Rethinking Our Ideas About the Winter Cluster

Part II

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In the last article I wrote* (July, 1998 ABJ) *about the observations made while examining colonies over a period of two winters in northern Scotland. They had produced the surprising fact that egg laying by the queen within the winter cluster is very much an ON/OFF affair, even though 'brood rearing' would be registered as 'continuous business' by any number of thermocouples inserted in the center of the cluster. The examinations showed that brood rearing in the hive-locked winter cluster is more complicated than we had thought, and that the initiation and cessation of egg laying , rather than brood rearing, itself, has to be investigated with fresh insight.

But before passing on to theoretical stuff, I want to report on a further experiment made in the year following the above examinations. In the Craibstone Apiary was a small hut with self-registering scales, and during the winter of 1976/77 we placed one colony in a Langstroth hive on its platform. Under its floor board we had put a sheet of extruded polystyrene (Roofmate) of 30 mm thickness. From another sheet of expanded polystyrene (50 mm thick) we constructed a box which we could place over the hive so that it would be encased all around in insulating material. An opening of 100 x 15 mm was left as an entrance, and this opening coincided with that of the hive itself. It also was at the same level as the flight board of the hut. When we lifted the outer casing and put it upright over the crown board, the hive was left 'in the cold' (apart from the sheet under the floor board), although the total weight had not changed.

The self-registering scale was very accurate and its sensitivity was adjusted so

Table 1 - Food consumption of colony on self-registering scales
Weekly weight loss in g; Winter period from 19th Oct. 1976 to 25th Feb. 1977

Period	Hive insulated	Insulat. removed	Bees lost
1		150	
2		200	
3	60		
4	100		
5 (Cleans. flights, 2 days)	90*	110**	400g (approx. 3500 bees)
6	120		
7	120		
8		250	
9		230	
10	150		
11	120		
12	80		
13	90		
14	85		
15 (Cleansing flight)		335	220 g (approx. 2000 bees)
16		220	
17		170	
18		255	
Consumption (g)	1035	1990	
Period (days)	68	58	
Average cons.; g/day	15.22	34.31	
Average cons. / bee / day	1.5 mg	3.4 mg	
Estimated loss of bee life			5500 bees

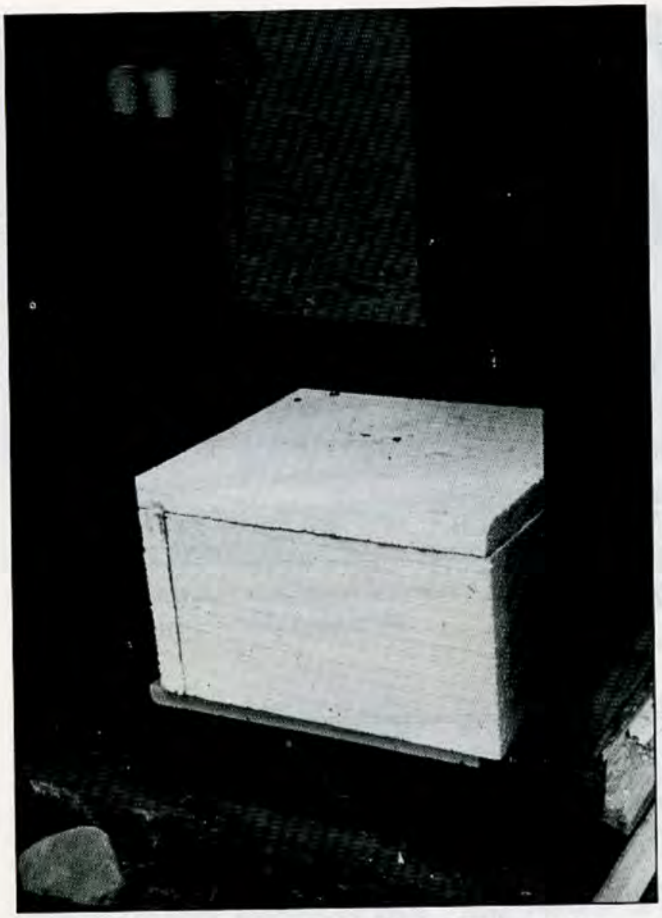

Fig. 1. Insulated hive on self-registering scales

Fig. 2. Hive 'in the cold'; the weight has not changed

as to read 50 g between the lines on the chart. The charts were changed weekly on Mondays at 9 a.m., and the consumption for the week was recorded. Measurements began with the onset of 'winter' and stopped when we could say 'It's spring!'. That winter we had no chances to examine colonies for winter brood and there were some long, cold periods. During the whole of the mid-winter period there were only three chances of cleansing flights, two of which occurred on consecutive days. Each time many bees were 'lost' from the heavily insulated hive. They were found—apparently chilled—on the ground, on grass blades and clinging to the side of the weighing hut as if the 'Isle of Wight' disease (acarine) had struck again. No other stocks showed such losses, and most bees from other hives returned home after a cleansing flight. The 'chilled' bees showed no acarine or Nosema disease. The sharp drop in weight on these days was taken as due to loss of bees, (after an average daily consumption had been allowed for) and we had to ignore any loss in weight from defecation—or any gain from water collection.

The table makes it clear that the insulation slashed the daily food consumption of the colony by more than half. On the other hand, even the weighing hut itself must have had a protective, insulating effect because, if we take the daily loss of weight 'in the cold' and apply it for the whole period of 126 days, then we would still have had the surprisingly low food consumption of 4.17 kg (9.2 lb) of honey. Checking with last month's article, we find that this figure agrees with the result of the regression equation for causal relationship established for normal colonies rearing no brood (in that apiary and climate). Although no thermocouples had been used, and no examinations could be made that winter, the low food consumption can be taken as proof that no brood rearing took place in that stock during the winter period.

Indeed, taking the strength of a 'normal' winter colony as between 10,000 to 15,000 bees, the average consumption of honey per bee and per day under insulated conditions was so minute (1.0-1.5 mg/day/bee) as to make us wonder if the bees lived indeed on love and altruism, rather than on honey. The production of

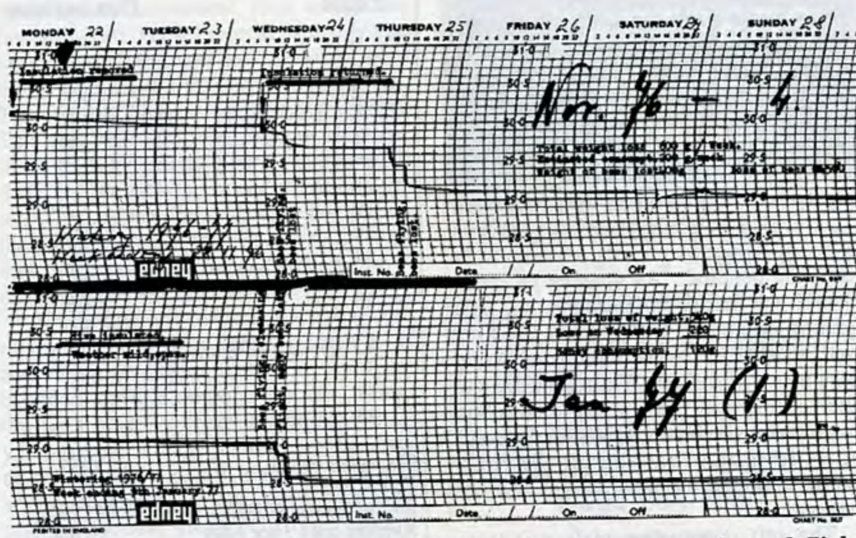

Fig. 3: Part of chart No. 5; Nov.1979; Weight loss 400g on two days of flight. Part of chart No. 15, Jan. 1977; Weight loss 220g on one day of flight.

brood, even of a single larva of about 100 mg weight in 5 days, would have been impossible on that ration! Leaving for the moment the implied suggestion that colonies with a low food consumption are probably not rearing any brood in the depth of winter, the disturbingly heavy losses of bee life from 'super colonies' and those surrounded by exceptionally thick insulation in a mild, maritime climate must make us take a new look at the often repeated advice 'that the best packing for bees are more bees'. Dr. Jeffree investigated this fairly commonsense advice with a critical eye. Extended and thorough investigation of colony sizes before and after winter made him come to a different conclusion. His findings surprised him and he announced that there is an 'optimum size' of winter cluster, and that colonies with smaller—or larger—populations will suffer greater losses than the stocks which could be called normal, standard, or optimum—for that climatic zone.

So it is time that we clear up old ideas of the winter cluster and introduce a new cluster model based on biological investigations rather than on traditional theories which have only gained credence by being repeated frequently—and slavishly—in most books. In order to present this traditional working model of the winter cluster, we can do little better than quote here from one of the most popular and standard books on beekeeping. In a revised 1975 edition of the book *The Hive and the Honey Bee*, Professor Furgala gives us the classical point of view:

"When forming a cluster, bees on the surface establish an insulating shell which varies in thickness from 25-75 mm. Bees enter the empty cells within the area of the food reserves embodying these cells, forming an integral part of the insulating shell. As the external temperature rises above 7°C (45°F) the cluster expands. As the temperature drops below 7°C (45°F) the cluster contracts, reducing the surface from which heat energy is radiated. Since bees use their honey reserves most efficiently at 7°C (45°F) (Betts, 1943), they do not consume as much of their stores at low temperatures as might be expected.

"The bees within the cluster are much less compact and generate heat through metabolic processes (Phillips and Demuth, 1914; Farrar, 1963). The heat produced within the cluster is conducted to the surface of the cluster. Sufficient heat is generated to equal the heat radiated from the surface at approximately 7°C (45°F) (Farrar, 1952).

"The expansion and contraction of the cluster, therefore, is the principal mechanism used by bees to sustain a favorable environment. This phenomenon will function as long as the cluster maintains firm contact with its food reserves."

This version of the traditional idea of the winter cluster can be found in most modern bee books, and the old treasured ones are even clearer in their opinion that the bees in the cold form an **insulating** shell to keep the center of the cluster warm and protected, with the bees in the center busily occupied in converting honey into heat 'by metabolic processes'. This is **conducted** (through insulation!) outward to keep the poor shivering sisters alive. Of course, this model grows more and more improbable as external temperatures drop and the quality of the insulation of the shell thickens—with improved conductivity to keep the outermost bees alive. Anyone who has studied physics—and is not a beekeeper—must be astounded to hear of an insulating conductivity or conductive insulation

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with such marvelously variable properties! Of course, any cluster model which credited the honey bee with altruistic, even miraculous behavior suited the beekeeper of the past and found ready ears, but all such chapters need revision in the light of modern research. Indeed, as far as the bees' cluster is concerned, careful research has shown that we all will have to make a Copernican about-turn.

It is not possible to quote every recent work on the subject, and so I will confine my arguments to the most important research on the subject of the wintering bee's metabolism. After a period of letting individual bees 'settle down' in minute cages, two researchers (Altmann and Gontarski) held the bees immobile for further 30 minutes at precisely maintained temperatures (See Fig. 4). Their metabolic efforts were established by the absorption of the carbon dioxide produced during the period and, at the same time, their loss of water through evaporation was measured. Each test was repeated many times with fresh 'winter' bees over the whole range of temperatures which can be found within the cluster. The results, as shown in the graph, prove conclusively that bees in the warmth used very little food, and therefore produced very little heat energy. The bees were at rest, their metabolism had been switched to 'idling', their energy producing 'motor' was just 'ticking over'. At the same time, these bees were found to be evaporating more water from their bodies than they were producing as a 'waste product' through their metabolic conversion of honey sugars.

On the other hand, the bees which

Figure 4

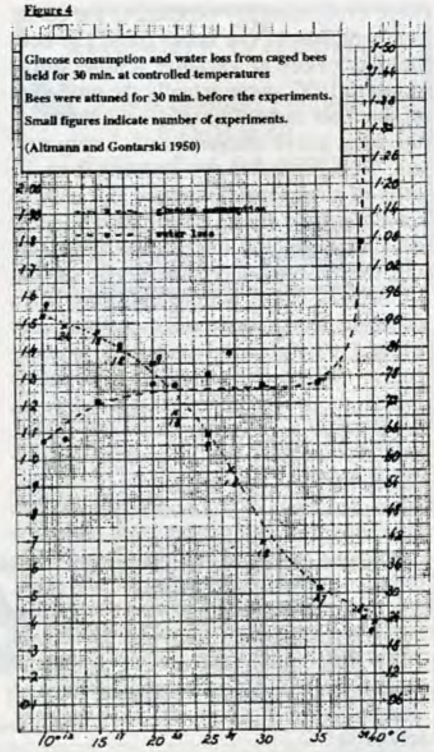

Fig. 5. Bees in the center are not clustered; they need - and actually produce - little warmth, they 'burn' little honey and produce very small quantities of metabolic water. Bees in that region tend to suffer from thirst and dehydration.

were experimentally exposed to the colder temperatures of the outer shell, the bees held in cages at variable temperatures down to 10°C, were actually the producers of the most carbon dioxide—and therefore the most active converters of honey sugars. Well, they were not far away from the cells of stored honey and did not have to travel far for a fill-up when this was needed. Of course, and this goes without saying, they also produced the largest amount of 'waste' water which, applying plain chemistry, amounts to 0.6 g water for every 1 g of glucose converted into heat energy through oxidation. The table shows that the bees consumed less and less food, the nearer they 'lived' to the warm center. On the other hand, the bees held at temperatures found further away from the center, consumed more and more honey with each drop in temperatures. And, even under the conditions of the experiment, they were slowly building up a water surplus, although the quantities of water evaporated was fairly even between 20°C and 30°C. Evaporation increased by leaps and bounds at brood nest temperatures and slightly above. In short, we must state the following:

When clustering is brought about by the onset of colder weather, each bee in the cluster will generate heat in direct proportion to its heat loss—which is in inverse proportion to its own temperature experience.

Bees in the warmth of the central region have a lower metabolic rate and will produce less water than they are evaporating here.

Bees of the outer shell will generate more heat energy, will consume more honey and will, consequently, accumulate more metabolic water than they can evaporate in this colder region.

A similar experiment made by Roth in France fully confirms the above findings. He, too, investigated the conversion of sugars into heat energy by measuring the production of carbon dioxide at various temperatures, although no measurements were made to investigate water loss through evaporation. Roth, quoted by Chauvin, found that the metabolic rate of heat production was at its highest at 12.5°C. Yet the graph shows that at 10°C the individual values obtained were so variable, that one can not even state that heat generation breaks down entirely at this precise point.

When he repeated the tests with groups of 25 bees, he found that the contact between bees immediately reduced the individual effort, but the graph for groups of bees still followed the curve established for individual bees, albeit at a lower level. But even Roth's results agree with the above findings: The colder the bee, the greater its personal effort to survive by increasing its own rate of heat generation, and that the density of clustering, the short-range social contact, serves to pool the personal heat resources as well as to benefit from the nearest neighbors. The bees in the warm center of the cluster, on the other hand, are not even clustered for closer contact; they are making the least effort and contribute little towards the common good—warmth.

Fig. 6. Bees in the cold shiver and produce heat in order to survive; clustering pools their resources and all benefit from their immediate neighbor's contribution to the warmth.

Now we must turn to the next point raised by the results of Altmann and Gontarki's experiments, and this may be, for beekeepers, the most difficult pill to swallow. The bees in the center with the lowest food consumption were found to be losing more water vapor than they were actually producing through oxidation of sugars. On the other hand, the bees in the cold outer shell are converting a lot of sugar into heat energy, and cannot help but produce a lot of metabolic water at the same time. Out in the cold, they evaporate little moisture, and a surplus must build up in tissues, in the bowel system (via Malpighian tubules) and must finally accumulate in the rectum.

This brings us to finding a solution (which, no doubt, the bees had discovered and used over, thousands of years of living in cold climates). Under normal cluster conditions bees from the center tend to drift to the outer shell for a 'metabolic drink' by increasing their rate of heat production and by lowering evaporative pressures. Moving into the center in order to 'dry out' is the solution for bees of the outer shell, and slow movements in and out of the cluster center are probably motivated by the driving force exerted by thirst or water surplus, rather than any thoughts of letting sister bees warm their feet! The selfish, survival-orientated exchange of bees between layers is biologically sounder than the altruistic motivation of the past.

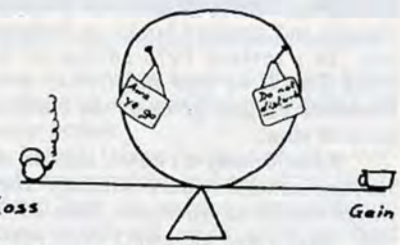

Fig. 7. A balanced water economy in an 'optimum sized' colony.

Of course, such an ideal solution for all personal 'water problems' works best when the size of the winter cluster is commensurate with that population which can form Dr. Jeffree's 'optimum winter cluster'—for its climate. His investigations showed that any large deviation from the ideal size—up or down—was 'punished' by Nature with occasionally heavy losses of bee life. Our numerous experiments with 'super colonies'—and the one in the weighing hut—had shown, that when there are too many bees in a hive, or when the hive is too insulated and too warm for a mild climate, thirst-crazy bees were driven out to fly at the slightest excuse; not to gambol in the sunshine, but to collect water. But, coming from the warmth without having contributed towards its maintenance, they quickly chilled before reaching it.

Colonies smaller than optimum size - and we all had our doubts about some stocks, even nuclei, at the start of a winter,

Table 2. Glucose consumption and water loss or gain from caged bees held for 30 min. at controlled temperatures.

Amb. Temp. °C	Gluc. cons. Mg / bee / / 30 min	No. of Measure-ments	Metabolic Water produ. mg	Total Water lost mg	Altmann/Gontarski, 1950 Water gain or loss mg	Percent. of metab. water
10°	1.53	9	.918	0.644	+ 0.274	+29.8
12°	1.49	24	0.893	0.649	+ 0.244	+27.3
15°	1.47	12	0.882	0.730	+ 0.152	+17.2
17°	1.40	18	0.840	0.850	- 0.010	- 1.2
20°	1.35	9	0.796	0.770	+ 0.026	+ 3.3
22°	1.17	18	0.699	0.770	- 0.071	- 10.1
25°	1.09	9	0.653	0.790	- 0.137	- 20.9
27°	0.96	18	0.577	0.853	- 0.276	- 47.8
30°	0.69	18	0.442	0.767	- 0.325	- 73.5
35°	0.52	27	0.314	0.768	- 0.454	-144.5
39°	0.41	18	0.249	1.071	- 0.822	-330.1
40°	0.39	9	0.234	1.458	- 1.224	-523.0

will have more bees in the cold, outer shell, all making great efforts to stay alive by converting honey into heat—and accumulating more and more 'waste water' within the totality of the cluster. The center being small, no movements in or out of the cluster center can cope with the situation and, only cleansing flights can—theoretically—bring relief. When these are not possible, it seems that dysenteric conditions must come about, forcing bees to defecate in the hive, on combs.

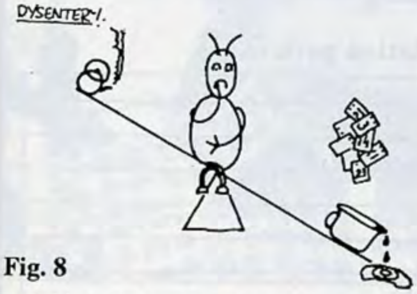

Fig. 8

Thirst and surplus, rather than heat or cold, seem to be a greater problem for wintering bees than we ever thought. Mild spells occurring regularly throughout the winter are, of course, providing the ideal solution for the 'personal' problems of colonies—and individual bees. After such flights—for water or to cleanse themselves—the bees can settle down again and cluster normally and peacefully once more. But not all climates and geographical locations can provide these chances on a regular basis, and not all colonies are of that 'optimum strength' for best wintering results. But bees know their *beesiness* best and have an ace up their sleeve.

Fig. 9 - Thirsty bees fly for water

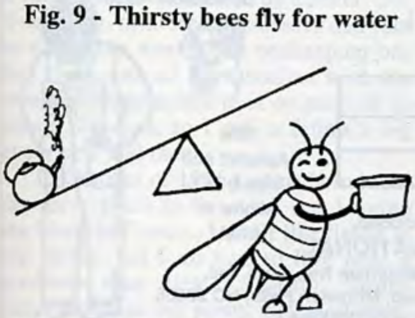

Fig. 10 - surplus needs emptying!

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(Additional to prev. article)

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