INTERNAL REPORT 136

TERRESTRIAL VERTEBRATE CONSUMERS OF CEDAR RIVER INTENSIVE SITES: PARAMETERS FOR MODELING

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OBJECTIVES

(1) Determine energy and material flow paths through terrestrial vertebrate consumers.
(2) Contribute toward population dynamics, energy/nutrient flow and production process (control function) models.

APPROACH

Animals exist in populations, which occupy landscape units. In order to obtain animal data suitable for use in ecosystem modeling, the significant animal populations existing in relevant habitats must be studied in the field.

Relevant habitats studied in 1972 were the Thompson Site and the Findley Lake Site. Significant animals studied in 1972 were the birds, the small mammals, the large herbivores, and the slugs. Each of these groups requires its own methodological approach, and for each, certain types of data are most readily obtained. Therefore our work was organized in two phases: (1) the field-laboratory phase, in which each significant animal group comprised one subproject, and (2) the model development phase, in which each type of model comprised one subproject.

This organization, which will be followed in the present report, permits the ready identification of individual persons with specific activities, thus not only giving due credit for individual contribution but also making each specialist readily identifiable for interaction within the Biome.

Further, in order to provide for preservation and retrieval of the original reports on the various subprojects, these have been included in the copy of the present report on file in the Wildlife Sciences Laboratory U.W., as appendices.

PHASE I: FIELD-LABORATORY

Subproject A: Small Mammal Studies (Terry, Erickson)

Earlier work on small mammals has established inventory, consumer role, abundance, biomass, and energy relationships for the Thompson Site (Miller 1970, Miller, et al. 1972). Through this work the relative importance of insectivorous species was evident.

During 1972 a special study of the insectivores was undertaken by Terry. This was aimed at determining for three common species (shrew mole, *Neurotrichus gibbsi*; Trowbridge shrew, *Sorex trowbridgei*, and vagrant shrew, *S. vagrans*), their relative food preferences, their rates of food consumption, their relations to potential prey species, their ecological relations to the forest floor and their interspecific behavioral relations.

In the course of this work it became evident that a fourth insectivore, *Sorex obscurus*, the dusky shrew, sometimes shares their forest habitat. From field observations, including trapping results, it is evident that all four insectivores can be found in the same general habitat. They must therefore either use separate microhabitats, or use different elements, such as foods, through the same habitat. The former appears more probable.

Ecologically, these insectivores play a role as primary (seed) consumers as well as predators upon primary consumers.

In addition to these studies of the insectivores of the Thompson Site, a preliminary assessment of population density of the Douglas squirrel (*Tamiasciurus douglasii*) has been completed. This squirrel subsists on conifer seed, supplemented with such other foods as fungi, insects, and berries. On the Thompson Site, squirrels were counted in the same way as birds, by territorial location and behavior. Both sexes are territorial and seasonally conspicuous.

During the period March-July 1972, there was a squirrel density on the Thompson Site of about 0.5 squirrels per acre, or 118 per 100 hectares. Squirrel population density is known to fluctuate in response to food abundance in "seed years," but 1972 was not such a year. The literature contains a wealth of data on squirrel populations relevant to model development.

Subproject B: Bird Studies (Erickson)

The bird populations of the Thompson Site have been studied earlier with respect to inventory, consumer role, abundance, and biomass, by season (Miller, et al. 1972). During 1972 this work was replicated.

In addition, the birds of Findley Lake Site were characterized with respect to the same parameters.

Inventory and relative abundance

Most abundant breeders were red-breasted muthatch, winter wren, varied thrush, Oregon junco, chestnut-backed chickadee, golden-crowned kinglet.

Less abundant breeders were hermit thrush, Lincoln's sparrow, robin, dipper, evening grosbeak, song sparrow, McGillivray's warbler, hairy woodpecker, rufous hummingbird, western flycatcher, pine siskin, Wilson's warbler, brown creeper.

Species not known to breed in study area were mountain chickadee, Townsend's warbler, hermit warbler, olive-sided flycatcher, red-shafted flicker, gray jay, common raven, great horned owl, red-tailed hawk, spotted sandpiper, black swift, Vaux's swift, bufflehead duck, common merganser.

Consumer role and biomass

Of the breeding birds, primary consumers had a total biomass of 176 grams within a zone of about 150 meters around the lake; secondary consumers in the same area had a biomass of 970 grams.

Subproject C: Large Herbivore Studies (Schoen)

The two principal large herbivores of the Cedar River intensive sites are the deer (*Odocoileus hemionus*) and the elk, (*Cervus canadensis*). These species pose certain mensurational problems with regard to data-gathering on the intensive site. Some of these are: (1) they may have movements which bring them to the intensive sites only seasonally or sporadically, (2) their populations may be increasing or decreasing during the period of study, (3) they interact with the vegetation not only through direct feeding, but also through a variety of physical effects including trampling and abrasion, (4) there is the possibility that the presence of investigators, and research apparatus, especially on intensively studied sites, may influence the behavior of large herbivores and thus bias the results with regard to their ecological role.

In order to understand the ecology of the large herbivores on the Cedar River intensive sites we have considered it necessary, at first, to study the population using each site through its entire seasonal range. Since direct observation is ordinarily not feasible in the forest, we have resorted to marking selected individuals for radio-tracking.

Elk

Up to 10-15 years ago, elk were seldom or never seen in the Cedar River area. Then a few individuals of the Rocky Mountain Elk, introduced into western Washington from Yellowstone National Park, were observed. Since then there has been a gradual increase in population. In 1972 we made a preliminary estimate f 150 for the Cedar River Watershed. It is evident that this is a growing population. If, as seems probable, there is no serious impediment to the growth of this population, we can expect it to increase at the rate of about 20 percent a year. If this rate of increase is continued through the next 10 years, we will then find a population *six times* as large as the one we observe today.

Since we can already observe a marked impact by the elk on the vegetation in certain favored areas, we can predict that in the next decade they will bring severe ecological pressure to bear on the forest vegetation. This will be one of our subjects of study.

At present, two measures are made of the pattern of elk distribution and intensity of use over the landscape at large: radio tracking and pellet-group distribution. In addition, aerial and roadside counts have given minimum population estimates and data on seasonal distribution. It is already evident that elk use the landscape in a highly irregular manner, avoiding certain areas and concentrating in others. It is of great ecological importance to analyze the seasonal patterns of ecological distribution and relate them to ecosystem function.

Direct counts of elk throughout the watershed have been made from the air in the early spring and from a systematic road sample in the summer. A comparison of results from year to year will provide a measure of population increase to corroborate or correct our present estimated rate of 20 percent per year.

Radio tracking requires capture of individual elk for marking. Both traps and dart-injected drugs were used for this purpose. Through early 1973 seven elk had been radio-marked and intensive observation of their movements had begun. This work has been materially assisted by David Zoeller and Deborah Hecathorn.

Studies of elk distribution through pellet group samples are also under way. The basis for this method is the observation that elk produce an average of 13 pellet groups daily. We plan to make independent studies of the rate of pellet deposition, but until these are completed we tentatively accept the production rate of 13 groups per day per individual. Studies through the winters of 1971-2 and 1972-3 indicated that elk concentrated heavily on certain forest sites. While the overall elk density is on the order of 1 or 2 individuals per square mile, pellet-group samples have given local density estimates of the order of 124 to 230 per square mile for a 3-month period.

From previous studies we can estimate the live weight of these elk, their rate of forage consumption, and their seasonal concentration in the vicinity of the Thompson Site.

A hypothetical herd-unit of three animals would approximate the following weight:

Adult cow	600 lb	(273 kg)
Calf	150 lb	(68 kg)
Yearling	300 lb	(136 kg)
Total	1050 lb	(477 kg)

Average 1050/3 = 350 lbs (159 kg).

Daily consumption of forage by elk has been found to be about 2 lbs (dry weight) per hundred weight per day, or 1 kg of forage per 50 kg live weight of elk.

From preliminary pellet-group data we have estimated elk winter concentrations near the Thompson site, as high as one elk per 3.5 acres (1.4 ka) for three months.

Forage consumption, over three months, by one average elk, can be calculated from the data above as follows:

> 3.5 (hundred weight pounds) x 2 (lbs daily forage consumption) x 90 (days) = 630 pounds (dry wt) of forage taken from 3.5 acres,
> Or 202 kg of forage per hectare.

When one recalls that this forage is not taken at random, but definitely selected from among the available plant materials, it can be seen heavy pressures can be exerted on favored food plants.

Deer

Deer are native to the Cedar River drainage. Genetically they range from the Columbian black-tailed race (*O. H. columbianus*) on the lower watershed to a hybrid between black-tails and mule deer (*O. H. hemionus*) as in the higher elevations.

Deer populations fluctuate with environmental conditions such as winter snows and forest manipulation. In the Cedar River Watershed they may well prove to be influenced detrimentally by elk populations as well, either through competition for food or through behavioral dominance, or both.

Much more data is available for deer than for elk in this general environment from earlier studies. Following these, we can estimate an overall deer density in the watershed on the order of 15-20 per square mile. Like elk, however, deer can concentrate seasonally on certain favored sites. As in the case for elk, we can calculate the consumption of plant food by a representative group of deer.

Adult doe	100 lbs	(45.5 kg)	
Fawns (2)	60 lbs	(27.3 kg)	
Yearling	75 lbs	(25.0 kg)	
Total	235 lbs	(97.8 kg)	live weight

Deer consume about 2.5 lbs of forage (dry weight) per day per hundred weight of live animal.

Pellet-group counts during the past two winters show deer concentrations as high as 138 per square mile for a one-month period. While it is useful to know of these general relationships, it remains to determine specific seasonal food habits, plant communities used, and impact on the vegetation.

Subproject D: Slug Studies (Richter)

Early in our investigations of the Thompson site we noted a high seasonal biomass of the native banana slug, *Ariolimax columbianus*. Subsequent surveys of the literature revealed that very little was known concerning the biology of this species. Since it seemed probable that it was of significance in ecosystem function on the Thompson site we undertook a study aimed first at sketching in the salient features of its biology, and second at relating these biological parameters ot the various ecosystem models under development. This work was conducted on the Thompson site, at Carkeek Park, a similar site convenient to our laboratory, and in the laboratory itself.

High slug densities were discovered at Carkeek Park. By belt-transect measurements a population of between 5,000 and 10,000 individuals per acre (D.I. .95) were estimated. This is believed to be an aggregation, perhaps a seasonal one. This same population had a live weight biomass of 147-377 pounds per acre. Two hundred pounds/acre would be 224 kg/ha.

Food consumption, in the laboratory, averages about 5 percent of body weight per 24 hours. The aggregation above, then, would consume about 7-19 lbs per acre (3.2 - 8.6 kg/ha) per day. Consumption following periods of inactivity is as high as 30 percent of body weight per day; however 5 percent is probably a better average figure over long periods.

The food of the slug includes green and semigreen vegetation, as well as carrion and probably slow-moving invertebrates. It feeds by the rasping action of its radula, which mechanically breaks open cell wells. Not only cell contents but also cellulose structures contribute to slug nutrition, since its digestive tract is characterized by high concentrations of cellulose.

Reproduction in nature is seasonal. Copulation occurs in the fall, the eggs (avg 36) are deposited in a group under moss. There they over-winter, to hatch in the spring.

Preliminary studies suggest that slugs first reproduce at 1.5 years of age and some individuals may survive to four or five years of age.

More definite data on longevity, as well as movement, is being obtained from the observation of marked individuals. It has been found possible to use freeze-branding for this purpose.

These population studies are leading into more detailed investigations of the role of the banana slug in consumption and decomposition.

PHASE II: MODEL DEVELOPMENT

Subproject A: Population Dynamics Model
(McCaughran, Mitchell, Bradley, Schoen)

A population dynamics model for a particular species requires a sound conceptual model of the relationships between birth and death rates and the factors influencing them. A general example of a population dynamics model, assuming no migration, is given by: $dn/dt = (b - d)\,n$, where n = population size at time t, b = birth rate, d = death rate, and b and d are modeled separately as functions of population size, age and sex structure, nutritional status, predator abundance, weather or other important factors.

In a real-life situation, movement must be assumed, so the given equation is inadequate as it stands.

Several approaches to population dynamics modeling are being pursued simultaneously. Mitchell is constructing a generalized model of the dynamics of black-tailed deer populations, using data from the entire range. Bradley is contrasting black-tailed deer populations under different regimes of predation and competition, within the Douglas-fir forest: Hunted = Unhunted and With Elk = Without Elk. Schoen is dealing with the elk population within the Cedar River Watershed, a population which seems to be rapidly increasing.

Subproject B: Consumption Model (Strand, Ryder)

The population is divided into a series of life stages such that the individuals in a life stage have common consumption and respiration rates on a gram per gram body weight basis. These life stages are defined by individual body weight ranges or by development stage, by shifting significant forces working on them.

$$M_i = \sum_{j=1}^{i-1} m_{ij}M_j - \sum_{\ell=i+1}^{n} m_{\ell i}M_i + f_{ii}\ (C_i - R_i - U_i - D_i - P_i)$$

$$N_i = \sum_{j=1}^{i-1} c_{ij}N_j - \sum_{\ell=i+1}^{n} c_{\ell i}N_i - d_iN_i - p_iN_i$$

M_i = biomass in the ith life stage

N_i = number of individuals in the ith life stage

m_{ij} = proportion of biomass of stage j maturing to stage i in one time unit

f_{ii} = proportion of biomass of stage i not maturing to another stage in one time unit

C_i = consumption rate for the ith stage

R_i = respiration rate for the ith stage

U_i = defecation rate for the ith stage

D_i = death (natural causes) rate for the ith stage

P_i = predation rate for the ith stage

c_{ij} = proportion of the number in life stage j maturing into stage i

d_i = proportion dying

p_i = proportion preyed upon

Where:

$$D_i = d_i \frac{M_i}{N_i}$$

$$p_i = P_i \frac{N_i}{M_i}$$

$$m_{ij} = \frac{c_{ij} N_j B_j}{M_j}$$

B_j = maximum body size reached in the jth life stage

From our present knowledge of both deer and elk we can provide at least approximate values for M, C, R, and U. At present D and P are thought to be negligible for elk in Cedar River. They remain to be determined for deer, but substantial progress toward their determination will be made during 1973, particularly if we can obtain support for radio-marking deer. During 1973 much work must be devoted to the thorough elucidation of C, since each food species must be considered separately, and in a population and community sense as well as a quantitative one.

For slugs, where there is so little information in the literature, but for which data from our own studies is accumulating at a gratifying rate, we should have at least preliminary data in all necessary categories by the end of 1973. At present, we are preparing data sheets for major herbivores. For birds and small mammals the main problem with regard to this model is the need for data on food preferences. The definition of the term "food preference" is important as well as the total impact of feeding upon the biotic community within which the food-organism exists.

Subproject C: Control Function Model (Hatheway)

The development of this model, which involves successional relationships, properly begins in 1973 rather than 1972. When possible, however, we have gathered information on animal populations in early successional stages. We now have a substantial amount of data for a clear-cut on the Thompson Site, at ages 5 and 6 years, and at 40 years postlogging. During 1973 a number of intermediate and subsequent stages will be added.

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