**What is Conservation Breeding?**
A brief summary by Karen Gerhart, drawing heavily from A Conservation Breeding Handbook, 1995, D.P. Sponenberg and C.J. Christman.

Part 1: Background Information:
Breeders of purebred animals commonly employ one or more of the following breeding systems: inbreeding, linebreeding, and linecrossing. Each has advantages and disadvantages, and a breeder may wish to use only one system, or all three at different points to reach different goals.

Inbreeding: Defined as "mating together animals which are related so that the resulting offspring have one or more ancestors that occur on *both* the sire's side and the dam's side of the pedigree." Close inbreeding would include the mating of full siblings, or father to daughter; more distant inbreeding might involve second cousins.

While inbreeding can be an emotionally charged subject, in itself it is neither good nor bad. Inbreeding tends to bring recessive traits (in St Croix, these would include colors other than white) to the surface; because of this, it should always be coupled with selection for excellent breed characteristics and the strict culling of individuals with undesirable traits. Used in this way, inbreeding tends to increase uniformity and consistency within a flock, and it has been used in the formation of most breeds. The St Croix breed started with only 22 bred ewes and 3 rams, and therefore all mating within the breed today involves some degree of inbreeding. However, for practical purposes, recent relatives have the most genetic impact and usually only the first 5 generations of the pedigree are considered when inbreeding calculations are made.

Inbreeding can lead to "inbreeding depression", a reduction in vigor, fertility and disease resistance. Studies of wool sheep suggest that each 1% increase in inbreeding corresponds to a reduction of 1.4 lambs born per 100 ewes bred, a reduction of 2.78 lambs weaned per ewe lambing, and a loss of 2.44 pounds per lamb weaned (Lamberson et al. 1984, as presented in the Sheep Production Handbook, 1995). However, breeds and populations differ in their tolerance to inbreeding depression; a general guideline used by the American Livestock Breeds Conservancy (ALBC) is to keep inbreeding below 5% per generation, and 30% in any individual.

Linebreeding: A form of inbreeding, linebreeding involves concentration of a particular ancestor within a pedigree (rather than several ancestors, as in other forms of inbreeding). Usually, this individual is a particularly excellent representative of the breed. The goal is to create a flock as much like this individual as possible, so matings often involve breeding half-brother to half-sister.

Like inbreeding, linebreeding reduces the variation within the flock, making the individuals more uniform and therefore more predictable. Again, the possible risk is inbreeding depression, including reduced vigor and reproductive performance. Strong selection and strict culling are necessary in a successful linebreeding program.

Linecrossing: A line (or strain) is a group of animals that are more closely related to each other than to the population as a whole. They might be the product of an inbreeding or linebreeding program. Linecrossing is the mating of individuals from one such line to those of another line. Generally, linecross individuals will show greater vigor, better growth, and more 'bloom', or 'presence' than individuals from either of the parent lines for at least the first generation. Thus, linecross individuals are more likely to succeed in the showring. Linecrossing can also be used to bring new vigor into an inbred or linecross flock.

Which is the best?

Each of these three breeding systems has advantages and disadvantages. If the goal is a *flock* with high predictability and low variability between individuals, then some degree of inbreeding or linebreeding will help the breeder achieve this goal. Individuals from such flocks will produce lambs much like themselves.

If, however, the breeder's goal is to produce excellent *individuals,* then linecrossing may be the better approach. These outstanding individual sheep may not be consistent in the types of lambs that they produce, however, and may not be able to produce lambs as good as themselves.

One advantage of a Conservation Breeding plan is that it can allow a breeder to include advantages of both linecrossing and linebreeding within a relatively simple program.

---

Part 2: So now that we have a common set of definitions, we can come back to the original question: What is Conservation Breeding?

Conservation breeding can be described as a breeding program that protects genetic diversity within a breed. A breed's long-term well-being and commercial utility depend on its genetic diversity. The breed benefits from the presence of many lines, as these distinctive genetic groups provide the material for linecrossing. If the distinct lines within the breed are lost, then there are no longer any groups within the breed to mate with to increase vigor, reproductive measures, and disease resistance, or to avoid a widespread negative trait; it also becomes more difficult to create an outstanding individual with bloom and presence. In extreme cases, breeders may be forced to bring individuals in from outside of the breed to address genetic problems caused by loss of genetic diversity.

Conservation breeding is designed to help a breeder maintain one or more lines, while also reducing inbreeding to manageable levels. In a conservation plan, each line of more closely related individuals is managed as a unit. This unit is alternately bred to a ram from within the line (linebred) and to rams from outside the line (linecross). All daughters are retained in the line, but linecross sons are not retained for breeding. The line as a whole retains its genetic distinctiveness, but inbreeding is reduced as the line consists of individuals with both more and less inbreeding.

---

Part 3: An Example of a Conservation Breeding Program

While there is no single, simple recipe that can be applied to all breeds or circumstances, the ALBC has designed a management plan to illustrate key requirements and to allow a breeder to more easily manage a flock within a conservation breeding program. This plan allows a breeder to keep three lines, but to use only one ram per year on his or her flock, by managing the three as one unit and using rams from different lines in different years. Each ram is used for only 1 year in the flock, so that his genetic influence is not excessive, and the genetic diversity within the line can be retained.

First, 3 groups of sheep must be identified to form the lines. Each group should be of approximately equal size, and consist of a number of ewes and 1 or more rams. Ideally, the sheep within a group should be more related to each other than to the flock as a whole, but the method of grouping is not critical. For instance, groups could be made by pedigree, with all descendents

of a particular sire or dam in the same group. Or, if the flock has been built from several other flocks, the groups can be formed according to these foundation flocks. These groups will then be considered lines within the flock, and will be designated in this discussion as lines A, B and C.

In the first cycle, the ram from Line A will be used on the entire flock. Ewe lambs that are sound representatives of the breed are retained in their mother's line, but may produce progeny for more than one line. For instance, lambs sired by the A-line ram and out of A-line ewes will be A/A (linebred, more than ½ A) and can only produce A lambs, but lambs sired by the A-line ram and out of B-line ewes will be A/B (linecross, with no line more than ½) and can produce lambs for the B line when bred to a future B-line ram, or for the A-line when bred to a future A-line ram. Ram lambs are kept only out of A-line ewes, and when mature, the best A-line ram is used for breeding (see cycle 4).

In the second cycle, the ram from the B-line is mated to all the ewes in the flock. Again, both linebred (B/B) and linecross (B/A, B/C) lambs are produced. Ewe lambs are retained in their mother's line, but ram lambs are retained only out of B-line ewes.

Finally, in the third cycle, the ram from the C-line is mated to the ewes. Now, the C-line is refreshed by the lambs out of the C line ewes (C/C, C/AC, C/BC and C/BAC). As before, ewe lines are kept in their mother's line, but now C-line rams are produced to replace their father.

In the fourth cycle, the new A-line ram is used. He is a son of the original A-line ram, and is out of an A-line ewe. He is used the same way that his father was, on all the ewes in the flock. Daughter are retained in their lines; his sons are kept to provide the 3rd generation A-line ram.

| Cycle | Ram used | Ewes bred | Offspring Produced | |
|---|---|---|---|---|
| | | | Linebred, save males and females | Linecross, save only females |
| 1 | A | A, B, C | A | A/B, A/C |
| 2 | B | A, B, C<br>A/B, A/C | B (includes B/AB) | B/A, B/C, B/AC |
| 3 | C | A, B, C,<br>A/B, A/C,<br>B/C, B/AB, B/AC | C (includes C/AC, C/BC, C/BAC) | C/A, C/B, C/AB, C/BAB |
| 4 | A | A, B, C,<br>A/B, A/C<br>B/C, B/AB, B/AC<br>C/A, C/B, C/AB,<br>C/BC, C/AC,<br>C/BAB, C/BAC | A (includes A/AB, A/AC, A/BA, A/CA, A/ABC) | A/B, A/C, A/BC, A/CB, A/CBC |

*Table modified for the short generation time of sheep. From Sonenberg & Christman. 1995. A Conservation Breeding Handbook. Page 81.

The key to this breeding program is that the genetic makeup of each line is alternating between inbred (linebred) and outbred (linecross). The distinct genetic identity of the line is retained, while the linecross individuals provide input of new genes, reducing the amount of inbreeding that the line accumulates. These linecross animals may also show hybrid vigor. Inbreeding is occurring in as many directions are there are bloodlines, so the genetic distance between the lines is maintained through time.

In contrast, most breeding programs attempt to reduce inbreeding across the entire flock at the same time. The consequence is that inbreeding slowly accumulates in the same direction throughout the flock. Thus, there is no outcross available within the flock and the breeder must seek outside the flock to bring in new vigor or to address other inbreeding problems. If other breeders have used similar strategies in managing their flocks, there may not be any flocks with enough genetic distance remaining to provide a true linecross, and the vigor sought may not be obtainable within the breed.

For a conservation breeding program to succeed, there must be enough individuals within each line to produce a good replacement male and several replacement females at every breeding cycle. Additional animals are required if the breeder wishes to select for better conformation, size, or production. The ALBC suggests a minimum of 10 females per line (including both linebred and linecross females). However, if your flock management results in a large percentage of twins and triplets, this number can be reduced somewhat.

---

Part 4: Three Disadvantages to Conservation Breeding:

While conservation breeding plans are a useful tool to maintain genetic diversity, there are disadvantages to using this sort of breeding system.

1. Rams within this program have a short breeding career, since use of a ram for more than a season or two will lead to a genetic bottleneck, that is, a reduction in the genetic diversity contained within a line. This can be frustrating for breeders who wish to develop and use an outstanding male over many years.

2. Selection of breeding animals must focus on the benefits of the animal to the entire flock, rather than on the traits of that individual alone. For instance, a breeder might select a moderately inbred ram even when a linecrossed ram has superior conformation. The inbred ram is expected to produce individuals more like himself than is the linecrossed ram; the inbred ram also works to conserve the line that produced him. The outstanding linecross rams can be sold to other breeders.

3. Finally, for a conservation program to succeed, the breeder must focus on longterm objectives and must break away from many established practices in animal breeding. This can be difficult for many breeders.

For more information, please read A Conservation Breeding Handbook, contact the ALBC, or contact the author of this summary.

---

What is a Coefficient of Inbreeding?

A coefficient of inbreeding is a measure of how much homozygosity we expect as a consequence of inbreeding. Sheep and other animals have two copies of each gene, one of which came from each of that sheep's parents. These two copies may be different from each other; different forms of a gene are called alleles. Genes are said to be homozygous when an individual has two identical alleles for a trait; when the two alleles are different, the individual is said to be heterozygous for that trait (or that gene). We don't yet have the technology to inexpensively

measure the actual gene combinations, but we can calculate the probability the alleles will be the same by looking at the pedigree.

Each parent contributes 50% of their genes to their offspring. Thus, half-siblings (like Ram B and Ewe C in the example below) have 50% of their genes in common. In this case, both were sired by Ram D. But Ram B and Ewe C may have from 0 to 50% of their genes in common with each other – that is, of the 50% of the Ram D genes that Ram B received, somewhere between all or none of those genes may have also been sent on to his half-sibling Ewe C. On average, they will have received the same genes from Ram D half the time – so they should share 25% of their genes with each other.

Now, if the half-siblings are bred together, they each contribute half of their Ram D genes (half of 50%, or 25%) to their offspring. On average, their offspring are expected to get the same Ram D genes from Ram B and Ewe C half the time – so Sheep A is expected to be homozygous for 12.5% of its genes.

Table 1. Pedigree of sheep A (12.5 percent co-efficient of inbreeding)

| | | |
|---|---|---|
| | | Ram D |
| | Ram B | |
| | | Ewe E |
| Sheep A | | |
| | | Ram D |
| | Ewe C | |
| | | Ewe F |

Table 2. Some possible relationships between a ewe and a ram, and the resulting coefficient of inbreeding for their offspring:

| Relationship between the parents | Coefficient of inbreeding for the offspring |
|---|---|
| Father-daughter, mother-son | 25% |
| Half-siblings | 12.5% |
| Grandparent-grandchild | 6.25% |
| First cousins | 6.25% |

When multiple ancestors are found on both the sire and the dam's pedigree, the calculations for coefficient of inbreeding become more complicated. A thorough discussion of 2 different ways of calculating a COI, and the errors involved in using only 5 generations of data to do so (using Thoroughbred horse pedigrees), is Coefficients of Inbreeding: An Investigation into Wright's Equation and Hardiman's Method.

With the advent of computers, it is much easier to use a software program to calculate coefficients of inbreeding than to calculate them by hand. There are various software programs available for this purpose, from free-ware to relatively expensive pedigree programs.