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In 1946, I began the periodic observation of several beaver colonies located near my family's summer cabin, in Crow Wing Co., central Minnesota. From 1953 to 1956, a detailed study of the colonies was conducted as a Junior Academy of Science project. During this period, several new colonies were established and many of the older ones abandoned. A study of aerial photographs, followed by a ground check on foot or by canoe, turned up many other beaver colonies, some active at the time of discovery and many apparently long deserted.

In searching for a method of ascertaining when these workings had been started or last occupied by beaver, a Swedish Increment Borer was obtained and a study begun of the growth layers of trees growing near beaver ponds. Trees were chosen that were growing close enough to the water table so that aeration of their root systems would be reduced by very slight rises in water level. Many of the trees studied showed several years of very slow growth, preceded and followed by many years of much greater growth. A cross check with trees growing nearby on high ground showed no similarity in relative growth rates for this period, thus tending to rule out insects or climatic causes. A comparison of the ring pattern, of trees growing at low sites, with the records kept on these ponds since 1948, showed a perfect correlation between the known dates when the areas had been ponded and the years of very slow growth as shown by unusually small rings formed these years.

A close correlation has been noticed between high ground water and abnormally slow growth in trees. One of the earliest mentions of this is well illustrated by Weaver and Clements (1929:34, Fig. 23) who show marked increase in ring width of tamarack following swamp drainage. A more recent study, of the growth rates in a tamarack bog, revealed that ring widths were narrow during extended

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periods of high precipitation (Isaak *et al.*, 1959). Inadequate aeration of the tree roots, due to a rise in the water table, is thought to be the direct cause of the very narrow growth layers.

MATERIALS AND METHODS. Beaver colonies can usually best be reached and studied by means of an aluminum canoe, which can be paddled up very small streams, dragged over beaver dams and snags without being damaged, or if necessary, can be carried over land to reach navigable sections of a stream or beaver pond. It may be possible to observe some ponds on foot, but travel on the shore of beaver ponds is very difficult most of the year; however, during the winter months, if the ponds and streams are covered with ice solid enough to walk on, many otherwise inaccessible colonies can be reached on foot, by means of skates, or if the ice is snow covered, by skis or snow-shoes which reduce the hazard of breaking through thin ice. A sharp metal tipped ski pole is used to test the ice, and will penetrate ice that will support a skier, but not a person on foot.

RESULTS. *Observable Features:* Upon reaching a beaver colony, a general survey is made of the dam, pond, and the shore line of the stream for at least one quarter mile in both directions. While beaver are not usually sighted in broad daylight, their active presence in a colony is indicated by many signs. Signs of recent beaver activity most easily spotted are listed below.

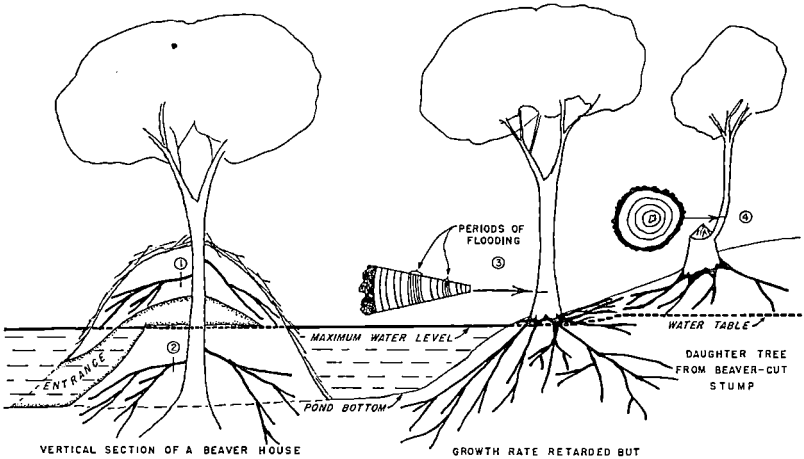
1. The dam is well maintained and the pond is level with its top.
2. There are many green, freshly cut and peeled twigs and logs on top of the dam and house, especially in the spring.
3. Unpeeled branches cut so recently that the leaves have not wilted; a period of less than one day if the branch is on land, up to several weeks if the cut end is under water, even if it has sprouted no roots.
4. Fresh unweathered stumps and partially cut but still standing trees.
5. Fresh tracks or drag marks at the point where trails from the cutting grounds enter the water.
6. In the autumn, a large number of green unpeeled logs and branches stuck vertically into the bottom in deep water near the house.
7. If the house is approached quietly, a splash may be heard and a stream of bubbles observed, as the beaver leaves through the under water exit.
8. On very cold winter days, a wisp of steam may be observed coming from the vent in the top of an occupied house. If the beaver house is covered with snow, the vent will show as a small thawed area.
9. A new dam is recognized by green branches at both the top and bottom of the dam and the presence of many living land plants standing in the water throughout a large part of the pond. Trees will usually die if their roots are completely submerged for a month or more, but many kinds, such as tamarack, black spruce, swamp willow, and alder, are able to survive longer periods of flooding.

If the majority of these signs are absent, especially if the pond has dropped so that the entrances to the house are exposed, then it is very unlikely that there are any beaver yet present.

Dating the founding of a colony: New colonies, less than one year old, can be easily recognized by the obvious newness of the dam and other signs previously mentioned. Keeping in mind the fact that new colonies are usually started in spring or summer, one can estimate their age at any time during the first year by simply noticing the degree of progress at the time of first observation.

A new colony will often be located on a site formerly occupied and then deserted by beaver. The new occupants will take advantage of any surviving structures. These, often after only a few years of disuse, are covered so completely by vegetation that the casual observer fails to recognize them as beaver structures. If noticed at all, old beaver dams are often mistaken for earth ridges of some other origin. Any breaks in the old dam will be repaired, restoring the pond to its former level. The old house may be renovated or, if completely collapsed, used as a foundation for a new lodge. By keeping this possibility in mind, a renewed colony will be recognized for what it is and not mistaken for an old continuously occupied one.

An active colony, that is more than one year old, can be dated by using one or several of the following methods: The minimum number of years since founding can be ascertained by a count of the growth rings of any trees found to be growing on the dam or house. In cases where there are trees growing through, rather than on, one of the beaver built structures (Figure 1:1) a ring count on any roots found growing into the structure above the original ground level will give the minimum age of that structure. A ring count may also be made on daughter trees that have originated as sucker shoots from the



stumps of trees cut by the beaver (Figure 1:4). The date the original tree was cut can thus be learned, and if it is the oldest at that site, it may be assumed to show the year of founding of that colony.

A very complete description of the methods used in tree ring analysis can be found in Glock (1937); therefore, no attempt is made to give the details here.

Ascertaining the period during which a site was flooded: If groups of very narrow rings are found in trees growing near a beaver pond, or former pond site, they may provide the most accurate record available of the period during which the colony was occupied and the pond was flooded. Another record may be found in any tree tilted as a result of the presence of the beaver; it will show a striking change in the symmetry of its growth layers the year of tilting, or the following year if tilted after the growing season had passed. Frequently trees are tilted through undermining caused by water impounded or diverted by a beaver dam. A tree may also be tilted from pressure from another tree felled against it by the beaver. Tilting of a living tree due to any cause will result in the following changes: While erect, the growth layers will have formed in concentric rings about the growth center; after the tree was tilted, the rings will have formed eccentrically, so that in conifers 80% or more of the growth may be on the lower side. In most broad leafed trees, the reverse situation will occur with the greatest growth on the upper side of the growth center (Lawrence 1950).

The method which has proved most useful in the writer's experience is the following. A cross section or boring is taken from a living tree which is growing on soil that is just above the level flooded by the beaver. If this near flooding has existed continuously for at least one complete growing season, the date of its onset will be shown by a marked decrease in the size of the rings formed from that time on until the flooding abated or the tree was killed. If none of the trees survived the flooding, the date on which they died can sometimes be worked out by cross dating. If the pond has been flooded and drained several times during the life of a surviving tree, each flooding will be shown as a group of very narrow rings preceded and followed by bands of much broader rings (Figure 1:3). In some cases these groups of narrow rings may be preceded by an unusually wide ring, since if the water in the pond was raised slowly, the tree may have had a year of rapid growth because of the readily available water which had not yet risen high enough to interfere with the aeration of its roots.

Dating the draining of the pond: The drainage of a pond may occur rapidly through a sudden wash-out or dynamiting of the dam, after which the beaver left, were killed, or were removed by trapping, before repairs were made on the dam. In cases of this type, the date of drainage can usually be ascertained by a slight variation in the method mentioned just previously for dating the onset of flooding. A series of

broad rings, in a tree growing close to the water table, starting abruptly after a group of narrow rings (Figure 1:3) clearly indicate that the high water subsided within a period of less than one growing season. The first broad ring following the narrow rings marks the first year after drainage of the pond.

Many dams continue to hold water for years after the beaver have departed. The water level in the pond will remain constant or drop only very gradually over a period of many years as the dam slowly rots away or is slowly eroded by the water with no sudden washouts occurring. In cases where this has occurred, there will be no sudden change in ring size. Instead, there will be a very gradual change from small to large rings as the water drops but a few inches each year, until the water has dropped to the point at which the trees are helped by its presence rather than hindered. At this point, very broad rings will be formed. If the dam holds the water at this optimal level for a few years, a series of uniformly broad growth rings will result. If the dam subsequently fails completely, allowing the water table to drop out of reach of these trees, this will appear as a sudden onset of fluctuation in ring size as the tree becomes dependent on rainfall rather than subirrigation as a source of water.

The minimum number of years since a pond has dried up can often be found by counting the rings of shrubs or trees found growing on the formerly flooded—but now drained—pond bed. Since they must have started growing only after the pond had emptied, the length of time they have been growing can be no greater than the period since the site they are on was last flooded; usually it is a year or two less than that period.

Dating the latest occupancy by beaver: If one wishes to learn the date of the most recent departure of the beaver, this can be found by the following procedure. If it is apparent that the pond drained rapidly, the date of drainage is the latest possible date of abandonment, for the disaster may have precipitated desertion of the site by the beaver or have coincided with their removal by man; this is indicated if the dam was dynamited. A date independent of that at which the pond drained, can be found by dating the most recent beaver sign to be found in the area. For example, the last year food was stock-piled can be found by cross dating any logs remaining submerged, and thus preserved, in the deepest part of the pond, the usual site of the winter food store, with a living tree of the same species from the area. Other evidence is to be found in the cutting grounds. There may still be a stump or log in good enough condition to permit determination of the cutting date, by cross dating it with some nearby living tree. Also there may be trees scarred by beaver which can be dated by a ring count on the wood formed in healing or callousing the scars. A detailed description of the procedure used in cross-dating con be found in the studies by Stallings (1939), and Schulman (1956).

SUMMARY: 1. The year in which a beaver pond was first flooded can be found by:

a. Ascertaining by cross-dating the year of death of trees flooded by the pond.

b. Studying the rings of trees not killed but retarded by the flooding.

2. The approximate date on which beaver last inhabited a site is found by dating the newest beaver sign still available.

3. The date a pond went dry is indicated by:

a. The age of trees growing on the drained pond bed.

b. The increase in size of the growth layers of trees previously retarded by the high water and benefited by its lowering.

4. Evidence that a site has been occupied and deserted by beaver several times, may be found in the rings of trees growing at the edge of the pond, close enough to the water table to have been effected by the fluctuations in the ground water level which were caused by the beaver activity. In such cases, sets of narrow rings reveal when the water table was high enough to interfere with aeration of the root systems, thereby inhibiting water absorption and growth.

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