Chapter 10:
General Discussion

The work described in this thesis developed from an examination of heat tolerance and evaporative cooling in cattle and buffalo working as draught animals in the field under tropical conditions in Indonesia. Since in the field the climatic conditions (environmental temperature, relative humidity, wind velocity and solar radiation), body weight and body condition could not be controlled, it was decided to conduct further laboratory work to both confirm and extend the field studies. Bali-cattle and swamp buffalo were not available in the Animal House complex of the Department of Animal Science at the University of New England, so goats were employed as an animal model and simulations were made by using treadmill exercise under controlled tropical conditions in a climate laboratory. Bali-cattle, buffalo and goats share physiological similarities in that all are ruminants, all have a hair coat, and buffalo and goats are poor sweaters.

Overall, it can be seen that RR, RT, ST, RML and SR increased with time during work or exercise in either the field or the laboratory in each of the different sexes, breeds and species (Experiments 1-19). This is to be expected from the basic knowledge that animals while working need energy that comes from the oxidation of energy sources (particularly carbohydrate and fat). That oxidation requires oxygen from air, which in turn causes an increase in RR. As a result of any increase in oxidation, more heat will be produced, and to dissipate this from the body involves increases in RR, RML, ST and SR. Any failure of heat dissipation will result in heat storage in the body, and hence increased RT.

Sex differences observed in both field and laboratory experiments showed that the male was more uniformly stressed by work and exercise than the female. Experiments 1 and 2 in the field, using male and female Bali-cattle and swamp buffalo revealed that males were more intolerant than females, when work was conducted under uncontrolled climatic conditions (environmental temperature, relative humidity, wind velocity and solar radiation), and when the animals were of different body weight and condition. For example, male Bali-cattle had higher RR, RT and ST (66/min, 39.4 and 37.6°C) than females (corresponding figures of 61/min, 39.2 and 37.1°C). To separate the confounded effects of sex, body weight, body condition and feeding level, further experiments with goats were then carried-out in the climate laboratory under appropriately controlled conditions.

In Experiment 5, Saanen goats with different body weights (the males almost twice as heavy as the females) but of similar age were employed. It was found that the male was less tolerant than the female (RR were 138 and 52/min respectively), a result which supported the previous result from field experiments with both Bali-cattle and buffalo. Experiment 6 was then undertaken with goats of similar body weight and condition score and fed a basal diet at the rate of 600 g/d. The result was again that the male was less tolerant than the female, with respective RR, RT and ST of 123 vs 38/min, 40.2 vs 40.1°C and 37.9 vs 37.5°C. Similar patterns were observed in Experiment 7 when goats of similar body weight and condition score were fed at either 400 (sub-maintenance) or 1200 g/d (above maintenance). Even in Experiment 8, when different levels of environmental temperatures (20, 30 and 40°C) were imposed, it was again demonstrated that the mean RR and RT in males were higher than in females.

From these overall results it can be concluded that male animals were more stressed than females in every test condition, and this clearly confirmed previous experiments conducted by MURRAY and YEATES (1967) in male and female cattle.

In Experiment 5, male goats had higher RR than the female (138 vs 52/min), but this was accompanied by lower RT (39.8 vs 40°C) and ST (37.6 vs 37.7°C) when exercise was conducted for 12 days and 120 min/day. Meanwhile, when a regime of 3 days exercise of 30-120 min/day was imposed, a higher RR in males was followed by higher RT and ST in comparison to females (Experiments 6, 7 and 8). For example, in Experiment 6, the RR, RT and ST of male and female goats were 123 vs 38/min, 40.2 vs 40.1°C and 37.9 vs 37.5°C respectively. Such responses clearly demonstrated that acclimation occured during a period of exercise. This could be due to the fact that during intensive exercise (longer time), more heat was progressively dissipated as evaporative moisture losses via both the respiratory and cutaneous routes (ie. the animals were cooled down more). Therefore, it is suggested that in practice all new (inexperienced) animals should be worked for shorter periods than experienced animals to avoid, or at least minimize, physiological stress.

The experiments with different sexes of Bali-cattle and swamp buffalo in the field (Experiments 1 and 2) and different sexes of goats in the laboratory (Experiments 5, 6, 7, 8, 13 and 15) clearly demonstrated that males were more stressed than females. In Experiments 1 and 2 for example, RR in male Bali-cattle and buffalo were 66 and 54/minute and the RT were 39.4 and 39.2°C respectively; corresponding figures in females were 61 and 46/minute followed by 39.2 and 38.9°C respectively. The results of Experiment 13 also demonstrated that there was a correlation between RR and RML, with a correlation coefficient of 0.8.

Additionally, males sweated more than females (Experiment 15). Thus, despite high rates of evaporative cooling (RML and SR), RT in males increased considerably during exercise, and they behaved, in part, as "heat storers". Under this circumstance males appeared to be more severely stressed than females, particularly after working for 2.5h (both salivation and dribbling), and it is suggested that working animals should then be rested in the shade for about 1-1.5 h (based on current 1h recovery figures) before continuing ploughing. The most likely cause of the greater rise in RT and ST in males, relative to females, is greater heat production in males; the current results clearly show that the rise in RT is not a consequence of any reduction of RML or SR in males.

With different seasons in the field experiments with Bali-cattle and buffalo (Experiments 1, 2, 3 and 4), the RR, RT and ST were found to be significantly higher during the hot/dry than in the cool/humid season. Ambient temperature differences between the hot/dry and cool/humid seasons were around 3-8°C. Similar patterns of response were observed in Experiment 8 in the climate laboratory (temperatures of 20, 30 and 40°C); RR increased significantly with rising environmental temperature (mean increases of 40, 62 and 90/min respectively). Therefore it is suggested that when animals work in the hot/dry season they should be allowed to wallow (buffalo) or be splashed with water or wet mud (cattle). For buffalo it is also suggested that wet hessian be placed over the body to provide enhanced evaporative cooling (and, perhaps, reduced radiant heating) over a prolonged period.

From the overall observations in the field with both Bali-cattle and swamp buffalo, it is suggested to not use males and females in pairs together, due to the fact that the larger male tends to pull along its smaller female pair-mate. As a result, the male would work harder, and expend more energy, than the female, and as a consequence experience still more stress. A further alternative, when it is essential that the male has to be employed with a female in a pair, is that the males and females be of similar body size. Because of the inevitable sex differences in body size, however, this would have limited application in the farm situation.

From the overall results in different breeds, it can be seen that increases in environmental temperature, and/or increasing duration of exercise, were followed by increases in RR, RT, ST, RML and SR. These findings are in accordance with MURRAY and YEATES (1967), and could in part be due to increased oxygen consumption for metabolic processes, which produce more heat which in turn would contribute to the increase in RT.

The different reactions of Bali-cattle and swamp buffalo in Experiment 3 (higher RR and RT in Bali-cattle) support the finding of BADRELDIN *et al.* (1951). However, the buffaloes in the current experiment and that of BADRELDIN *et al.* showed a relatively greater increase in RT and RR compared to cattle, and suffered more from the effects of hot weather and work. The slope of the RT response with time in buffalo was higher than in Bali-cattle and this clearly indicates that buffalo were affected more than Bali-cattle. The suggestion to improve working conditions is thus that buffalo be stopped after about 2h work and allowed to wallow, or that they be sprinkled with water and/or have wet hessian placed on the body. The fact that albino buffalo were apparently less tolerant than black ones in Experiment 4 (RT 0.3°C higher) could be associated with lack of pigment in the albino's skin, but no relevant information was found in the literature and further experimentation is thus required on this point.

From the results of Experiments 9 to 12 in different breeds of goat it can be concluded that there were definite breed differences in physiological responses during exercise. The Toggenburg had the highest RR, followed by Saanen and Anglo Nubian. For example, in Experiment 11 the mean RR of Toggenburg, Saanen and Anglo Nubian were 185, 137 and 73/minute and the slopes of their linear regressions (with time during exercise) were 5.1, 3.8 and 3.5 respectively. Additionally, results in Experiments 9 (different body weights and feed intakes), Experiment 10 (similar condition score and the same feed intake of 750 g/d) and Experiment 11 (similar condition scores but different feed intakes of 500 and 1000 g/d), clearly showed that the Anglo Nubian had a lower RR than both Saanen and Toggenburg, even though RML increased with increasing RR. In Saanens and Toggenburgs, RR of 62 and 99/min, for example, corresponded to RML of 316 and 421 mg/min respectively. Such results are in general agreement with ALEXANDER and WILLIAMS (1962) in sheep.

Subsequently, despite their relatively low RR, Anglo Nubians still had the highest RT amongst the breeds studied, a fact which clearly indicates that total heat dissipation was not sufficient to remove from the body all the heat they produced during exercise. In other words, heat was stored in the body and caused an increase in RT, but the Anglo Nubian as a breed was apparently able to tolerate this higher RT without corresponding increases in RR. In contrast, Toggenburgs had the lowest RT, which suggests that the heat stored by them was the lowest among the 3 breeds. The increased RR is an indication that more heat was being dissipated through panting. Saanens on the other hand, are seen as an "intermediate" breed in heat storage ability. They maintained both RR and RT between the Toggenburg and Anglo Nubian values. It is concluded that the Anglo Nubian has not developed such effective evaporative cooling mechanisms for maintaining a constant body temperature during exercise and instead stores heat ("heat storer"), while the Saanen and Toggenburg breeds have developed the opposite strategy.

This difference is likely related to the evolution of the Nubian breed in an arid, desert area of north eastern Africa (DEVENDRA and McLEROY, 1982).

Results from the different nutritional levels imposed in Experiment 11 showed that the higher the level of feed intake, the greater the reaction to exercise (higher RR, RT and ST), but the magnitude of the differences was small (eg. only about 0.1°C in RT). Such observations are in line with the results of both MURRAY *et al.*, (1981) and GRAHAM *et al.* (1959). From the current results it is thus concluded that even reducing feed intake to sub-maintenance levels does not greatly reduce in biological terms, the level of heat stress experienced during exercise.

The results of Experiment 12 clearly showed that the goats became more stressed (higher RR, RT and RML) as environmental temperature during exercise increased from 20 to 40°C (mean RR were 53, 75 and 113 while walking at 20, 30 and 40°C respectively), and are in general agreement with SIQUEIRA *et al.* (1993). The increase in RR could be due to the animal's need for more oxygen to activate carbohydrate oxidation and provide more energy during exercise, as well as for cooling processes. 20°C was clearly the most comfortable temperature for working animals and in the field situation, and particularly in tropical countries like Indonesia it is suggested that farmers employ their animals for ploughing in the early morning (ie. before 09.00 when environmental temperature could be expected to reach 30°C or more).

Differences in tolerance between breeds were also seen in Experiment 14, which also showed that an increase in RR was followed by a proportional rise in RML. Such a fact is in general agreement with the results of ALEXANDER and WILLIAMS (1962). Additionally, it was found that the increases in RML with time during exercise could be described by the linear equations: $Y=8.5X + 214$ and $Y=6.8X + 189$ for Toggenburgs and Saanens respectively. These equations clearly demonstrate that the rate of increase of RML (slope) in the Toggenburg was higher than in the Saanen. In other words, Toggenburgs were less tolerant than Saanens.

However, when the differences between Saanens and Toggenburgs in Experiment 14 were compared to those in Experiment 12, particularly for RR and RT, the RR's of the

Saanen and Toggenburg after 30 minutes of exercise were 62 and 99/min, with respective RT's of 39.6 and 39.4°C. In contrast the corresponding figures in Experiment 14 were 79 vs 130/min and 39.5 vs 39.8°C respectively after 60 min of exercise. It seems likely that during a shorter period of exercise (30 min) only an irregular pattern of response was expressed, but when the animals had longer exercise (60 min) they showed a clear cut pattern, with the Saanen more tolerant than the Toggenburg (a rise in RR followed by a marked increase in RT). Again such facts confirm that the Toggenburg was the less tolerant breed.

It was found in Experiment 13 that when RR increased from 16 to 129/min, RML per respiration declined from 8 to 5 mg/respiration. A similar pattern occurred in Experiment 14; when RR increased from 17 to 177/min, then the RML declined from 9 to 3 mg/respiration. Overall, the current investigations revealed the same pattern of response as reported by ALEXANDER and WILLIAMS (1962) for heat stressed sheep. Together, the current experiments clearly demonstrate the importance of panting as a thermoregulatory mechanism when goats are in a stressed condition.

Experiment 16 indicated that SR varied with different positions over the body (rump, loin and ear); a result which is in general agreement with SCHLEGER and BEAN (1971). With time during exercise, both RSR and ESR declined, and mean values also decreased gradually with day of experiment. Additionally, while mean ESR in the current experiments was generally higher than LSR, on a between-breed basis the lowest mean EST were associated with the highest SR from the ear. Overall, these results confirm the thermoregulatory importance of the ear.

When a series of experiment was done to confirm the importance of sweating, it can be seen that animals which were "coated" (with a plastic coat) were clearly more stressed than uncoated ones (higher RR, RT, RML and SR), a fact that clearly demonstrates the importance of sweating to the animal during exercise. Such a finding confirms the earlier suggestion (Experiments 1 to 16) that an increase in sweating during exercise contributed to heat dissipation. Differences between breeds (Toggenburg higher RR, RML and SR but lower RT) clearly demonstrated with more heat was dissipated through panting and sweating in he Toggenburg, and as a consequence that breed experienced a decrease in RT. Such a fact supports the results from Experiments 9-12, and suggest that clipping the hair from exercising (and working) animals should improve their heat tolerance by improving the efficiency of evaporation of sweat.

From the overall results of Experiment 18 it can be concluded that animals inhaling air at 75% RH were more stressed than those in which the RH was 45% (higher RR, RT, RML and SR), a fact that presumably contributes to the observed seasonal effects. This experiment clearly demonstrated the importance of panting to the animal. Similarly, from Experiment 19 it can be concluded that sprayed animals were less stressed (lower RR, RT, RML and SR) than unsprayed ones, a result which indicates that the natural sweating response of these goats was at less than the ideal level. In practical situations in the field, the clear suggestion is that wallowing, or the application of mud or wet hessian to the body would be beneficial to the thermoregulation of working animals.

The overall results for PCV showed a significant decrease during working, and during the hot/dry as compared to the cool/humid season. These findings extend those of ARAVE *et al.* (1978) and IGBOKWE *et al.* (1992). Various explanations could apply to this phenomenon, including destruction of red blood cells during exercise (SING *et al.*, 1968b), and changes in splenic function (IGBOKWE *et al.*, 1992). In addition, CHEN *et al.* (1993) uoth the number of red blood cells and the haemoglobin level

decreased after exercise due to an increase in plasma volume. In Experiment 3 the PCV decreased from 28.0 to 26.3% when the animals worked for 2.5h, however, in Experiment 12 it was found that the PCV increased from 32.7 to 35.2% when the animals worked for only 30 min. It is concluded from the current field and laboratory trials that when PCV decreased (as during longer periods of exercise) it was an indication that acclimatisation had occurred in those animals. Conversely, when PCV increased (as during a short period of exercise), the animals were considered to have been stressed. It is thus possibly that changes in PCV could be used as an indicator of the acclimatisation of animals to temperature stress during work.

The overall conclusion reached with regards the different breeds is that the Toggenburg was the most intolerant breed (highest RR), then followed by the Saanen (of "intermediate" type) and then the Anglo Nubian as a better adapted, "heat-storer" breed during exercise. Clearly, for potential use in tropical countries, the Anglo Nubian (or, to a lesser extent the Saanen), is to be preferred relative to the Toggenburg. In the more general situation, these results in goats point to the likelihood of similar breed differences in other species (eg. cattle, buffalo). Clearly such effects need to be investigated, for example, before new breeds are introduced to a tropical area.

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