Internal Report 37

ANNOTATED BIBLIOGRAPHY ON THE ROLE OF FOLIAGE-FEEDING INSECTS IN THE FOREST ECOSYSTEM

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This bibliography, an apparently haphazard sampling of literature from many sources, grew out of a general project that was intended to elucidate the role of consumers in the forest system. The 124 articles briefly abstracted here are ones that give some insight into the role of foliage-feeding insects. The process of consumption and its effect on the forest were explored most thoroughly. This is by no means a complete listing; however, some review articles are cited that will provide an in-depth look into a few specialized subjects.

I had three objectives in this search of the literature: (1) to locate materials relevant to the impact or role of foliage-feeding insects in the forest system, (2) to aid in forming concepts of possible control functions exerted by these insects, and (3) to find information necessary for building energy-flow models. Literature strictly related to the stated objectives was scarce. Closely allied fields also were explored and articles containing data, models, and background information on insects in other systems are included in the bibliography. Population models are not included, because some good bibliographies already list them.

Originally, the direct impact of insects on forest trees was the subject for the literature search, but the subject was expanded as more facets of the role of foliage-feeding insects became apparent. The topic was expanded to include (1) the gross observed impact of defoliation and (2) aspects of tree physiology that could be affected by insects, but where insects are not directly considered. Because the process of consumption was an important focal point, literature on factors that affect consumption rates--such as feeding stimulation, assimilation efficiency, ability to locate food, nutritional requirements, and food quality--also were explored. Insect energetics and environmental effects on physiological processes were included in the literature search to aid in the formulation of energy-flow models. I hope this bibliography will serve, not just as a listing, but as a stimulant to a greater expansion of the topics explored.

Each article included here has been abstracted briefly and given a set of key words. Some articles were of interest mainly because they contained relevant data. How these data were related is included in the abstract. A sampling of the table headings gives the gist of the contents. Articles with background material for concepts may have only topics of discussion listed. Key ideas were given when these could be expressed briefly. Many articles contain much more information than is indicated by the abstract or key word set. Inclusion of articles and of specific information within their abstracts was at the discretion of the reviewer with, presumably, the rational objectives in mind.

KEY WORD LIST

Included with all articles:

DATA 1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16, 18, 19, 20, 22, 24, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 40, 41, 43, 45, 46, 47, 48, 49, 50, 51, 53, 54, 55, 57, 59, 60, 64, 65, 66, 67, 68, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 108, 109, 110, 111, 112, 114, 115, 116, 117, 118, 119, 120, 121, 123, 124

NO DATA 3, 13, 17, 21, 23, 25, 37, 38, 39, 42, 44, 52, 56, 58, 61, 62, 63, 69, 89, 105, 106, 107, 113, 122

MODEL 46, 81, 82, 84, 94

REGRESSION MODEL 4, 57, 59, 104, 108, 109

NO MODEL 1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 58, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 83, 85, 86, 87, 88, 89, 90, 91, 92, 93, 95, 96, 97, 98, 99, 100, 101, 102, 103, 105, 106, 107, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124

Referring to the process of consumption by the insects:

FEEDING RATE 2, 16, 20, 22, 24, 46, 48, 49, 53, 57, 60, 77, 79, 93, 94, 98, 103, 108, 110, 111, 112, 119

FEEDING BEHAVIOR 5, 6, 20, 39, 75, 78, 87, 103, 115

FEEDING STIMULATION 23, 25, 37, 38, 44, 51, 55, 89, 97, 105, 106, 107

FOOD QUANTITY 2, 13, 16, 19, 26, 64, 81, 92, 115, 121

FOOD QUALITY 1, 6, 8, 9, 12, 21, 25, 26, 27, 28, 31, 32, 36, 51, 53, 56, 73, 74, 89, 95, 97, 98, 110, 1111, 114

NUTRITIONAL REQUIREMENTS 2, 6, 25, 37, 42, 46, 52, 53, 54

ASSIMILATION EFFICIENCY 22, 24, 34, 54, 60, 94, 95, 98, 103, 110, 112

EXCRETION 2, 22, 57, 111

ENVIRONMENT 1, 4, 12, 15, 81, 90, 109, 115, 122

Referring to the insect population:

POPULATION QUALITY 71, 96, 116, 117, 118, 119

POPULATION NUMBERS 21, 26, 27, 75, 81, 82, 87, 91, 93, 99, 117, 120, 124

LARVAL DEVELOPMENT 1, 4, 6, 8, 15, 16, 28, 31, 32, 47, 54, 60, 90, 109

LONGEVITY 1, 12

FECUNDITY 1, 8, 9, 12, 26, 27, 28, 56, 81, 119, 122

MORTALITY 6, 8, 9, 11, 26, 47, 51, 78, 80, 81, 82, 91, 93, 95, 101, 115, 118, 122, 123

ENERGETICS 23, 33, 45, 48, 49, 84, 87

Referring to effect of insects on trees:
DEFOLIATION 3, 7, 10, 14, 17, 18, 28, 30, 39, 40, 43, 47, 50, 58, 59, 65, 66, 67, 68, 72, 76, 83, 85, 86, 87, 88, 99, 100, 101, 104, 123, 124

TREE GROWTH 3, 7, 14, 18, 29, 35, 39, 43, 50, 61, 63, 64, 66, 68, 69, 70, 73, 74, 83, 85, 86, 87, 99, 100, 101, 102, 113, 114, 124

PHOTOSYNTHESIS 41, 61, 62, 63, 65, 70, 73, 92, 102, 113

PLANT HORMONES 35, 62, 69, 102

1. ATWAL, A. S. 1955. Influence of temperature, photoperiod, and food on the speed of development, longevity, fecundity, and other quantities of the diamond back moth Plutella maculipennis. Aust. J. Zool. 3:185-221.

Mean length of larval life (hatching to pupation) in days, mean live weight of pupa (mg), and mean ratio of live weight were related to dry matter in pupa, to different levels of temperature, and to quality of food. The influence of temperature on fecundity also was observed.

Key words: DATA, NO MODEL, FOOD QUALITY, LONGEVITY, FECUNDITY, LARVAL DEVELOPMENT, ENVIRONMENT.

2. AUCLAIR, J. L. 1963. Aphid feeding and nutrition. Annu. Rev. Entomol. 8:439-490.

Literature review concerns aspects of aphid feeding, including: structure of mouth parts, types of penetration and feeding sites within the host, saliva, beginning of sap intake, and rate of sap intake. Also included is a review of aphid nutrition, including biochemical constituents of ingesta and nutritional requirements. Other aspects of aphid physiology and honeydew production are discussed. Tables concern type and rate of style of penetration and feeding sites in three species of aphids and rates of sap intake of aphids in relation to excretion and body weight.

Key words: DATA, NO MODEL, FOOD QUANTITY, FEEDING RATE, EXCRETION, NUTRITIONAL REQUIREMENTS.

3. BAILEY, I. W. 1925. Notes on the spruce budworm biocoenose: II. Structural abnormalities in _Abies balsamea_. Bot. Gaz. 80:30-310.

Frequently, two or three narrow, dark reddish-brown zones of discolored tissue appear in transverse sections of stems of balsam fir that have been attacked by spruce budworm. A possible explanation of this abnormality is discussed.

Key words: NO DATA, NO MODEL, TREE GROWTH, DEFOLIATION.

4. BEAN, J. L., and L. F. WILSON. 1964. Comparing various methods of predicting development of the spruce budworm, _Choristoneura fumiferana_, in northern Minnesota. J. Econ. Entomol. 57(6):925-928.

Two climatological and two phenological methods were used to predict spray application dates. Methods were: degree-hour temperature summation, day-degree temperature summation, actual shoot growth of balsam fir, and 15 percent of shoot growth of balsam fir. The degree-hour method was the most accurate for predicting the date of the peak of the third instar; however, the day-degree method was nearly as accurate and more easily computed.

Key words: DATA, REGRESSION MODEL, ENVIRONMENT, LARVAL DEVELOPMENT.

5. BECK, S. D. 1956a. The European corn borer _Pyrausta nubilalis_ (Hubn.) and its principal host plant. I. Orientation and feeding behavior of larva on the corn plant. Ann. Entomol. Soc. Am. 49:552-558.

Feeding behavior of the larvae was accounted for on basis of negative phototactic, positive thigmotactic, and saccharotrophic behavior. Larvae concentrate feeding on tissues containing highest concentrations of sugars. Tables relate position of larvae on artificial corn plants 3 hours after hatching, the effects of different tissues of the corn plant on the establishment behavior of newly hatched larvae, and plant tissue sugar level and principal feeding sites of larvae on corn plant.

Key words: DATA, NO MODEL, FEEDING BEHAVIOR.

6. BECK, S. D. 1956b. The European corn borer _Pyrausta nubilalis_ (Hubn.) and its principal host plant. II. Influence of nutritional factors on larval establishment and development on the corn plant. Ann. Entomol. Soc. Am. 49:582-587.

Larval requirements for dietary sugar and protein were correlated with the normal biology and feeding behavior of the borer on corn plants. Experiments failed to support hypothesis that nutritional deficiencies in the host plants are responsible for high mortality among borer larvae feeding on leaves of corn seedlings. Tables included: mortality of newly hatched larvae under different dietary conditions for 72 hours, effect of dietary glucose and casein concentration on the growth and development of the larvae, and sugar and protein content of the corn plant tissues in relation to the nutritional requirements of the larvae.

Key words: DATA, NO MODEL, FOOD QUALITY, LARVAL DEVELOPMENT, FEEDING BEHAVIOR, MORTALITY, NUTRITIONAL REQUIREMENTS.

7. BENJAMIN, D. M., S. E. BANASH, and R. B. STEWART. 1961. Losses attributable to the jack pine budworm during the outbreak in Wisconsin. Univ. Wis. For. Res. Note 73. 4 p.

Effects of budworm are discussed generally, including intensity of defoliation, duration of attack, and impact on tree productivity.

Key words: DATA, NO MODEL, DEFOLIATION, TREE GROWTH.

8. BLAIS, J. R. 1952. The relationship of the spruce budworm (Choristoneura fumiferana Chem.) to the flowering conditions of balsam fir. Can. J. Zool. 30(1):1-29.

Flowering balsam fir trees were found to harbor higher populations in the early larval stages. Larvae that fed partially on pollen developed more rapidly than larvae fed exclusively on foliage. Also, mortality was higher, development was retarded, and fecundity was reduced in insects forced to feed on old foliage. Table related instar and sex of larvae and food (flowering compared to nonflowering trees) to mean weight.

Key words: DATA, NO MODEL, FOOD QUALITY, LARVAL DEVELOPMENT, MORTALITY, FECUNDITY.

9. BLAIS, J. R. 1953. Effects of the destruction of current year's foliage of balsam fir on the fecundity and habits of flight of the spruce budworm. Can. Entomol. 85:446-448.

Studies indicate that when budworm population reaches the point where all the current year's foliage is destroyed before completion of the larval stage, the number of eggs per surviving female adult decreases. Fecundity increases again as population declines to a point where defoliation of the current year's growth is not complete. A table relates the degree of defoliation to the average number of eggs produced by the moths.

Key words: DATA, NO MODEL, FOOD QUALITY, FECUNDITY, MORTALITY.

10. BLAIS, J. R. 1959. The vulnerability of balsam fir to spruce budworm attack in northeastern Ontario, with special reference to the physiological age of the tree. For. Chron. 34:405-422.

Small, suppressed trees (less than 3 inches dbh) were the first to succumb to budworm defoliation. Mortality was initiated by the third year of severe defoliation. Trees of merchantable size (4 inches dbh and greater) began to die after five years of severe defoliation. Beyond a certain threshold of defoliation, recovery was apparently impossible.

Key words: DATA, NO MODEL, DEFOLIATION.

11. BLAIS, J. R. 1965. Parasite studies in two residual spruce budworm outbreaks in Quebec. Can. Entomol. 97:129-137.

In eastern Canada, aggregate parasitism during peak years of budworm outbreaks usually varies between 20 and 40 percent. During the declining years of an outbreak and, more specifically, during the year of collapse, the action of parasites may increase.

Key words: DATA, NO MODEL, MORTALITY.

12. BLAKE, G. M. 1961. Length of life, fecundity, and the oviposition cycle in Anthrenus vertasci as affected by adult diet. Bull. Entomol. Res. 52:459-472.

Diet was found to be related to mean weight at emergence, length of life, frequency of oviposition, periodicity of peaks in the oviposition rate, and number of eggs laid. Effects of different relative humidities and temperatures on length of adult life and length of inactive periods were reported.

Key words: DATA, NO MODEL, FECUNDITY, LONGEVITY, FOOD QUALITY, ENVIRONMENT.

13. BRAY, J. R. 1961. Measurement of leaf utilization as an index of minimum level of primary consumption. Oikos 12:70-74.

Method was given for determining how much of a leaf has been consumed by insects. Leaves were traced on graph paper, and holes where insects had been feeding were outlined. The area of the holes was used to estimate consumption by insects.

Key words: NO DATA, NO MODEL, FOOD QUANTITY.

14. BRUCE, D. 1956. Effect of defoliation on growth of longleaf pine seedlings. For. Sci. 2:31-35.

Seedlings were defoliated artificially (30, 60, and 90 percent) with shears at three different dates (July, November, and February). All defoliation caused growth loss about in proportion to the amount defoliated. Clipping in November reduced growth significantly more than July treatment; February was the least damaging.

Key words: DATA, NO MODEL, DEFOLIATION, TREE GROWTH.

15. CAMERON, D. G., G. A. McDOUGALL, and C. W. BENNETT. 1968. Relation of spruce budworm development and balsam fir shoot growth to heat units. J. Econ. Entomol. 61(3):857-858.

The mean day-degrees required for spruce budworm development from April 1 to peak occurrence of each instar was calculated. Mean day-degrees required for shoot growth of balsam fir from April 1 to completion of percentages (10, 25, 50, and 75 percent) of total growth were also calculated.

Key words: DATA, NO MODEL, ENVIRONMENT, LARVAL DEVELOPMENT.

16. CARNE, P. B. 1966. Growth and food consumption during the larval stages of Paropsis atomaria. Entomol. Exp. Appl. 9:105-112.

The relative gross efficiency of food utilization for separate growth stages was found for the foliage feeder on eucalyptus. Efficiency declines temporarily after each ecdysis as the final instar larva approaches maturity. Tables include: changes in body weight during development of the larval stages in relation to amounts of foliage consumed, comparison of conversion rates (increase in live weight of insect divided by fresh weight of food eaten) of the immature stages of a range of phytophagous insects, and trends in conversion ratios within and between instars of various phytophagous insects. Gross fresh weight conversion ratios for phytophagous insects listed ranged from 0.137 to 0.341.

Key words: DATA, NO MODEL, FOOD QUANTITY, LARVAL DEVELOPMENT, FEEDING RATE.

17. CHURCH, T. W. 1949. Effects of defoliation on growth of certain conifers. U.S. Dep. Agric., For. Serv., Northeast For. and Range Exp. Stn. Pap. NE-22. 12 p.

A summary of research literature was given. Topics include defoliation by spruce budworm, pine butterfly, larch sawfly, gypsy moth, hemlock looper, tussock moth, fire, fungi, and hail.

Key words: NO DATA, NO MODEL, DEFOLIATION.

18. COOK, J. A. 1961. Growth reduction in lodgepole pine defoliated by the needle miner, Evagora starki Freeman. For. Chron. 37:237-241.

An outbreak of needle miners occuring between 1938 and 1952 was evaluated with regard to percentage of defoliation and the amount of subsequent growth reduction. Growth reduction was detected only when defoliation exceeded 40 percent. Good agreement was found between length of time defoliation exceeded 40 percent and percentage loss of increment.

Key words: NO MODEL, DATA, DEFOLIATION, TREE GROWTH.

19. CROSSLEY, D. A. 1966. Radioisotope measurement of food consumption by a leaf beetle species. Ecology 47(1):1-8.

Radioisotopes were used to estimate consumption of vegetative plant parts by insects. These measurements were used to compare field and laboratory feeding rates. In the field, insects consumed 7-16 mg dry weight of plant tissue per larva per day and in the laboratory, 9-10 mg.

Key words: NO MODEL, DATA, FOOD QUANTITY.

20. CROWELL, H. H. 1943. Feeding habits of the southern army worm and rate of passage of food through its gut. Ann. Entomol. Soc. Am. 36:243-249.

Tables show: (1) the relations of length of time spent feeding, resting, and wandering of six larvae of the fifth and sixth instars over a 24-hour period; (2) the relations of defecations to feeding, resting, and wandering; and, (3) rates of alimentation of several larvae of fifth and sixth instars. Fifth and sixth instars require about 3 1/4 hours for main bulk of food to pass through digestive tract. Foreguts of larvae are cleared of solid leaf particles during rest periods, but retain much leaf juice at all times.

Key words: NO MODEL, DATA, FEEDING RATE, FEEDING BEHAVIOR.

21. CUTRIGHT, C. R., and L. L. HUBER. 1928. Growth condition of the host as a factor in insect abundance. Ann. Entomol. Soc. Am. 21:147-153.

Examples of where and how growth conditions of the host affect the ecology of an insect are given. Insects cited are the silkworm, shot hole borer, plum curculio, oriental fruit moth, corn leaf aphid, San Jose scale, bean leaf hopper, and European corn borer.

Key words: NO MODEL, NO DATA, POPULATION NUMBERS, FOOD QUALITY.

22. DADD, R. H. 1960. Observations on the palatability and utilization of food by locusts with particular reference to the interpretation of performances in growth trials using synthetic diets. Entomol. Exp. Appl. 3:283-304.

Data from experiments with Locusta and Schistocera hoppers were presented to show amount eaten, weight of feces, and utilization of the food for eight different diets.

Key words: NO MODEL, DATA, EXCRETION, ASSIMILATION EFFICIENCY, FEEDING RATE.

23. DARNELL, R. M. 1968. Animal nutrition in relation to secondary production. Am. Zool. 8:83-93.

The fate of consumed energy is discussed generally. Several methods for evaluating the intake of food in natural populations are given and factors that influence food intake and feeding are discussed.

Key words: NO DATA, NO MODEL, ENERGETICS, FEEDING STIMULATION.

24. DAVEY, P. M. 1954. Quantities of food eaten by desert locust Schistocerca gregaria (Forsk.) in relation to growth. Bull. Entomol. Res. 45:539-551.

Average total weights of fresh grass eaten by hoppers between hatching and becoming adults were 10.2 g for males and 12.9 g for females. Amounts eaten by adults between molting and maturity were 20.5 g by males and 31.4 g by females. Percentages of food assimilated were given for the instars.

Key words: DATA, NO MODEL, FEEDING RATE, ASSIMILATION EFFICIENCY.

25. DETHIER, V. G. 1954. Evolution of feeding preferences in phytophagous insects. Evolution 8:33-54.

The evolution of feeding preferences in phytophagous insects entails the simultaneous evolution of resistant mechanisms by plants and of tolerance by insects. Thus, the picture at any time is one of dynamic equilibrium moving toward symbiosis. The role of nutritionally unimportant, token stimuli produced by plants is discussed. Five lines of development from a primitive polyphagous state are presented.

Key words: NO MODEL, NO DATA, FOOD QUALITY, FEEDING STIMULATION, NUTRITIONAL REQUIREMENTS.

26. DIXON, A. F. G. 1970a. Quality and availability of food for a sycamore aphid population. IN: A. Watson (ed.), Animal populations in relation to their food resources, p. 271-287. Blackwell Sci. Publ., Oxford.

The changes in quantity and quality of amino nitrogen present in the phloem sap of plants with the progress of growth and maturity of leaves and shoots were recorded. Phloem sap in inactively growing or senescing (spring and autumn) leaves was found to contain relatively high concentrations of amino nitrogen. Insect reproduction rate was found to change markedly during the seasons and be correlated strongly with levels of amino nitrogen. In spring, few aphids reach adulthood because of heavy mortality, although adults have high reproductive rates. A population peak occurs in summer, followed by a decline. Increases occur again in autumn. The peak number in autumn is correlated with number of adults present at start of increase.

Key words: NO MODEL, DATA, FOOD QUANTITY, FOOD QUALITY, FECUNDITY, MORTALITY, POPULATION NUMBERS.

27. DIXON, A. F. G. 1970b. Stabilization of aphid populations by an aphid-induced plant factor. Nature 227(5265):1368-1369.

In the course of a year, three peaks in aphid populations are found: spring, summer, and autumn. Spring and autumn peaks are inversely related. An abundance of aphids in spring affects the nitrogen metabolism of the leaves so that little nitrogen is translocated from leaves before abscission, and food for autumn population is poor. Small aphids with a low reproductive rate result from low food quality. The number of aphids present in spring depends on the number of eggs laid the previous autumn. Aphid-induced changes in leaves result in a delayed, overcompensating negative feedback which stabilizes aphid numbers.

Key words: NO MODEL, DATA, FOOD QUALITY, FECUNDITY, POPULATION NUMBERS.

28, DROOZ, A. T. 1970. The elm spanworm (Lepidoptera: Geometridae): How several natural diets affect its biology. Ann. Entomol. Soc. Am. 63:391-397.

Larval diets of young leaves from pignut hickory or northern red oak were found to produce adults with considerably greater fecundity than those on diets of normal leaves. Tables relate diet (young compared with old leaves) to developmental time, head width, and fecundity. More eggs were produced by adults from larvae fed foliage from trees previously defoliated twice. Tables relate diet (foliage from trees previously defoliated compared with nondefoliated) to developmental time, head width, and fecundity.

Key words: NO MODEL, DATA, FECUNDITY, LARVAL DEVELOPMENT, FOOD QUALITY, DEFOLIATION.

29. DUFF, G. H., and N. J. NOLAN. 1953. Growth and morphogenesis in the Canadian forest species: I. The controls of cambial and apical activity in Pinus resinesa. Can. J. Bot. 31:471-513.

Nutritional gradient is postulated as the controlling factor in the distribution of cambial growth activity along the tree bole. The effects of shading and degree of foliation on this gradient are discussed. Environmental and intrinsic factors affecting terminal formation are presented as possible mechanisms controlling the variation in magnitude of terminal growth.

Key words: NO MODEL, DATA, TREE GROWTH.

30. DUNCAN, D. P. and A. C. HODSON. 1958. Influence of the forest tent caterpillar upon the aspen forests of Minnesota. For. Sci. 4:71-93.

The effect of defoliation upon aspen is reduced average leaf size and tip clustering by leaves produced the year after defoliation. A high correlation was found between degree of defoliation and volume of dead twigs. No significant difference was found between the growth occuring the year after a light defoliation after one year of heavy defoliation compared with growth during period of no defoliations.

Key words: NO MODEL, DATA, DEFOLIATION.

31. EDELMAN, N. M. 1963. Age changes in the physiological condition of certain arbivorous larvae in relation to feeding conditions. Entomol. Rev. 42:4-9.

The effects of changes in food quality on the physiological processes of selected groups of leaf-feeding insects are discussed. Mass outbreaks of insects can occur when seasonal changes in biochemical composition of food coincide with food requirements of the insects at all stages of their development. The effect of food of unvarying compositon on the gypsy moth is presented.

Key words: NO MODEL, DATA, FOOD QUALITY, LARVAL DEVELOPMENT.

32. ELLIS, P. E. D., D. B. CARLISLE, and D. J. OSBORNE. 1965. Desert locust: Sexual maturation delayed by feeding on senescent vegetation. Science 149:546-547.

A diet of senescent Brassica spp. was found to delay sexual maturation in the desert locust. The senescent leaves were shown to be short of gibberellins and a dietary supplement of gibberellin A_3 (1 mg per locust per day) restored rate of maturation to that found in animals feeding on green leaves. The sexual immaturity of desert locusts during the dry season may result from the senescent condition of their desert food plants. Thus, breeding of desert locust is geared to the rains.

Key words: NO MODEL, DATA, FOOD QUALITY, LARVAL DEVELOPMENT.

33. ENGLEMANN, M. D. 1966. Energetics, terrestrial field studies, and animal productivity. Adv. Ecol. Res. 3:73-115.

Three approaches to energetics studies are suggested: physiological studies (individuals), analysis of maintenance energy (populations), and trophic dynamics (communities). Article provides review of literature in energetics.

Key words: NO MODEL, DATA, ENERGETICS.

34. EVANS, A. C. 1939. The utilization of food by certain lepidopterous larvae. Trans. R. Entomol. Soc. Lond. 89:13-22.

Statistics of food utilization are calculated for four lepidopterous larvae. The coefficient of utilization (weight of food utilized divided by weight of food consumed), coefficient of growth (increase in weight of larvae divided by weight of food utilized) and coefficient of metabolism (weight of larvae divided by weight of food utilized) were compared for the larvae.

Key words: NO MODEL, DATA, ASSIMILATION EFFICIENCY.

35. EVERT, R. F., and T. T. KOZLOWSKI. 1967. Effect of isolation of bark on cambial activity and development of xylem and phloem in trembling aspen. Am. J. Bot. 54:1045-1055.

Evidence is presented to indicate that normal cambial activity and xylem and phloem development require a supply of currently translocated regulatory substances from the shoots.

Key words: NO MODEL, DATA, PLANT HORMONES, TREE GROWTH.

36. FEENY, P. 1970. Seasonal changes in oak leaf tannins and nutrients as a cause of spring feeding by winter moth caterpillars. Ecology 51:565-581.

Concentration of feeding in the spring by caterpillars is believed to be correlated with seasonal changes in texture and chemical composition of leaves. Late larval feeding may be prevented by increase in leaf toughness. Early feeding coincides with maximum protein and minimum sugar content in the leaves. The feeding times suggest that availability of nitrogen rather than carbohydrate is the limiting factor for spring-feeding larvae. The growth of winter moths is inhibited by oak tannins which increase in concentration during the summer.

Key words: NO MODEL, DATA, FOOD QUALITY.

37. FRAENKEL, G. S. 1951. The nutritional value of green plants for insects. Trans. IXth Int. Congr. Entomol. Amst. 2:90-100.

Leaves are found to differ relatively little in chemical composition as far as nutritional needs of insects for food substances are concerned. The specificity of food plants for various insects is based on the presence of chemical compounds that serve as chemical stimuli for sensory organs of smell and taste.

Key words: NO MODEL, NO DATA, NUTRITIONAL REQUIREMENTS, FEEDING STIMULATION.

38. FRAENKEL, G. S. 1959. The raison d'etre of secondary plant substances. Science 129:1466-1470.

The author suggests that food specificity of insects is based solely on the presence or absence of secondary compounds in plants. These compounds do not necessarily play any role in the basic metabolism of either the plant or the insect. The mechanism of evolution of monophagous insects is discussed.

Key words: NO MODEL, NO DATA, FEEDING STIMULATION.

39. FRANKLIN, R. T. 1970. Insect influences on the forest canopy. IN: D. E. Reichle (ed.), Analysis of temperate forest ecosystems. p. 86-99. Springer Verlag.

Classification of feeding habits, factors influencing population size, insect dispersal, and the effects of insect feeding are reviewed. Experimental approaches to assessing insect influences are discussed, and management programs for control at the ecosystem level are given.

Key words: NO MODEL, NO DATA, FEEDING BEHAVIOR, DEFOLIATION, TREE GROWTH.

40. FRAUSS, D. L., and W. R. PIERCE. 1969. Stand conditions and spruce budworm damage in a western Montana forest. J. For. 67(5):322-325.

Report of relations of site quality, crown closure, and percentage of Douglas-fir in the stand to defoliation caused by spruce budworm.

Key words: DATA, NO MODEL, DEFOLIATION.

41. FREELAND, R. 1952. Effect of age of leaves upon the rate of photosynthesis in some conifers. Plant Physiol. 27:685-690.

Leaves of all species were found to attain their maximum photosynthetic capacity about the time of apparent leaf maturity during the first season of growth. The rate decreased slowly with increase in age of leaves during the second year.

Key words: NO MODEL, DATA, PHOTOSYNTHESIS.

42. FRIEND, W. G. 1958. Nutritional requirements of phytophagous insects. Annu. Rev. Entomol. 3:57-74.

Literature on requirements of phytophagous insects for carbohydrates, proteins and amino acids, lipids, water-soluble vitamins, and minerals is reviewed. No direct evidence of plant resistance to insect attack because of specific nutritional deficiencies or harmful imbalances of nutrients was found.

Key words: NO MODEL, NO DATA, NUTRITIONAL REQUIREMENTS.

43. FURUNO, T. 1964. The effects of feeding-damage of the pine caterpillar upon the red pine by artificial defoliation. J. Jap. For. Soc. 46:52-59.

The effects of increasing defoliation (0, 30, 40, 50, 60, 70, 80, 90, 100 percent) on growth in height and diameter at the root collar were followed.

Key words: NO MODEL, DATA, DEFOLIATION, TREE GROWTH.

44. GELPERIN, A. 1971. Regulation of feeding. Annu. Rev. Entomol. 16: 365-378.

The regulation of food intake is asserted to be part of a larger mechanism for metabolic homeostasis. Feeding behavior is involved in introducing energy stores into the animal, gut activity determines the rate of delivery of these stores to the blood, and a third set of controls operates to control energy stores from blood to tissues.

Key words: NO MODEL, NO DATA, FEEDING STIMULATION.

45. GOLLEY, F. B., and J. B. GENTRY. 1964. Bioenergetics of the southern harvester ant, Pogonomyrmex badius. Ecology 45(2): 217-225.

Energy flow (cal m^{-2}) by season and population density are given for the ants. These energy values are compared to net production and to energy flow in other granivore and herbivore populations.

Key words: DATA, NO MODEL, ENERGETICS.

46. GORDON. H. T. 1968. Quantitative aspects of insect nutrition. Am. Zool. 8:131-138.

The reasons for growth failure of animals on a certain diet are discussed. Several physiological formulae are given.

Key words: MODEL, DATA, NUTRITIONAL REQUIREMENTS, FEEDING RATE.

47. GRAHAM, S. A. 1956. The larch sawfly in the lake states. For. Sci. 2(2):132-160.

Damage in terms of deformed twigs and mortality was related to amounts of defoliation by the sawfly. Life cycle, food requirements, survival percentages, and principal mortality factors are given.

Key words: DATA, NO MODEL, MORTALITY, DEFOLIATION, LARVAL DEVELOPMENT.

48. HAGSTRUM, D. W. 1970a. Ecological energetics of the spider Tarentula kochi (Araneae: Lycosidae). Ann. Entomol. Soc. Am. 63(5):1297-1304.

Weight gained for amounts consumed were given for each instar. Ingestion was calculated as the weight gained during instar plus 0.02 mg mg^{-1} wet weight per day respiration times the length of instar in days times the weight of the spider.

Key words: NO MODEL, DATA, ENERGETICS, FEEDING RATE.

49. HAGSTRUM, D. W. 1970b. Physiology of food utilization by the spider Tarentula kochi (Araneae: Lycosidae) Ann. Entomol. Soc. Am. 63(5):1305-1308.

Meal size, mean weight, respiration loss, and weight gain are given for various feeding intervals.

Key words: NO MODEL, DATA, ENERGETICS, FEEDING RATE.

50. HARPER, A. G. 1913. Defoliation: its effects upon the growth and structure of Larix. Ann. Bot. 27:621-642.

The effects of the loss of photosynthetic organs upon the structure of larch wood are discussed. A reduction in the thickening of walls of cells of part or all of the zone of autumn wood was found after attacks by large larch sawflies.

Key words: NO MODEL, DATA, TREE GROWTH, DEFOLIATION.

51. HERON, R. J. 1965. The role of chemotactic stimuli in the feeding behavior of spruce budworm larvae on white spruce. Can. J. Zool. 43:247-269.

After emergence, the larvae begin to feed. If staminate flowers are present, they are favored sites for larval feeding until pollen is shed. The larvae then move to vegetative shoots. In the absence of flowers, the larvae may wander before beginning to pine needles or unopened buds. Survival is poor if larvae are forced to feed on mature needles only. Preference for new needles and staminate flowers may be related to high concentration of sugars in these areas.

Key words: NO MODEL, DATA, FEEDING STIMULATION, MORTALITY, FOOD QUALITY.

52. HOUSE, H. L. 1962. Insect nutrition. Ann. Rev. Biochem. 31:653-672.

Review includes some remarks on the ecological implications of insect nutritional requirements.

Key words: NO MODEL, NO DATA, NUTRITIONAL REQUIREMENTS.

53. HOUSE, H. L. 1965. Effects of low levels of nutrient content of a food and nutrient imbalance on the feeding and nutrition of a phytophagous larva, Celerio euphorbiae. Can. Entomol. 97(1): 62-68.

The tendency for larvae to eat less and to gain less weight on unbalanced diets than on adequate diets was noted. The conversion of foodstuffs into body material was not as efficient on the unbalanced diets. When the entire nutrient concentration is low, an insect may increase its rate of consumption without suffering serious metabolic impairment. The ecological significance of food quality suggested by this tendency is that the degree of destructiveness may depend in part on the degree of succulence and corresponding nutrient concentration of food plant tissues.

Key words: NO MODEL, DATA, NUTRITIONAL REQUIREMENTS, FOOD QUALITY, FEEDING RATE.

54. HOUSE, H. L. 1969. Effects of different proportions of nutrients on insects. Entomol. Exp. Appl. 12:651-669.

The proportions of essential nutrients in a foodstuff are asserted to contribute more to nutritional quality than do absolute amounts of nutrients. Qualitative nutrient requirements of several larvae are given and mean weights of food eaten are related to body weight gained and efficiency of food conversion. The effects of nutrient balance on growth and development rate are discussed.

Key words: NO MODEL, DATA, NUTRITIONAL REQUIREMENTS, LARVAL DEVELOPMENT, ASSIMILATION EFFICIENCY.

55. HSIAO, T. H. 1969. Chemical basis of host selection and plant resistance in oligophagous insects. Entomol. Exp. Appl. 12:777-788.

Feeding stimulants are discussed, using the Colorado potato beetle and the alfalfa weevil as examples.

Key words: NO MODEL, DATA, FEEDING STIMULATION.

56. JOHANSSON, A. S. 1964. Feeding and nutrition in reproductive processes in insects. Symp. R. Entomol. Soc. ond. 2:43-55.

Literature on the effects of different qualities and quantities of food on female fertility, egg size, and accessory glands is reviewed. The ecological implications of nutrition of insects are discussed.

Key words: NO MODEL, NO DATA, FECUNDITY, FOOD QUALITY.

57. KASTING, R., and A. J. McGINNIS. 1962. Quantitative relationship between consumption and excretion of dry matter by larvae of the pale western cutworm, Agrotis orthogonia Morr. (Lepidoptera: Noctuidae). Can. Entomol. 94:441-443.

A simple linear relation is generated between consumption and excretion on a dry matter basis. Fecal pellet counts are considered unreliable for comparing consumption of different diets.

Key words: REGRESSION MODEL, DATA, FEEDING RATE, EXCRETION.

58. KEEN, F. P. 1952. Insect enemies of western forests. U.S.Dep. Agric., Misc. Publ. 273. p. 75-126.

Damage caused by insects including defoliators in coniferous forests is described. Lists of insect pests are given.

Key words: NO MODEL, NO DATA, DEFOLIATION.

59. KINGHORN, J. M. 1954. The influence of stand composition on the mortality of various conifers, caused by defoliation by the western hemlock looper on Vancouver Island, B.C. For. Chron. 30:380-400.

Four stand types including various quantities of Douglas-fir, hemlock, and amabilis fir were followed with respect to mortality after an outbreak of western hemlock looper. The relation of basal area and stem mortality to percentage defoliation was given. Multiple regression equations were generated to show the relation of basal area mortality to stand composition and proportion defoliated.

Key words: REGRESSION MODEL, DATA, DEFOLIATION.

60. KOGAN, M., and R. D. GOEDEN. 1970. The biology of Lema trilineata daturaphila (Coleoptera: Chrysomelidae) with notes on efficiency of food utilization by larvae. Ann. Entomol. Soc. Am. 63(3):537-546.

The relation between the weight of food consumed and larval weight is presented. The change in the assimilation efficiency during larval development is discussed.

Key words: NO MODEL, DATA, FEEDING RATE, LARVAL DEVELOPMENT, ASSIMILATION EFFICIENCY.

61. KOZLOWSKI, T. T. 1963. Growth characteristics of forest trees. J. For. 61:655-661.

Review of literature on the regulation of shoot and cambial growth. Evidence is presented to show that shoot growth of many species depends on stored foods rather than products of current photosynthesis. Cambial growth is related to live crown ratio and degree of suppression.

Key words: NO MODEL, NO DATA, TREE GROWTH, PHOTOSYNTHESIS.

62. KOZLOWSKI, T. T. 1969. Tree physiology and forest pests. J. For. 67:118-122.

General article discusses how forest pests affect tree growth by interfering with rates and balances among internal processes--especially food, hormone, and water relations. Many references to areas of tree physiology are given.

Key words: NO DATA, NO MODEL, PHOTOSYNTHESIS, PLANT HORMONES.

63. KOZLOWSKI, T. T., and J. J. CLAUSEN. 1966. Shoot growth characteristics of heterophyllous woody plants. Can. J. Bot. 44:827-843.

Growth of long shoots of heterophyllous species appears to use considerable amounts of current photosynthate. The presence of normally growing, early leaves is probably essential for normal shoot development and survival. The contribution by early as compared with late leaves of photosynthate and growth regulators is discussed.

Key words: NO DATA, NO MODEL, TREE GROWTH, PHOTOSYNTHESIS.

64. KRUEGER, K. W. 1967. Nitrogen, phosphorus, and carbohydrate in expanding and year-old Douglas fir shoots. For. Sci. 13:352-356.

The average dry weight and nitrogen, phosphorus, and carbohydrate concentrations and amounts are related to days since bud burst for year-old and current foliage.

Key words: DATA, NO MODEL, FOOD QUANTITY, TREE GROWTH.

65. KULMAN, H. M. 1965a. Effects of artificial defoliation of pine on subsequent shoot and needle growth. For. Sci. 11:90-98.

The effects of defoliation on the availability of needles as storage organs and producers of photosynthate is discussed. Needle-length changes are related to the availability of photosynthate at time of needle elongation. Tables show effect of defoliation treatments and needle growth, year of origin of needles for 3 years after defoliation, age distribution of needles, and association between average number of needles removed in each treatment, and the change in shoot and needle length.

Key words: NO MODEL, DATA, DEFOLIATION, PHOTOSYNTHESIS.

66. KULMAN, H. M. 1965b. Effects of disbudding on the shoot mortality, growth, and bud production in red and sugar maples. J. Econ. Entomol. 58:23-26.

Four treatments were used to assess the impact of disbudding: removal of all buds, removal of all terminal buds, removal of distal terminate buds of each branch, and no buds removed. Tables relate the survival of terminal buds, shoot growth, and bud production to the disbudding treatments.

Key words: NO MODEL, DATA, DEFOLIATION, TREE GROWTH.

67. KULMAN, H. M., and A. C. HODSON. 1961. The jack pine budworm as a pest of other conifers with special reference to red pine. J. Econ. Entomol. 54:1221-1224.

Discussion of effects of large populations of budworms on mortality and top killing in stands. The dead portion of the crowns was correlated with the length that was 80 percent or more defoliated.

Key words: NO MODEL, DATA, DEFOLIATION.

68. KULMAN, H. M., A. C. HODSON, and D. P. DUNCAN. 1963. Distribution and effects of jack pine budworm defoliation. For. Sci. 9:146-157.

Defoliation was classified so that new and old needles were considered separately to study distribution and effects of defoliation by the budworms. Mortality and growth reduction were recorded by defoliation class and tree position in the stand. Regressive trees were found to be more heavily defoliated during periods of light defoliation than progressive or provisional trees.

Key words: NO MODEL, DATA, DEFOLIATION, TREE GROWTH.

69. LARSON, P. R. 1962. Auxin gradients and the regulation of cambial activity. IN: T. T. Kozlowski (ed.), p. 97-118. Ronald Press, N. Y.

Evidence is presented that indicates that cambial activity may be regulated through an auxin-mediated system originating in the terminal meristems. The activity curve of auxin closely parallels the pattern of development of the apex. The role of auxin in xylem differentiation is discussed.

Key words: NO MODEL, NO DATA, TREE GROWTH, PLANT HORMONES.

70. LARSON, P. R. 1964. Contribution of different aged needles to growth and wood formation of young red pines. For. Sci. 10:224-238.

Cumulative weekly height growth, tracheid diameter, wall thickness, specific gravity and cumulative weekly needle elongation were measured for trees with current year's needles exposed, all needles exposed, and grown in the dark.

Key words: NO MODEL, DATA, TREE GROWTH, PHOTOSYNTHESIS.

71. LEONARD, D. E. 1970. Intrinsic factors causing quantitative changes in populations of Porthetria dispar (Lepidoptera: Lymantriidae). Can. Entomol. 102:239-249.

Evidence is presented to suggest that the gypsy moth is numerically self-regulating through a shift in quality of individuals induced by changes in nutrition. Tables relate egg size to position of eggs within egg mass, to percentage parasitized, and to number of molts. The distribution of percentage of larvae with additional molts is presented. The change in quality can be induced either in the previous generation by the amount of nutrient preserves provided the eggs or, during the current generation, by hunger, crowding, or cool temperature.

Key words: NO MODEL, DATA, POPULATION QUALITY.

72. LINZON, S. N. 1958. The effect of artificial defoliation of various ages of leaves upon white pine growth. For. Chron. 34:50-56.

Removal of any year's foliage affected height growth, but diameter growth was reduced when first year and another year's foliage were removed. One-year-old foliage seems to be the most important to white pine.

Key words: NO MODEL, DATA, DEFOLIATION.

73. LITTLE, C. H. A. 1970a. Derivation of spring-time starch increase in balsam fir. Can. J. Bot. 48(11):1995-1999.

Starch, total sugar, crude fat, and moisture contents were determined during the spring (late March to mid-June) in needles, bark, and wood of one-year-old balsam fir shoots variously shaded, defoliated, and girdled in late March. The bulk of starch accumulated in conifers during spring apparently is derived from current photosynthesis.

Key words: NO MODEL, DATA, FOOD QUALITY, TREE GROWTH, PHOTOSYNTHESIS.

74. LITTLE, C. H. A. 1970b. Seasonal changes in carbohydrate and moisture content in needles of balsam fir. Can. J. Bot. 48(11):2021-2027.

Starch, total sugar, fructose, glucose, sucrose, raffinose, crude fat, and moisture contents were determined for current and one-year-old needles at about two-week intervals.

Key words: NO MODEL, DATA, FOOD QUALITY, TREE GROWTH.

75. LONG, D. B. 1953. Effects of population density on larvae of Lepidoptera. Trans. R. Entomol. Soc. Lond. 104:543-585.

Ten species of Lepidoptera were tested: three that feed on brassica, five on hawthorn, and one each on elm and poplar. The normal larval population densities ranged from not aggregated to closely aggregated. The effects of crowding on morphology, histology, physiology, and behavior were observed. Crowding increased the rate of larval development. Crowded larvae of Plusia gamma were four times more active and spent 25 percent more time feeding.

Key words: DATA, NO MODEL, FEEDING BEHAVIOR, POPULATION NUMBERS.

76. McCAMBRIDGE, W. F. 1955. Effects of black-headed budworm feeding on second-growth western hemlock and sitka spruce. Proc. Soc. Am. For. p. 171-172.

A single year of heavy budworm defoliation in second-growth western hemlock killed tops in the majority of those trees whose crowns were most exposed to sunlight. Tables relate length of top kill and percentages of top kill to crown class.

Key words: NO MODEL, DATA, DEFOLIATION.

77. McGINNIS, A. J., and R. KASTING. 1964. Chromic oxide indicator method for measuring food utilization in a plant feeding insect. Science 144(3625):1464-1465.

Method for determining percentage of utilization of three diets prepared from lyophilized plant tissue was given.

Key words: NO MODEL, DATA, FEEDING RATE.

78. McGUGAN, B. M. 1954. Needle-mining habits and larval instars of the spruce budworm. Can. Entomol. 86:439-454.

The feeding behavior of the larvae before they enter the vegetative buds is discussed. Tables relate larval mortality during the needle mining stage and the ratio of needles mined to buds attacked.

Key words: NO MODEL, DATA, FEEDING BEHAVIOR, MORTALITY.

79. McMILLIAN, W. W., K. J. STARKS, and M. C. BOWMAN. 1966. Use of plant parts as food by larvae of the corn earworm and fall army-worm. Ann. Entomol. Soc. Am. 59:863-864.

Chromic oxide was used as an indicator of food use by insects. Table relates development of two species of larvae fed on lysophilized plant tissue of principal and alternate hosts.

Key words: NO MODEL, DATA, FEEDING RATE.

80. MILLER, C. A. 1966. The black-headed budworm in eastern Canada. Can. Entomol. 98:592-613.

Life cycle and bionomics of black-headed budworm are given. Age-interval survival rates and factors affecting large larval survival are discussed.

Key words: NO MODEL, DATA, MORTALITY.

81. MORRIS, R. F. 1963. The dynamics of epidemic spruce budworm populations. Mem. Entomol. Soc. Can. 31:1-332.

Life tables for spruce budworm in sprayed and unsprayed areas are given. Factors which regulate population numbers are discussed in detail.

Key words: MODEL, DATA, MORTALITY, FECUNDITY, FOOD QUANTITY, ENVIRONMENT, POPULATION NUMBERS.

82. MORRIS, R. F., and C. A. MILLER. 1954. The development of life tables for the spruce budworm. Can. J. Zool. 32(4):283-301.

A method for preparing life tables is described, and two examples are presented. Column headings for age interval (x), survivorship (lx), death (dx), and death rate (qx) are adopted from human life tables. An additional column, death factor, should be added to insect life tables so that different causes of death can be tabulated.

Key words: MODEL, DATA, MORTALITY, POPULATION NUMBERS.

83. MOTT, D. G., L. D. NAIRN, and J. A. COOK. 1957. Radial growth in forest trees and effects of insect defoliation. For. Sci. 3:286-304.

Assemblages of ring widths for a single tree are used to assess the influence of insect defoliation on radial growth.

Key words: NO MODEL, DATA, DEFOLIATION, TREE GROWTH.

84. ODUM, E. P., C. E. CONNELL, and L. B. DAVENPORT. 1962. Population energy of three primary consumer components of old-field ecosystems. Ecology 43:88-96.

Population energy flow of three major primary consumer groups living in the early stages of old-field succession was considered in relation to the net primary production of the ecosystem. The populations studied were: herbivorous orthoptera, savannah sparrows, and old-field mice.

Key words: MODEL, DATA, ENERGETICS.

85. O'NEIL, L. C. 1962a. Some effects of artificial defoliation on the growth of jack pine. Can. J. Bot. 40:273-280.

Pines were defoliated manually to measure the effects of defoliation on growth and to determine the relative efficiency of foliage of different ages with respect to growth. Current foliage was found essential for the maintenance of normal height, diameter, and shoot growth.

Key words: NO MODEL, DATA, DEFOLIATION, TREE GROWTH.

86. O'NEIL, L. C. 1962b. The suppression of growth rings in relation to defoliation by the Swaine jack-pine sawfly. Can. J. Bot. 41:227-235.

Sawfly defoliation was found to precede the production of discontinuous and missing growth rings.

Key words: NO MODEL, DATA, DEFOLIATION, TREE GROWTH.

87. RAFES, P. M. 1970. Estimation of the effects of phytophagous insects on forest production. IN: D. E. Reichle (ed.), Analysis of temperate forest ecosystems, p. 100-106. Springer Verlag.

The effect of phytophagous insects on the forest ecosystem is discussed. Concurrent with tree increment inhibition, some other phenomena also take place in the ecosystem. The quantity and quality of foliage consumed by insects determine, in part, their gross production and, thereby, their impact on the energy flow through forest food chains. The effect of foliage consumption by insects on later-developing insect populations, saprophagous populations in forest litter, and predator populations are discussed. Tables relating increment loss to tree species, insect defoliation, habitat type, and stand age are given.

Key words: DATA, NO MODEL, TREE GROWTH, DEFOLIATION, ENERGETICS, POPULATION NUMBERS, FEEDING BEHAVIOR.

88. REDMOND, D. R. 1959. Mortality of rootlets in balsam fir defoliated by the spruce budworm. For. Sci. 5:64-69.

A sequential sampling plan was used to assess rootlet mortality in trees defoliated by spruce budworm. Three mortality classes were formed by the percentages of dead roots: heavy (greater than 75 percent), medium (31-50 percent), and normal (less than 15 percent). These mortality classes were related to the percentage of defoliation.

Key words: DATA, NO MODEL, DEFOLIATION.

89. RODRIGUEZ, J. G. 1966. Nutrition of the host and reaction to pests. IN: L. P. Reitz (ed.), Biological and chemical control of plant and animal pests. P. 149-167. Am. Assoc. Adv. Sci. Publ.

How nutritional changes in the host influence reactions of phytophagous insects is discussed. Nutritional changes occur by feeding through the foliage, insecticides, and fertilizers. The preferred hosts are not always the ones with the optimum nutritional condition.

Key words: NO DATA, NO MODEL, FOOD QUALITY, FEEDING STIMULATION.

90. ROSE, A. H., and J. R. BLAIS. 1954. A relation between April and May temperatures and spruce budworm larval emergence. Can. Entomol. 86:174-177.

The mean maximum temperatures for days between April 1 and June 20 affect the percentage of various instars in the larval population.

Key words: NO MODEL, DATA, ENVIRONMENT, LARVAL DEVELOPMENT.

91. SILVER, G. T. 1960. The relation of weather to population trends of the black-headed budworm Acleris variana (Fern.) (Lepidoptera: Tortricidae). Can. Entomol. 92:401-410.

Budworm populations increase rapidly immediately after two years of below average precipitation in July and August. Outbreaks decrease and collapse during or immediately after periods of heavier than usual precipitation during the later periods of larval development.

Key words: DATA, NO MODEL, MORTALITY, POPULATION NUMBERS.

92. SILVER, G. T. 1962. The distribution of Douglas-fir foliage by age. For. Chron. 38:433-438.

The percentage of foliage for five youngest years was found to be 28, 23, 17, 13, and 10 percent. Although considerable variation occurred between crown levels, trees, and years, the averages were reasonably uniform. Table relates average number of needles per inch of twig by crown level and age.

Key words: DATA, NO MODEL, PHOTOSYNTHESIS, FOOD QUANTITY.

93. SILVER, G. T. 1963. A further note on the relation of weather to population trends of the black-headed budworm, Acleris variana (Fern.) (Lepidoptera: Tortricidae). Can. Entomol. 95:58-61.

A decrease in budworm population was associated with prolonged periods of cold, wet weather. The wet weather retarded larval feeding and development, which resulted in heavy larval mortality.

Key words: DATA, NO MODEL, MORTALITY, POPULATION NUMBERS, FEEDING RATE.

94. SMALLEY, A. E. 1960. Energy flow of a salt marsh grasshopper population. Ecology 41(4):672-677.

Energy flow values are given for grasshopper and *Spartina*. Oxygen consumption rates for the grasshopper are related to dry weight by a simple model. Primary production, consumption, and assimilation efficiency values are given.

Key words: MODEL, DATA, ENERGETICS, FEEDING RATES, ASSIMILATION EFFICIENCY.

95. SMITH, D. S. 1959. Utilization of food plants by the migratory grasshopper *Melanoplus bilituratus* (Walker) (Orthoptera: Acrididae), with some observations on the nutritional value of the plants. Ann. Entomol. Soc. Am. 52:674-680.

Efficiency of conversion of food to body tissue was given for three foods. This efficiency was found to be negatively correlated to the amount of food utilized. Tables relate effect of three foods on growth and survival; average utilization, consumption, and weight gains on three foods, and preference for three foods.

Key words: DATA, NO MODEL, ASSIMILATION EFFICIENCY, FOOD QUALITY, MORTALITY.

96. SMITH, S. G. 1954. A partial breakdown of temporal and ecological isolation between *Choristoneura* species. Evolution 8(3):206-224.

A table shows the percentage of daily adult emergence for males and females on balsam fir from June 28 to August 19 for two species of budworms.

Key words: DATA, NO MODEL, POPULATION QUALITY.

97. SOO HOO, C. F., and G. FRAENKEL. 1966a. The selection of food plants in a polyphagous insect, *Prodenia eridania* (Cramer). J. Insect Physiol. 12:693-709.

The postulate that the choice of a food plant by polyphagous insects is determined by presence or absence of repellents rather than reinforcement by attractants is discussed. Protein content of leaves is correlated with insect growth.

Key words: NO MODEL, DATA, FOOD QUALITY, FEEDING STIMULATION.

98. SOO HOO, C. F., and G. FRAENKEL. 1966b. The consumption, digestion, and utilization of food plants by a polyphagous insect, *Prodenia eridania* (Cramer). J. Insect Physiol. 12:711-730.

Some plants did not support optimal larval growth because of any one or a combination of the following factors: low digestibility, low efficiency of conversion, or low consumption rates. These factors and others relating to food quality are discussed and the results of feeding experiments are summarized. Tables relate food consumption and utilization efficiencies for fifth instar southern armyworms and fourth instar silkworms.

Key words: NO MODEL, DATA, FEEDING RATES, FOOD QUALITY, ASSIMILATION EFFICIENCY.

99. STARK, R. W., and J. A. COOK. 1957. The effects of defoliation by the lodgepole needle miner. For. Sci. 3(4):376-400.

Terminal and lateral growth were reduced significantly by defoliation of 40 percent with a negligible reduction at 10 percent. Tables show the proportion of needle miner attack in each year's needles, number of live larvae per tip at various times and altitudes, sequential sampling classes relating live larvae per tip to defoliation percentage, and lateral-terminal growth reduction because of defoliation.

Key words: NO MODEL, DATA, TREE GROWTH, DEFOLIATION, POPULATION NUMBERS.

100. STILLWELL, M. A. 1956. Pathological aspects of severe spruce budworm attack. For. Sci. 2(3):174-180.

Trees forked as a result of the 1912-1920 spruce budworm outbreak in northern New Brunswick are described.

Key words: NO MODEL, DATA, TREE GROWTH, DEFOLIATION.

101. STRUBLE, G. R. 1957. Biology and control of the white fir sawfly. For. Sci. 3(4):306-313.

Life cycle of the sawfly and lists of its predators and parasites are given. The effects of defoliation on basal area growth are discussed.

Key words: NO MODEL, DATA, DEFOLIATION, MORTALITY, TREE GROWTH.

102. SWEET, G. B., and P. F. WAREING. 1966. Role of plant growth in regulating photosynthesis. Nature 210:77-79.

Evidence is presented that suggests growth can affect the photosynthetic rate. The role of a metabolic sink and growth hormones is discussed. Experiments with *Pinus radiata* with either the plant apex removed before formation of the winter bud or with all fully expanded leaves removed were used to demonstrate the reduction in photosynthetic rate when growth is prevented.

Key words: DATA, NO MODEL, TREE GROWTH, PHOTOSYNTHESIS, PLANT HORMONES.

103. TANTON, M. T. 1962. The effect of leaf "toughness" on the feeding larvae of the mustard beetle, *Phaedon cochleariae* Fab. Entomol. Exp. Appl. 5:74-78.

The results of feeding experiments on turnip leaves of different toughness are presented. The amount eaten, weight gained, and the number of nibbles per replicate are measured for the varying degrees of leaf toughness.

Key words: NO MODEL, DATA, FEEDING RATE, FEEDING BEHAVIOR, ASSIMILATION EFFICIENCY.

104. TERRELL, T. T. 1961. Estimating defoliation caused by spruce budworm from undamaged shoots. U. S. Dep. Agric., For. Serv., Intermt. For. and Range Exp. Stn., Res. Note INT-86.

A simple regression model relates defoliation rate to percentage of undamaged shoots.

Key words: REGRESSION MODEL, DATA, DEFOLIATION.

105. THORSTEINSON, A. J. 1953. The role of host selection in the ecology of phytophagous insects. Can. Entomol. 85:276-282.

The factors that determine the host plant selected by phytophagous insects are reviewed. The idea that insects choose certain host plants because they are nutritionally most suitable is rejected.

Key words: NO MODEL, NO DATA, FEEDING STIMULATION.

106. THORSTEINSON, A. J. 1958. The chemotactic influence of plant constituents on feeding by phytophagous insects. Entomol. Exp. Appl. 1:23-27.

Chemotactic (usually gustatory) stimuli that release feeding activity are discussed. Soluble nutrients in plants serve this function and they may be non-nutritive substances of limited botanical distribution.

Key words: NO DATA, NO MODEL, FEEDING STIMULATION.

107. THORSTEINSON, A. J. 1960. Host plant selection in phytophagous insects. Ann. Rev. Entomol. 5:193-218.

Literature on food-plant perception, food-plant finding, food-plant recognition, permissive factors, visual stimuli, gustatory stimuli, genetic variability in food-plant selection, patterns of host-plant selection, antecedent theories, and catenary theory of host-plant selection is reviewed. The mechanisms for weeding out aberrant genetic tendencies are discussed.

Key words: NO MODEL, NO DATA, FEEDING STIMULATION.

108. TURNBULL, A. L. 1962. Quantitative studies of the food of Linyphia triangularis Clerck (Araneae: Linyphiidae) Can. Entomol. 94 (12):1233-1249.

Rates of food consumption were given for this spider. Simple regression models related duration of life stage to daily food consumption and mean growth to daily food consumption.

Key words: REGRESSION MODEL, DATA, FEEDING RATES.

109. WAGG, J. W. B. 1958. Environmental factors affecting spruce budworm growth. Forest Lands Research Center, Corvallis, Oregon. Res. Bull. 11. 26 p.

Simple regression models are presented that relate spruce budworm development to lateral growth of grand fir and to accumulated degree-days. In dense stands, the insect develops before the foliage, but insect and foliage develop at about the same time in sparse stands.

Key words: DATA, REGRESSION MODEL, LARVAL DEVELOPMENT, ENVIRONMENT.

110. WALDBAUER, G. P. 1964a. The consumption, digestion, and utilization of solanaceous and non-solanaceous plants by larvae of the tobacco hornworm, Protoparce sexta (Johan.) (Lepidoptera: Sphingidae). Entomol. Exp. Appl. 7:253-269.

The growth rate, the rate of food intake, the percentage digestibility, and the gross and net efficiency of utilization of food for growth were measured on the basis of dry weights. Even foods readily eaten by the larvae were not equal in their ability to support growth.

Key words: NO MODEL, DATA, ASSIMILATION EFFICIENCY, FOOD QUALITY, FEEDING RATE.

111. WALDBAUER, G. P. 1964b. Quantitative relationships between the numbers of fecal pellets, fecal weights, and the weight of food eaten by tobacco hornworms, Protoparce sexta (Johan.) (Lepidoptera: Sphingidae). Entomol. Exp. Appl. 7:310-314.

The weight of food consumed per mg excreted is found to vary with quality of food, age, and physiological state of the larvae, and various environmental factors. The number of fecal pellets is found to be an unreliable index of food consumption.

Key words: NO MODEL, DATA, EXCRETION, FEEDING RATE, FOOD QUALITY.

112. WALDBAUER, G. P. 1968. The consumption and utilization of food by insects. Adv. Insect Physiol. 5:229-288.

The literature on nutritional requirements, utilization efficiencies, and consumption rates is reviewed. Tables of these values are presented for a wide range of insects. Methods for calculating the indices are given.

Key words: DATA, NO MODEL, ASSIMILATION EFFICIENCY, FEEDING RATE.

113. WARDLAW, I. F. 1968. The control and pattern of movement of carbohydrates in plants. Bot. Rev. 34:79-105.

Literature on the distribution of assimilates in plants is reviewed. Topics included are: control of carbohydrate movement from the leaf, leaf position and assimilate distribution, the role of vascular connections in the pattern of ditribution, the demand for assimilates, and environment and assimilate distribution. The effects of defoliation are mentioned.

Key words: NO DATA, NO MODEL, TREE GROWTH, PHOTOSYNTHESIS.

114. WAY, M. J., and M. CAMMELL. 1970. Aggregation behavior in relation to food utilization by aphids. IN: A. Watson (ed.), Animal populations in relation to their food resources. Blackwell Sci. Publ., Oxford. p. 229-247.

Aphids thrive on actively growing parts of plants which are physiological "sinks" for soluble nutrients. Examples are stems and petioles, which translocate such nutrients, or senescing leaves where stored foods are being made soluble for translocation elsewhere.

Key words: DATA, NO MODEL, TREE GROWTH, FOOD QUALITY.

115. WELLINGTON, W. G. 1946. The light reactions of the spruce budworm, Choristoneura fumiferana Clemens (Lepidoptera: Tortricidae). Can. Entomol. 80:56-82.

The phototrophisms of the larvae are discussed with respect to the population density and the quantities of available food. The significance to population survival of their reactions to light is postulated.

Key words: NO MODEL, DATA, FOOD QUANTITY, FEEDING BEHAVIOR, MORTALITY, ENVIRONMENT.

116. WELLINGTON, W. G. 1957. Individual differences as a factor in population dynamics: the development of a problem. Can. J. Zool. 35:293-323.

The author assumes that the range of variation within a population may undergo successive changes and might affect the subsequent efficiency of some factors believed to regulate population density. An example of variations in the activity of larvae of the western tent caterpillar is given and the consequences of these are discussed.

Key words: NO MODEL, DATA, POPULATION QUALITY.

117. WELLINGTON, W. G. 1960. Qualitative changes in natural populations during changes in abundance. Can. J. Zool. 38: 289-314.

Colony formation by various activity types of moths of the western tent caterpillar are described. The vitality of a population is found to decline as it ages, and sudden recovery occurs at or near minimal abundance when its least viable portion has been eliminated.

Key words: NO MODEL, DATA, POPULATION QUALITY, POPULATION NUMBERS.

118. WELLINGTON, W. G. 1964. Qualitative changes in populations in unstable environments. Can. Entomol. 96:436-451.

Inactive moths of western tent caterpillar oviposit near their birthplace and most offspring are also inactive. Active moths travel farther before they oviposit and have a higher proportion of active progeny. The ecological significance of these facts is discussed with respect to population numbers and survival in a fluctuating environment.

Key words: NO MODEL, DATA, POPULATON QUALITY, MORTALITY.

119. WELLINGTON, W. G. 1965. Some maternal influences on progeny quality in western tent caterpillar, Malcosoma pluviale. Can. Entomol. 97(1):1-14.

Differences in feeding rate and food capacity displayed by different types of females during their larval development affect the proportions of the activity types in their progeny as well as the viability of consecutive groups within the egg mass. The significance of these differences to local population survival is discussed.

Key words: NO MODEL, DATA, POPULATION QUALITY, FEEDING RATE, FECUNDITY.

120. WELLINGTON, W. G., and D. A. MAELZER. 1967. Effects of farnesyl methyl ether on the reproduction of the western tent caterpillar, Malacosoma pluviale: Some physiological, ecological and practical implications. Can. Entomol. 99:249-263.

The results of the treatment of female pupae with farnesyl methyl ether provided evidence that the behavior types of the caterpillar are mainly nutritional products. Number of eggs produced, adult survival, oviposition rates, egg viability, and percentages of activity types resulting from egg masses were recorded for treated and untreated females. Ecological significance of a naturally occurring hormonal imbalance is discussed.

Key words: DATA, NO MODEL, POPULATION QUALITY, POPULATION NUMBERS.

121. WERNER, R. A. 1969. The amount of foliage consumed or destroyed by laboratory-reared larvae of the black-headed budworm, Acleris variana. Can. Entomol. 101:286-290.

The impact of the timing of the hemlock and spruce budbreak on the attack by black-headed budworm is discussed. Amounts of needles consumed or destroyed for both species and amounts of needles produced are given. Tables relate mean length of twig to number of needles per twig inch, mean number of needles consumed or destroyed to larval instar, and mean number of buds or needles consumed to sex and instar.

Key words: NO MODEL, DATA, FOOD QUANTITY.

122. WHITESIDE, J. M., and V. M. CAROLIN, Jr. 1961. Spruce budworm in the western United States. U.S. Dep. Agric., For. Pest Leafl. 53. 8 p.

Literature is reviewed on host range, life cycle, and ecology of the spruce budworm. The phenology of budworm development, its predators and parasites, and the mean fecundity of the female are discussed.

Key words: NO MODEL, NO DATA, FECUNDITY, MORTALITY, ENVIRONMENT.

123. WILLIAMS, C. B., Jr. 1966. Differential effects of the 1944-56 spruce budworm outbreak in eastern Oregon. U.S. Dep. Agric., For. Pac. Northwest For. and Range Exp. Sta., Res. Pap. PNW-33.

The damage from defoliation by spruce budworm and larval survival are compared for four conifer species. Differences are explained by phenological differences between the species.

Key words: NO MODEL, DATA, DEFOLIATION, MORTALITY.

124. WILSON, L. F. 1966. Effects of different population levels of the European pine sawfly on young Scotch pine trees. J. Econ. Entomol. 59:1043-1049.

Tables relate time of development and foliage consumption for peaks of larval instars; leader elongation, annual-ring growth and percentage mortality to various defoliation levels, and height-growth rates were given for various levels of the insect population.

Key words: NO MODEL, DATA, DEFOLIATION, TREE GROWTH, POPULATION NUMBERS.