ADVANCE IN SECONDARY PRODUCTIVITY RESEARCH IN ALPINE MEADOW ECOSYSTEM

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Since the establishment of Haibei Research Station of Alpine Meadow Ecosystem, studies on subsystem of consumer have centered on secondary and third productivity of alpine meadow ecosystem which is one of the major project of the Chinese Academy of Sciences.

Studies on secondary productivity can start from the level of individual, population, community or ecosystem and the research directions gernerally involve in: (1) analysis of energy budget and energy flow of the individual population; (2) analysis of energy flow of certain food chain; (3) analysis of the energy flow of the ecosystem as a whole. of course, these three researching directions are not separate, instead they are interdependent and mutually complementary.

Since 1976—1986, around the above-mentioned researching directions, we have unfolded a series of studies at different levels with the objects of the major livestock in alpine meadow as Tibetan sheep, yak (*Bos grunniens*) and the dominant herbivorous small mammals in the ecosystem like plateau pika (*Ochotona curzoniae*), plateau zokor (*Myospalax baileyi*), root vole (*Microtus oeconomus*). As to the birds nesting in alpine meadow, horned lark (*Eremophila alpestris*), small skylark (*Alauda gulgula*) and mountain finch (*Leucosticte brandti*) have been taken as the main objects together with some insects. For the last ten years, near 50 papers have been published on the relevant journals like "Acta Biologica Plateau Sinica", "Acta Theriologica Sinica" and some other publications both at home and abroad, and furthermore, better achievements have been obtained. The progress in concerned studies are introduced below.

1. Investigations of basic data

With the help of Menyuan Stud Ranch of Haibei, Qinghai province, we wound out the data on compositions of livestock in the region of the research station, on the grazing and utilization of grassland resources, and on the production status and economic benefit etc.

The terrestrial vertebrates in the area had been extensively investigated. There are 86 species in all, including 2 species of Amphibia, 1 species of Reptilia, 61 species of Aves and 22 species of Mammalia, of which 3 species belong to Artiodactyla and 10 species fall into Rodentia. Moreover, terrestrial invertebrates (taking the insects as the major objects) in the area were investigated as well. According to the preliminary survey, 9 orders of insecta and three orders of Arachnoida were recorded on the ground, 7 orders of insecta belong to 27 families and 66 genera and species were recorded in soil. More than half genera and species and almost 80% of individuals belong to Diptera.

2. Exploration and improvement of studying methods

We tried to use the methods defined by IBP as far as possible. However, in many cases there were no methods to follow due to some specific characteristics of the objects in alpine meadow ecosystem, so that we had to explore and improve the means of study on our own. For instance, in the measurement for food intake of Tibetan sheep, we used mask, to do the work and obtained better results after repeated experiments, for the methods available did not fit for our experiments. In the meantime evaluations were made on the AlA method of different equivalent in the measurements of daily food intake by yaks. We designed by ourselves the live-trap for the capture of plateau zokor and improved the electrolytic oxygen supplement respirometer in cooperation with some other concerned units, and we also developed an activity recorder for small mammals etc..

3. Studies at individual level

Studies on secondary productivity at individual level involve: intake by animals (C), digestion (D), assimilation (A), the excretion of feces and urine (F.; U), respiritory metabolism (including resting metablism rate, average daily metabolic rate, movement metabolism) and energy requirement during reproduction, measurements of caloric value of natural food for various animals and caloric value for animal body. Studies like these belong to the physiological field, thus the above data can be refered to physiological parameters which require precise determination. Once they are combined with population number, sex ratio, age structure and some other characteristics of ecology, the productivity of a population, community or a certain ecosystem can be estimated. Therefore studies at individual level are fundamental to the above estimations, so that considerable labours and materials have been put into the studies at individual levels. Progresses achieved involve in the following aspects:

(1) Domestic animals:

Mask method was adopted to determine the daily food intake and excretion of feces and urine of Tibetan sheep and the result of which indicated that the annual average daily intake by a sheep was 1.81 kg (dry matter), making up 3.75% of the body weight and showing significant seasonal changes. The highest might reach 2.38 ± 0.13 kg (dry matter)/individual/day during green up period.

Besides, Kibler's open-circuit respiration apparatus method was also used in the study of basal metabolism of Tibetan sheep and Xinjiang Tibetan hybrid sheep. All of the achievements provides the basic data for the understanding of energy requirement and efficiency of energy utilization of sheep under different production status.

(2) Small mammals:

The resting metablism rate and average daily metablic rate of plateau pika, Cansu pika (*Ochotona cansa*), plateau zokor, root vole, marmot (*Marmota himalayana*) polecat and alpine weasel were measured by the use of kalabuhov-Skvortsov's respirometer. A lot of parametres of energitics were obtained as basal metabolism rate, resting metabolism rate, critical temperature, critical gradient, conductivity, thermal conductance and thermal insulatity of fur etc.

Wang Zuwang (1980) and Liang Jierong et al. (1985) tried to use the balance method to measure the preferences of natural food in platerau pika, zokor, polect and alpine weasel, and their food intake, digestibility, assimilation and excretion of feces and urine in mtabolic cages. The data concerned may be summarized as follows (Table 1).

Zeng Jixiang (1981) used Animex (DSE model) recorder of animal activity and combined

Table 1 Data Concerned to Food Assimiilation in some Small mammals

Species	Energy Intake		Digestibility %	Feces %	Urine %	Assimilation %
	Kcal/animal/day	Kcal/g·wt./day				
Ochotona curzoniae	130.94	1.07	69.24	30.75	4.66	64.59
Myospalax baileyi	159.07	0.68	77.72	22.12	4.98	72.78
Mustela eversmanni	721.27	0.709	85.42	14.86	5.25	80.18
Mustela altaica	250.39	1.259	88.21	11.79	5.58	82.63

with the measurement of average daily metabolic rate, studied the activity rhythm of plateau pika, plateau zokor, root vole, polecat and alpine weasel. It has been found that plateau pika is diurnal for the most part and root vole is nocturnal in activities while plateau zokor is active both in daytime and in night. The daily rhythm of polecat and alpine weasel vary with their prey. The co-evolution of the predator and its prey, is reflected in the activity rhythm, showing the detachment of the niche of two carnivores.

(3) Birds

The study concentrates on the effect of temperature on energy balance of the mountain finch and the relation of oxygen consumption to ambient temperature. It merits attention that the thermal conductance is 2.18 kcal/m^2 which is caculated according to the equation $c = M/\Delta t$. It indicates that the thermal insulatity is lower and a higher level energy consumption at the thermoregulation than other passerines.

(4) Measurments of caloric value

Altogether, 250 plant samplings (including 15 species of plants), 859 animal samplings (including 32 species of animals), 490 feces and urine samplimgs have been measured.

4. Studies at population level

Excluding the population structure of Tibetan sheep, the variations of population ($\bar{N}$), body-weight ($\overline{W}$), sex, age structure, breeding status, ecological longevity, home range, family structure of three dominant small habivorous mammals were made for a long time. Moreover, two small carnivorous mammals, polecat and weasel, were also investigated concerning their population numbers, reproduction, habit etc.. From the above studies combining with the research results at individual levels, the population energy budget, biomass, production, turnover rate and energy flow through the population of the above-mentioned animals were estimated. The results indicate: Energy flow through the population of Tibetan sheep is $A = 0.798 \times 10^6$ kcal.ha^{-1} year^{-1}; and energy flow through population of plateau pika is 640.51—6094.65 10^3kJ ha^{-1}year^{-1} respectively. The energy consumption per gram body weight per day by plateau pika or plateau zokor are 6.1 and 4.1 times the consumption of Tibetan sheep respectively. Energy lost in feces and urine of these two small mammals is 46 and 22 times of the caloric value of their body tissue respectively, and this indicates that the two small mammals play an important role in accelerating energy flow in alpine meadow ecosystem. Energy flow through the populations of two carnivourous small mammals (polect and weasel) is 0.917×10^5; 0.376×10^5 kcal ha^{-1} yr^{-1} respectively.

In addition, studies were also made on population density, breeding and nestling periods, clutch size, survival rate and the mean numbers of fledgelings per nest of 10 species of passerine birds. It has been found that birds nesting on the ground have highest survival rate and the potentail of population growth is largest.

As to the insects, the population of alpine meadow red-thorax forest and (*Formica* sp.) was extensively studied upon its life history, sociality, food habit and relations with some ecological factor.

5. Researches at community level

Researches in secondary productivity at community level pays great attention to birds and insects. The progresses are as follows:

Zhang Xiaoai (1982a, b) studied the breeding bird communtity on alpine meadow and found that there are 18 species of breeding birds belonging to passerine except 2, among them 78% were ground nesters; 61% were resident birds; 56% were omnivorous birds. In six habitats, the diversity index (1.48) and evenness (0.83) on the swamp meadow are higher, therefore, the stability of bird community is the greatest, while on the *Elymus nutans* meadow, diversity index (0.66) and evennes (0.47) are lower, consequently, this community is the lowest in stability.

Based on the data obtained from studies at both individual and population level, Zhou Li (1986) constructed a simulation model for the population densities and energy flow of each species considered. Bird communities consist of 10 species that are higher densities within avian consumers in alpine meadow ecosystem. The dynamics of the population densities and energy flow of the nestling, fledgeling, juvenile and adult age classes of each species were simulated. Estimation for the total community as well as for each population were made. Results obtained may be summarized below:

1. Due to the low density and biomass of birds, the energy flow through the avian community is small, amounting to 18.5 kcal/m^2/yr.

2. The energy flow through the adult and juvenile age classes in the energy age distribution within bird communities is 95%.

3. The climate in alpine meadow is cold and annual mean temperature is 0.6°C, the energy costs of thermoregulation within bird communities are 28.4% of the energy flow through bird communities.

4. The energy cost for egg production is rather small amounting to 0.04% of the energy flow through the birds communities.

A survey of insect communities and their structures at different space and time and the character of soil insect communities were made by Wu Yar and Jin Cuixia (1980, 1982a, b). The results show:

(1) From the food habit point of view, almost half of the insect occurring on alpine meadow are harmful to plants, only 9% of the insects are beneficial to plant production. Predator and parasite amount to 22% and play an effective role of regulation in dynamic balance. Peces-eater, saprophagous insects continuously destroy and remove the organic wastes accumulating on the meadow and the detritus of which becomes the decomposable material for microorganism. Such interdependant and interactive relations form a rather complicated food web of insects.

(2) For the diversity indices and similarity indices of the community, diversity index of swamp meadow is highest, while those of shrub and slope meadow are lowest. It is noticeable that the number of insects species have decreased greatly after alpine meadow being re-

claimed and it results in the decrease of diversity of insect communities.

6. Researches at ecosystem level

Researches in secondary productivity at ecosystem level are rather complicated and measurements of various relations of energy are largely involved. It puts forward a question about mode of thinking, should we rigidly adhere to the details of various energy relations or lay particular emphasis on macroscopically approximate comparison, expecting to gain important enlightenments? We consider the latter to be a right mode of thinking. Achievements obtained are introduced below:

Jiang Zhigang (1982a, b) studies the niches and niche overlaps of domestic yak, Tibetan sheep and plateau pika, and their variation in different phenolgical period, in alpine meadow ecosystem. The results indicate: (a) Through the analysis of food resource species and resource utilization spectra, pick food hight, vegetation and phenological period as the four niche tlimensions, it demonstrates that the niche breadth of yek in alpine meadow ecosystem is largest, Tibetan sheep takes the second plateau pika is the smallest. (b) Much overlap occurs in the niche of yak and Tibetan sheep, and next comes plateau pika and Tibetan sheep's, the smallest one is plateau pika and yak's. (c) There exists a variation in niche breadth (as well as niche overlap) of yak and Tibetan sheep in different phenological period. (d) When pressure of intraspecific competition increases, it enables the niches of herbivores to generalize. The occurence of this generalization is not only on one dimension and the result of which gives rise to the increase in niche overlap between species and as a result aggravating interspecific competition. (e) Because of the differences of niche, considering space and time management, hydrophyte-grassland should be used to graze yak and summer bush grassland should be used for grazing Tibetan sheep. (f) Coefficient of competition has been estimated according to niche overlap, and balance population density of yak and Tibetan sheep is 1:3.1 calculated by Lotaka-Voltarra equation.

(2) Plants-phytophagous animals system is not only conformable to prey-predator system but also a special case of that system. With this enlightenment, Liu Jike, Wei Shanwu et al (1986) proposed a dynimic model for producer (plants)-consumer (plateau pika) system. The model simulated the connection and interaction between the production of plant and the production of plateau pika. One the whole, the simulated results conform to the actual data and it can be used in practical work.

(3) A simulation model of biomass dynamics for consumer subsystem in the alpine meadow ecosystem has been built according to studies of secondary production at individual, population and community levels.

The objective of the model is to simulate the biomass dynamics of six consumers (Tibetan sheep, plateau pika, plateau zokor, weasel, horned-lark and steppe caterpillar (*Cynaephora qinghaiensis*)). Producers consist of the above-ground part of four types of plants (grasses, sedges, forbes and *Dasiphora fruticosa*), litters and the underground part of plants. The model uses a set of non-linear differencial equations to describe the instantaneous variations of principal state variables, namely density, body-weight, feces and dead bodies. The mathematical representation biomass is presented in product of density and body-weight. The purpose of this model is to quantatively explain the changing laws of each consumer in the alpine maedow ecosystem such as the growth of body-weight, fluctuations in numbers, changes in biomass and energy flow, the productivity of consumers, ecological efficiency and some other mechanisms. On the other hand does the system response the comsumer to the disturbances of other subsystems or factors coming from the outside environment. Through the calculation,

most of basic results being simulated with the model, e.g. the numbers of the consumer, body-weight, daily food intake, energy budget, food utilization by comsumers etc. are conformable with the observed values. In the mean time, some problems have been point out and the future goals to achieve have also been suggested.

For the last ten years, much progress has been made in the studies on secondary productivity in ecosystem and it fills not only the gaps in this field in our country but also reduces the distance between the international level as well. No need for reticence that we still have a long way to go in terms of combining the discipline development with production practice.

To consider from the development of the scientific researches in secondary productivity at different levels are out of balance to some extend, for the fact that studies in individual and population levels, comparatively speaking, are well developed, however, studies at community and ecosystem levels should not be neglected. As to the objects of studies, small mammals and birds have been better studied, but week in entomology, especially on soil insects at individual and population levels.

In the view of serving the production, some work has been done, e.g. the application of the achievement of secondary productivity and the theory of ecosystem to solve the problems in changing the backward status of production and management, rodent pest control, and find optimal population structure of livestock and optimal slaughter rate etc. and an optimum grazing system are also in progress. Nevertherless, we are deficient in actively propagating our achievements to using departments and popularizing them. Usually, a good idea or plan for raising the productivity is not easely recognized or accepted by the leaders or the people, particularly in a poor area where economic and technological level are backward.

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高寒草甸生态系统次级生产力研究的进展

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摘　要

自1976年海北高寒草甸生态系统定位站建立以来，消费者亚系统的研究是作为中国科学院院属重点课题之一而进行的．次级生产力的研究，可以从个体、种群、群落或生态系统不同水平出发，今结合基础情况调查与方法的改进，介绍于下：

1. 基础资料的调查．　除查明定位站所在地——门源马场的畜牧业情况外，着重调查了陆栖脊椎动物，计有 86 种，其中两栖纲 2 种，爬行纲 1 种，鸟纲 61 种，哺乳纲 22 种，以啮齿目占优势．另外，昆虫纲 9 目，蛛形纲 3 目，而以双翅目的种类及数量为最多．

2. 研究方法的探讨与改进．对藏系绵羊日食量的测定用：口罩法，认为比较符合自然放牧的情况．　对牦牛日食量的测定采用 AIA 法，以浓盐酸消化粪便加以推算，比较简便．对小哺乳动物与鸟类的代谢率研究，则改装了封闭式流体压力呼吸计和电解式补氧呼吸计．研制成小哺乳动物活动记录仪，并制备特别运用于鼢鼠的活捕笼．

3. 个体水平的研究．包括动物的摄入、同化、粪便和尿、呼吸代谢的静止代谢率、平均

每日代谢率、运动代谢和繁殖时期的能量需要以及各种天然食物和动物身体热值、研究的动物包括绵羊、高原鼠兔、甘肃鼠兔、高原鼢鼠、根田鼠、旱獭、艾虎、香鼬和高山岭雀等.此外还研究了一些鼠类和食鼠小兽(艾虎、香鼬)的昼夜活动节律.

4.种群水平的研究. 作了种群的数量、生物量、年龄、寿命、出生与死亡、周转率和种群结构等. 包括绵羊、草食和肉食的小哺乳动物、小型鸟类等.

测得通过绵羊种群的同化能为 0.798×10^6 大卡/(公顷·年), 而摄入能为 1.136×10^6 大卡/(公顷·年). 并据优化原则提出绵羊的合理种群结构及出栏率, 预计可增加17% 的活重.

以标志流放法研究了根田鼠、高原鼠兔、高原鼢鼠、艾虎、香鼬、小型鸟类的种群数量变动、种群结构、巢区、繁殖、家庭结构、生命表等问题,认识到高原鼠兔每公斤体重消耗的能量为绵羊的2.5倍. 注意到鼠类的粪便在能量与物质流动中的重要性. 同时研究了赤胸林蚁的生态学.

5.群落水平上的研究. 研究了高寒草甸繁殖鸟类的群落结构,发现6个生境中,金露梅灌丛的群落种类最多、密度最大; 沼泽化草甸者生物量最大. 多样性指数变化也较大,沼泽化草甸鸟类群落的多样性指数最高(1.48),垂穗披碱草草甸者最低(0.66). 建造了高寒草甸鸟类群落能流的模拟模型,发现在鸟类低密度、低生物量的条件下,流入鸟类群落中的能量仍有 0.185×10^6 大卡/(公顷·年). 计算了成鸟、幼鸟、卵的能量分配.

对昆虫的群落也作了研究,从食性方面提出了食物网的结构,同时观察到不同生境下昆虫群落的差异、相似性的不同. 注意到开垦为农田后,种类减少,数量增加,多样性指数降低,故开垦后应注意虫害的发生.

6.生态系统水平上的研究. 重点在初级生产与次级生产两个营养层次的关系上, 如放牧对草地群落的影响等. 研究了牦牛、藏系绵羊和高原鼠兔的生态龛,通过食物谱,食物利用谱,采食高度和植被类型四个生态龛维上结合物候期进行分析,计算出它们的生态龛宽度与重叠,探讨了它们种内与种间斗争的问题,提出牦牛与绵羊的平衡种群密度应为1:3.1.

以捕食被捕食的关系探讨了生产者(草)与消费者(高原鼠兔)的动态数学模型. 模拟结果符合实际资料.

建立了"高寒草甸生态系统消费者亚系统生物量动态模型"(摘要见本集), 内容包括6种消费者和4类植物. 涉及植物摄入、消化、同化、能量收支、二级消费者对一级消费者的捕食. 给出种群密度、体重与种群生物量的季节动态过程.