The nutritional value of the biomass of butterflies and moths in temperate and tropical climates, II

By

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Abstract. Previously, we have determined the raw protein content, as derived from the total lipid and total nitrogen contents, of some Rhopalocera moths both from temperate (Hungary) and tropical (Vietnam) regions. This was used to determine the amount of biomass produced by them (Gere, 1993). In order to further clarify the questions arising in the study, we conducted more collections in both the northern and southern parts of Vietnam in October and November, 1996. We performed the same analyses as previously (Table 1). After calculating the necessary averages (Table 2), we were able to make the following conclusions: *1.* The relative amounts of the studied components vary greatly among individual animals. Within the group of Rhopalocera, no differences can be shown among the various species. It seems that their lipid content is primarily dependent upon the nutrition available to the animals. *2.* Generally, both their fat content and their protein content are lower at hot temperatures than in cooler weather. We, therefore, have to assume that their source of energy in hot weather is primarily glycogen instead of lipids. *3.* Female Rhopalocera usually contain somewhat more lipids than males, which is contrary to the case of non-feeding imagoes.

Biological communities are made possible by the constant circulation of matter and energy. This flow originates - with few exceptions - in green plants, and is kept in motion by the various organisms' nutrition systems that are structured on one another through metabolism. The quantity and quality of the total mass of living bodies (biomass) developing by means of this flow substantially influence the entire community's functioning, productivity, usefulness, and level of tolerance. Because of these reasons, we consider it very important to study the biomass of the populations that make up the community and collect data on its importance.

In developing our project, we were lead by the assumption that butterflies and moths play a very important role in most land communities because of their great numbers and many various species. Valuable information about the nutritional value of their bodies can be gained by studying their lipid reserves and the quantity of their organic matter rich in protein and nitrogen.

We already know that the composition of imagoes' bodies show great differences depending on whether they feed or not (Gere, 1964, 1978). According to our observations, the imagoes that do feed tend to maintain the composition of their bodies as long as sufficient nutrition is available. The same observation is made by

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Cross and Owen (1970) and Soltava and Lovlajainan (quoted in Hanegan and Heath, 1970). The former studied *Deilephila nerii* and *Herse convulvuli,* sphinx moths, while the latter studied *Phytometra gamma,* a noctuid moth. As opposed to this, imagoes that do not feed during their lifetimes tend to „live up" almost all „mobilizable" parts of their bodies during their short lifetimes.

The composition of the bodies of moths and butterflies depends on many other circumstances besides this one. Especially important in this respect are the effects of weather, especially temperature. *Danaus plexippus* butterflies store fat when the weather is hot or cold, but not at moderate temperatures (James, 1986). According to Pullin (1987), the lipid-content of butterflies belonging to the family Nymphalidae differ very much before and after overwintering.

In light of these observations and other similar data, we considered it important to become acquainted with the effects of climate and climatic seasons on the composition of butterflies' and moths' bodies. To this end, we embarked on a series of examinations in a suitable temperate region (Hungary) and a tropical area (Vietnam). Based on our examinations published earlier (Gere, 1993), the following points seemed very probable:

1) In temperate regions, the butterflies belonging to the genus *Pieris,* producing several broods yearly, have a higher fat content in spring and in the relatively warm part of autumn than in the middle of summer. Late in the autumn, however, probably because of the decrease of available nutrition, their fat content decreases again.

2) In the tropics, the feeding imagoes have a higher fat content in the cooler season and in cooler areas than under hotter circumstances.

3) It is particularly striking that there can be great variations in fat content among various individuals, probably because of the differences in access to nutrition. This phenomenon was also pointed out by Mason & al. (1989). This means that general observations can only be made if sufficiently large number of specimen are examined.

This last point indicated to us that we needed to continue our work. Therefore, we made more collections in Vietnam in October and November, 1996.

Methods and materials

Collections were made both in the northern and southern parts of Vietnam. During the time of the year when collections were made, the temperature is hot throughout the entire country, with daily maximums above 30 degrees Centigrade. There was only very little rainfall, and the sun was shining every day almost uninterruptedly.

The collected imagoes were stored in 96 % ethanol. In the laboratory, the air-dry mass of the animals' bodies was measured after evaporating the ethanol. The per cent results of our analyses are expressed in terms of these measurements. The amount of fatty and lipoid substances was determined by the Soxhlet's extraction method. Petrolether was used as extracting medium. The total nitrogen content was determined at the end, after performing destruction by sulphuric acid using Kjeldahl's method. Based on the data obtained, we were able to calculate the raw protein content. The calculations made in this way include nitrogen reserves that are not bound in protein.

Results and conclusions

The primary results are shown in Table 2. All except the last two genera belong to the group of Rhopalocera (which includes the family of Hesperidae). It should be noted that the composition of the animals' bodies, particularly their fat content, varies greatly. The males and females of *Junonia almana* had particularly high fat contents. This species occurred mostly in the parks of Hanoi, in areas with plenty of blooming flowers, supporting the assumption that the Rhopalocera accumulate great amounts of nutriment (energy) when plentiful food is available. The specimens of *Danaus genutia* lived in areas that were similarly abundant in blooming flowers. Interestingly however, among this species only females exhibited large amounts of fat. The males of *Appias paulina* in Cat Tien were apparently in the middle of migration, as suggested by the long rows they formed during their flight. Since they did not touch ground at all in the areas under examination, they were obviously not taking any food. Consequently, their fat content was very low.

Besides these differences that can be explained by environmental factors, there was no significant variation among the species. We can therefore assume that in this respect all Rhopalocera are similar, they all belong to the same type. And this fact made it possible to use their data together and thus reduce the effects of individual variations. In this way, we studied the general characteristics of the group as a whole instead of concentrating on the characteristics of any particular species.

Table 1 presents the data of Rhopalocera in two distinct groups, according to whether the imagoes were found in the northern or southern sections of Vietnam. In the same table, our previous results from Vietnam (Gere, 1993) can also be seen grouped in the same manner. Data of Rhopalocera found in Hungary (Gere, 1978, 1993) are also found in the table, which are divided according to whether they were collected in cool weather (spring, early autumn) or in hot weather (summer).

These data confirm our assumptions described above in points 1 and 2, with respect to Rhopalocera in both tropical and temperate regions. For a completely satisfying evaluation of the available data, it is important to note that in January, there is a marked difference in temperature between the northern and southern parts of Vietnam, whereas in October and November, the entire country is equally hot. In January, the total lipid content of imagoes collected in the northern parts of the country was almost double that of the ones collected in the southern areas. In October and November, the males had only slightly higher lipid contents in the north, whereas the females had actually somewhat less lipid in the north than in the south.

The raw protein or total nitrogen contents also show significant variations, but not nearly as much as the lipid reserves. It seems that the amounts of both lipids and nitrogen-containing materials found in the bodies of Rhopalocera are smaller at very hot temperatures than under cooler circumstances. This naturally raises the question of what constitutes the bulk of the dry matter content in the animals' bodies during the hot seasons. More research is needed to give a satisfying answer to this question, but it can be assumed that the relative proportion of hydrocarbons, especially glycogen, increases. It is well known that glycogen (next to or in place of fats), plays an important role in the metabolism of many insects, primarily as a means of storing energy. According to Hill and Goldsworthy (1970), glycogen is the main source of energy for *Locusta migratoria*, and fat is used only after the entire reserve of hydrocarbons is consumed. A similar observation was made previously by Weis-Fogh (1952), with respect to the flight of Orthoptera. According to Walker & al. (1970), the flying muscles of *Schistocera* locusts use a mixture of hydrocarbons and lipids. The high glycogen content in the various developmental stages of bees is well known (Pflugfelder, 1952; Roeder, 1953). It is certain that the ability to make use of nutrients depends largely on temperature. Uschatinskaja (1957) mentions that glycogen gains special significance during overwintering, probably because invertebrates are able to make use of it at low temperatures. This observation seems to be contradicted by the fact that it is usually the fat content of animals that increases significantly prior to overwintering. This is mentioned, among others, by Jasič (1970), with respect to *Perillus bioculatus* (Rhynchota). Keeping in mind this last observation, it seems probable that cooler temperatures shift the metabolism of Rhopalocera in the direction of synthesizing and using more fats and less glycogen. An advantage of this might be the high energy content of fats and lipids, causing more heat to be released when they are burned, thus raising the body temperature of the animal. And this is very important for the animal which strives to increase its „life-intensity."

We can further conclude, based on the available data, that female Rhopalocera usually have somewhat higher fat contents than males. This is opposite to the case of butterflies and moths whose imagoes do not feed, especially those whose females' movements are greatly reduced (Gere, 1964). This difference can be explained the following way. In the case of non-feeding imagoes, the male animals use the stored fat as their source of energy for flying. The females in this case need less fat, but more protein for producing eggs. In the case of imagoes that do feed, both sexes continuously gain enough energy for their movements from the food they consume, and so there is no need for sexes to develop wide differences in this area. The little extra fat in females finds its way to the eggs.

Table 2 contains data on some imagoes that do not belong among the Rhopalocera. These are *Tirathaba leucotephras*, *Creatonotus* sp., and *Creatonotus transiens*. They are listed in this article only for information. We will consider them, together with their relatives, in a future study.

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Table 1. Total lipid and raw protein contents of butterflies averaged for different seasons and temperatures in Hungary and Vietnam

Species	Locality	Season	Number of specimens	Male	Both genders	Female	Male	Both genders	Female
				Total lipid expressed as % airdry body mass			Raw protein expressed as % airdry body mass		
Lysandra coridon Poda	Hungary	summer	83+59	6,95		11,76			
Melanargia galathea (L.)	Hungary	summer	10+5	3,80		4,48			
Artogeia rapae (L.) and *napi* (L.)	Hungary	spring and autumn	49+18	12,16		16,00	64,9		61,0
Artogeia rapae (L.) and *napi* (L.)	Hungary	summer	42+30	11,93		10,92	58,1		58,3
Artogeia canidia (Sparrman) and *Zemeros flegyas* (Cramer)	Northern Vietnam	January	35		13,32			64,5	
Delias hyparete (L.) and *Junonia atlites* (L.)	Southern Vietnam	January	50		7,02			61,0	
Rhopalocera /4 species/	Northern Vietnam	October-November	34+24	9,67		11,18	60,5		62,5
Rhopalocera /7 species/	Southern Vietnam	October-November	102+50	6,80		11,88	62,3		63,0

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Table 2. Total lipid and raw protein contents of butterflies and moths collected in Vietnam during October and November

Species and family	Locality	Number of specimens	Gender	Total lipid	Raw protein
				expressed as % airdry body mass	
Artogeia canidia Sparrman (Pieridae)	Dalat	15	male	11,41	67,5
Artogeia canidia Sparrman (Pieridae)	Dalat	15	female	7,85	57,8
Appias albina Boisduval (Pieridae)	Dalat	3	male	6,87	70,7
Appias lyncida Cramer (Pieridae)	Ba Vi	3	male	6,99	69,6
Appias paulina Cramer (Pieridae)	Cat Tien	15	male	3,81	54,8
Appias paulina Cramer (Pieridae)	Cat Tien	14	male	3,42	57,7
Delias hyparete L. (Pieridae)	Saigon	12	male	6,53	68,6
Delias hyparete L (Pieridae)	Saigon	10	female	6,30	62,9
Eurema hecabe L (Pieridae)	Buon ma huot	18	male	5,26	76,6
Eurema hecabe L (Pieridae)	Buon ma huot	10	female	9,64	74,6
Neptis clinia leuconata Butler (Nymphalidae)	Ba Be	12	male	5,48	65,4
Neptis clinia leuconata Butler (Nymphalidae)	Ba Be	10	female	6,89	69,9
Junonia almana L (Nymphalidae)	Hanoi	4	male	20,50	45,5
Junonia almana L (Nymphalidae)	Hanoi	4	female	19,00	57,2
Danaus genutia Cramer (Danaidae)	Yokdon	15	male	6,89	46,7
Danaus genutia Cramer (Danaidae)	Yokdon	5	female	20,10	45,9
Mycalesis visala visala Moore (Satyridae)	Ma da gui	10	male	10,22	55,5
Mycalesis visala visala Moore (Satyridae)	Ma da gui	10	female	15,50	73,7
Caltoris brunnea (de Nicéville) (Hesperidae)	Hanoi	15	male	5,73	61,4
Caltoris brunnea (de Nicéville) (Hesperidae)	Hanoi	10	female	7,65	60,4
Tirathaba leucotephras Meyrick (Pyralidae)	Dalat	15	both genders	4,97	73,1
Tirathaba leucotephras Meyrick (Pyralidae)	Dalat	25	both genders	6,54	69,1
Creatonotus sp. (Arctiidae)	Ba Be	15	male	3,06	47,4
Creatonotus sp. (Arctiidae)	Ba Be	5	female	13,67	47,2
Creatonotus transiens Walker (Arctiidae)	Ma da gui	20	both genders	10,44	65,7