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THE EPICENTER CONCEPT IN FOREST INSECT CONTROL.

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Stehr (1969)[1] states that "epicenters are the initial locations of insect outbreaks", and goes on to point out that there are two possible interpretations of the phrase "initial location of an outbreak". i.e. "Either the insect population that grows up in such a location will begin to spread into the surrounding territory, thereby constituting a colonizing population; or there is no actual spread but the epicenter is merely the spot at which a general and already widespread population surfaces first, the surface being some recognizable density level". Macdonald (1968)[2] seems to be in an intermediate position, and considers that "these potential epicenters will be areas where conditions are most frequently ideal for budworm growth and survival". Apparently he envisages a physical spread from these areas in sufficient magnitude to induce an outbreak in the surrounding areas, but does not imply any inherent superiority in the spreading population.

The foregoing definitions, if you want to call them that, are too vague for critical examination or discussion. I shall therefore redefine the term as follows:

I. Genotype-epicenter - A strain or variety appears in an area, either through natural selection or immigration, that has superior survival power, sufficient to allow it to build up in numbers more rapidly than the resident strain and to eventually replace it.

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[1] Stehr, G. 1969. Proc. Ent. Soc. Ont. 100:54-56.

[2] Macdonald, D. R. 1968. For. Chron. 44:33-36.

II. Environment-epicenter - (a) No radical change in the genetic makeup of the species is involved in this concept. It recognizes that a certain minimum density is required to maintain populations during periods of adversity, and that survival of populations is most likely to occur in epicenters because conditions in these areas are more favorable than elsewhere. It also is implicit in this definition that populations outside of the epicenters are much less likely to "escape" from natural control agents than those in the epicenters unless they are augmented by "spillover" from the epicenters.

(b) In this version, the epicenters are those areas where populations "surface" first, but there is no actual spread from one area to another. If there is no spread, this version does not lend itself to control measures, since the outcome in one area is not dependent upon populations in another.

The problem now becomes a matter of determining which of the three concepts apply to a particular situation. I shall briefly review the outbreak histories of three defoliators, the larch sawfly, the spruce budworm and the forest tent caterpillar, to see which concept seems to fit each.

Maps prepared by Muldrew[3] show that an outbreak of the larch sawfly started in Manitoba in 1938 and by 1942 covered much of the southern part of the province. It gradually intensified and spread until by 1953 the out-

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[3] Muldrew, J. A. Northern Forest Research Centre, Edmonton. Personal Communication.

break extended from the Alberta-Saskatchewan border to north-central Ontario. In 1954 populations subsided in much of the older portions of the outbreak, but continued to spread to the east and west. By 1962 the sawflies were infecting most of Alberta and infestations had extended along both sides of the St. Lawrence River in Quebec. During the next three years the severity of the outbreak started to decline over most of the area, while spreading into the Maritimes and northeastern United States. By 1966, infestations had disappeared from most of Alberta, Saskatchewan, eastern Ontario and Quebec, although a new outbreak appeared to be starting in southeastern Manitoba.

Maps prepared by Brown (1970)[4] show that an outbreak of the spruce budworm started in 1918 in western Quebec, and by 1921 it had extended into Ontario. Between 1923 and 1926 several infestations were reported in northwestern Ontario and eastern Manitoba, but these disappeared by 1927, leaving only the infestation centered around Timmins in northern Ontario. The area infested remained fairly static until 1939, when there were definite indications that it was starting to spread. By 1941, the outbreak covered most of Ontario and scattered infestations were reported throughout southern Quebec. It continued to spread and increase in severity, until by 1946 the outbreak extended from west of the Lakehead to the Gaspé Peninsula. By 1948, most of New Brunswick was infested. In 1949 the outbreak subsided in parts of Ontario, although it continued to spread in the Maritimes. Most of the original outbreak had subsided by 1954, but the area affected in northwestern Ontario expanded considerably, and continued to do so until 1958. In 1959 there was a general decline, which continued for

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[4] Brown, C. E. 1970. Can. For. Ser. Pub. No. 1263. 4 pp.

several years. The only major infestations remaining by 1964 were in New Brunswick.

The outbreak histories of the larch sawfly and spruce budworm show marked similarities. The outbreaks appear to have arisen in a central location and to have spread out from these areas. Whether or not there has been a physical spread of insects cannot be determined from a superficial examination of a series of maps. However, the average annual distances involved, 70 miles per year for the larch sawfly and 85 miles per year for the spruce budworm, suggest that mass invasions were unlikely, and that the apparent spread may have been due to a wave-like build-up in local populations in response to favorable weather conditions, although this has not been documented and seems unlikely. Colonization by long range dispersal of a superior genotype therefore seems to be indicated.

In the case of the larch sawfly, there is strong circumstantial evidence that a superior genotype did in fact spread out across the country. In 1912 and 1913 cocoons containing the icheumonid parasite *Mesoleius tenthredinis* Morley were released in southwestern Manitoba. The introduction was initially successful, but when the larch sawfly again reached outbreak proportions in 1945 it was noticed that many of the eggs were encapsulated in a translucent sheath which prevented hatching.

Subsequent research revealed that this encapsulation was due to an immunity reaction in some strains of larch sawfly. Those from Manitoba showed the encapsulation reaction, while those from other areas did not. There was a continual spread of the encapsulation reaction, both east and west, until by 1968 the only areas where this did not occur were on western larch and in Newfoundland.

A number of explanations could be advanced to account for the observed phenomenon. We think that the following is the most plausible. The original source of the introduced material was England, where subsequent research has revealed a small proportion of sawflies displaying the encapsulation reaction. Some of these resistant sawflies must have been collected and accidentally released in Manitoba, since parasitized cocoons were placed in the field, rather than parasite adults. During the next 25 years their population gradually built up, until they outnumbered the resident population. The larch sawfly is parthenogenetic, so there would be little or no dilution or mixing of the genotype. It therefore seems a fairly safe assumption that the outbreak that I have outlined was a physical spread of a superior genotype, unlikely as this may seem to be to anyone familiar with the flight habits of the larch sawfly.

The marked degree of similarity between the outbreak history of the spruce budworm and the larch sawfly raises the question of whether or not a genetically superior strain of spruce budworm spread across the country from a point of origin in western Quebec. If a gene favoring survival did in fact originate in this area, it would take several years for the population to build up to recognizable levels, and a 25-year period between the origination of a genotype and its eventual spread is quite possible.

If a superior genotype is involved, little in the way of control measures can be done. The chance of being able to recognize a new genotype soon enough to prevent its spread seems so remote that there is little to be gained in pursuing the topic any further. However, one should be extremely careful about moving insects from one part of their range to another, even in the same country, as there is always the possibility that there may considerable genetic variation, and the transferred strain may be superior to the local strain.

The situation for the forest tent caterpillar is quite different from the above. During endemic periods the populations drop to very low levels, and few, if any, insects are recovered, in spite of extensive sampling. The insect may therefore become locally extinct over parts of its range, and populations may exist only in the more favorable locations. Where these locations might be, and how many, cannot be determined from survey data. Indications are, however, that local populations persist in most parts of the country, so that refugia, rather than epicenters, might be a better term to use. From the original locations the infestations spread out until they amalgamate with adjoining areas, but long distance movements of the outbreaks do not seem to occur, at least in the same sense as already outlined for the larch sawfly and spruce budworm.

There are a number of similarities in the life cycle of the forest tent caterpillar and the spruce budworm. Both spend the winter in the crowns of the trees, one as unhatched larvae within the eggs and the other as unfed larvae within hibernacula. Thus both are exposed to the elements for long periods of time while in an inactive state. For the forest tent caterpillar, I have found that there is a relation between temperature and the initiation of outbreaks. Favorable temperatures 2 - 4 years prior to noticeable defoliation seem to trigger the build-up of populations. I can't help wondering if something similar might not apply to most outbreaks of the spruce budworm.

In conclusion, I would like to raise a number of points that I think should be given serious consideration before deciding if the epicenter concept has a useful bearing on insect control.

1. How numerous are the epicenters and how well defined are they? If numerous and/or ill defined, the amount of time and effort required in identifying and deliniating them would probably be prohibitive.

2. How favorable to survival are the epicenters? If survival in the epicenters is only slightly greater than in surrounding areas there is little liklihood that elimination of infestations will prevent an eventual erruption in the surrounding areas, except perhaps near the limits of distribution for a species.

3. How much "spill-over" is required to start an outbreak in areas surrounding epicenters, assuming these do exist? If the amount is small, the control may be ineffective, or alternately have to cover such a large area as to be economically impractical.

4. How often would control measures have to be applied? Unless control was 100% effective, several applications might be required to stop a population build-up, and costs could soon become prohibitive.

5. Assuming dispersal of the species occurs, what is to prevent insects from the areas surrounding the epicenter from moving into it? If this occurred, control might have to be applied again and again.

In the foregoing, I have assumed that control measures stopped short of removing the host trees. Harvesting of trees in high hazard areas, as suggested by Macdonald, would certainly be a practical and effective approach, assuming that the areas can be identified and that logistics made harvesting economically feasible.