure 19. If such a chart is drawn such that the y-axis scaling is equal (per inch) to the x-axis, then the angles will also be portrayed correctly at any give location.

Such a horn map simultaneously displays basal angle, horn diameter (roughly) at any point, horn length, asymmetry, clearance, and tip divergence. One could add angular reference points in the plane of the spiral (say, at 90 degree intervals) and the plot would then also include a measure of horn diameter.

Figure 19. Map of the inside edge of Max's horns as if the spiral were unrolled onto a flat surface.



While this measurement method is appealing to me, performing it on a live animal is difficult, with the neck and head interfering with many or most of the measurements. It would require some sort of large calipers to perform properly, and as such seems fairly impractical. The only purpose I could envision that might make it worthwhile, for a specific study, would be to gather data to examine the question about whether the horns remain in the same relative position (compared to say, the skull) as they grow in length. That is, do the horns always "follow the tips", regardless of where the tips go, or instead do the horns actually get wider or narrower at a given point? It seems doubtful to me that such a complex measure would be embraced widely and routinely.

Symmetry

A number of the measures already discussed could quantify the degree of symmetry. For example, recording both the left and right clearance separately would suffice. Measuring the basal angle in two separate portions, each from a centerline reference would also suffice. The detailed 'unspiralling map' shown above would also suffice. Therefore, symmetry can be assessed with many of the other measures.

Tip Twist Angle

It can be observed that the tips of many Soay ram's horns are largely blade-shaped in cross-section, thus one could measure the angle formed with the long axis of that blade shape and the vertical. For example, in Figure 4 one can see the tips of Max's horns are nearly horizontal, while in Figure 10, Juniper's tips are either straight vertical or only slightly tilted outward. In just the relatively short period I've been observing rams horns develop, I have seen the tips of 2 to 3-year old rams changing angles, so until some correspondence between tip twist at an earlier age and final mature horn configuration is established, it does not seem that widespread measurement of this aspect should be promoted.

Tips converging or diverging

It can be seen that the tips of some mature rams horns diverge quite strongly (e.g., Max in Figure 2), and some are fairly straight (Fedan in Figure 1). As with the other tip measurements, until some data is collected over time from juvenile to maturity for a significant number of rams, whether this can be correlated to some early expression remains to be seen. It is not a measure that can be taken on young rams—when information is typically submitted for registration or flockbook data.

Cross-sectional shape

The literature describes some basic horn shape variations in wild sheep (roundly rectangular, oval, or circular). The works I have read suggest that the wild Mouflon is typically roundly rectangular, and the Soay rams horns I've seen are also of this basic shape. I do not see sufficient variation, nor any particular motivation to collect data about this trait (not to mention the difficulty of actually assessing it accurately without actually destroying the horn).

Conclusions and Recommendations

Soay rams horns are a very complex shape and are quite difficult to quantify precisely and accurately. While such measurements are possible, they seem beyond the level of effort most would want to undertake routinely. In order to collect some of the most important measures so that we can start to learn about patterns of development in individuals and inheritance, I recommend that we adopt the following as the few, key, precise measurements that we obtain on rams to be entered into any open community flockbook database.

1. **Clearance**: For rams old enough that the horn spiral is nearing the jaw (typically end of second year's horn growth—at about 16 months ram age, or late fall / early winter of ram's second year), Clearance of both the left and right horns should be either estimated by comparison to known common spheres, or better, directly measured on a captive animal. Report in inches.
2. **Basal Angle**: For rams old enough that the horns have defined a measurable angle (typically 3 or months of horn growth), measure the angle formed by the inner surfaces of the horns as depicted in a photograph taken normal to the nose plane (along the skull centerline and 90º to the nose plane).Report in degrees.

For those with enough interest in the subject of horn development in individual rams, I would suggest that at a minimum, annual photographic records be made for each ram – one normal to the nose-plane and one from each side, normal to the centerline axis of the ram to show the extent and diameter of curl. With these annual photographic records for a number of animals, over time we may well start to better understand how much of the mature ram horn geometry is influenced by genetics and how much by other causes.