DIVING BRADYCARDIA IN THE DOMESTIC DUCK

An Undergraduate Fellows Thesis

by

Paul W. Gainer

April 1978

ABSTRACT

1. Submersion of the nasal passages in water causes significant bradycardia in the domestic Mallard, *Anas platyrhynchos*.

2. The degree of bradycardia does not appear to be markedly different between the wild and domestic Mallards

3. Bradycardia continues to develope in a linear fashion throughout the first 40 seconds of diving in the domestic Mallards while maximum bradycardial response is reached by the wild Mallard within 20 seconds after submergence.

INTRODUCTION

Diving animals have been of interest to biologist for over 100 years (Bert, 1870). Physiological explainations for extended diving times were first proposed by the French physiologist, Charles Richet (1894). In his pioneer experiment, Richet blocked the tracheae in two groups of ducks and let the subjects of one group suffocate in air and the others in water. Those animals immersed in water lived, on the average, 23 minutes, while those left in air died in 7 minutes. Richet demonstrated that submersion was involved in an animal's ability to survive prolonged periods without air. He concluded that physiological changes occurred during the dive which enabled the duck to conserve its limited oxygen.

Diving bradycardia is a reduction in an animal's heart rate which occurs with submersion. It occurs in ducks from lack of oxygen and ventilation reflexes. This is in contrast to diving mammals, where nasal reflexes initiate bradycardia (Butler and Taylor, 1973). Decreasing the amount of work done by the heart decreases the organ's need for oxygen and thus extends the diver's oxygen supply and submersion time (Irving, 1939; Scholander, 1961-1962).

Diving bradycardia is most highly developed in diving animals (Anderson, 1966). A slowdown of the heart rate as a response to diving has also been observed in non-diving mammals, birds, reptiles and amphibians (Scholander, 1961-1962).

Catlett and Johnston (1974) compared the bradycardial response for 4 species of wild ducks. Diving bradycardia was more highly developed in diving species than in dabbling or surface feeding species.

The purpose of this investigation is to study diving bradycardia in semi-domesticated Mallard ducks, *Anas platyrhynchos*. Results from this investigation are compared with results for live-trapped wild Mallards (Bond, et al., 1961).

MATERIALS AND METHODS

Seven adult Mallards were obtained from Sea-Arama Marineworld where they were permanent residents in the park's bird display. The display area contained a water pool approximately 2 feet deep and 600 square feet in area. The ducks ate a Purina feed mix from plastic containers along the edge of the pool. Submersion of the duck's head was not necessary for their attaining food.

Experimental birds were obtained from the display area and kept overnight in a cage before testing. The ducks were brought to the biology laboratory at Moody College in order to record electrocardiograms (EKG's).

In the lab the animal's legs were bound together and tied behind the body to discourage struggling. Two needle electrodes were inserted just beneath the skin on either side of the sternum. They were securred against the bird's breast with masking tape to prevent their accidentally being dislodged.

The duck was then placed along the groove of a "U" shaped duck board. The animal's neck extended over the edge of the board, allowing the lowering of the duck's head into a tub of water. The bird was held snuggly within the groove by an elastic bandage strapped on either side of the board and across the duck's back. The leads from the needle electrodes were connected to a high-gain preamplifier coupled to a Narco Physiograph®.

The ducks were allowed 15 minutes of acclimation on the board before a pre-dive EKG was recorded. Two minutes of baseline readings were obtained then the animal's head was lowered into the water until the nares were covered. The birds were kept in this position for 50 seconds before being allowed to remove their heads from the water. Each duck performed 3 simulated dives with 5 minutes allowed between submersions.

The mean heart rates for the 3 replicates were determined from physiograph recordings. The mean beats/minute were calculated for 10 second intervals during the 20 seconds immediately before submersion, the first 40 seconds of the dive and the initial 30 seconds of recovery. An overall mean and its standard error were obtained from the mean rates collected for each of the seven ducks. A one-way analysis of variance was administered to determine if the observed diving bradycardia was significant. The results from these birds were then compared to those presented by Bond (et al., 1961) for wild Mallards.

RESULTS

A significant bradycardia (95% significance level) ensued the submergence of the duck's nares in water and was followed by tachycardia (an increase in heart rate) upon surfacing (Figure 1). Each of the seven animals tested showed a gradually increasing bradycardia with time underwater (Figure 2).

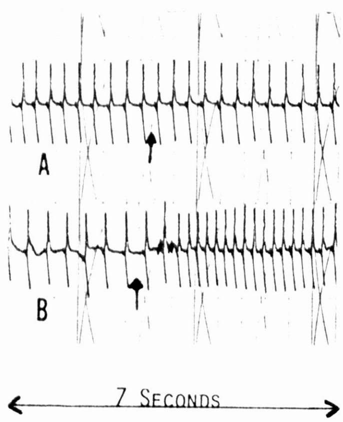

Fig. 1. EFFECTS OF SUBMERSION (A) AND EMERSION (B) ON THE CARDIAC RESPONSE OF A MALLARD DUCK

Variation between the seven pre-dive heart rates was quite large. Some duck's minimum dive cardiac rates were faster than other duck's pre-dive rates. Differences between an individuals 3 repetitions was less marked (Table 1).

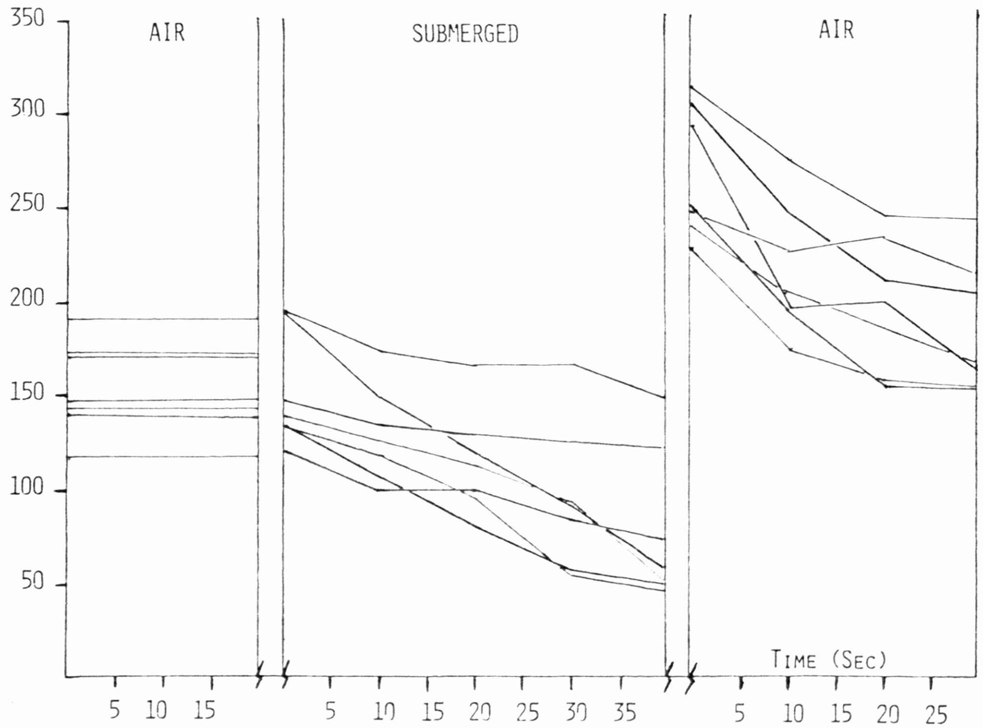

Fig. 2. MEAN INSTANTANEOUS CARDIAC RATES OF 7 TEST MALLARDS WITH HEAD IN AIR, SUBMERGED IN WATER AND RETURNED TO AIR

Table 1--MEAN HEART RATES AND STANDARD DEVIATIONS OF SEVEN MALLARDS DURING WATER IMMERSION

	Seconds under water				
Duck	0	10	20	30	40
1	120± 0	98±18	100±24	86± 9	75± 9
2	196±14	176±21	168±12	168±18	151±14
3	148±18	134±13	130± 3	128± 7	125± 8
4	196±14	150±31	122± 9	92±24	60±36
5	136± 7	108± 6	80± 3	58±13	48± 3
6	136± 7	120±16	96± 6	54± 6	46±17
7	140±14	106±12	112±17	94±12	52±23

The mean cardiac values for the domestic ducks showed an almost linear decrease throughout the duration of submergence. This linear development was quite unlike the response seen in wild Mallards (Bond et al., 1961) where maximal bradycardia occurred during the first 20 seconds after submersion and then leveled out for the remainder of the dive (Figure 3).

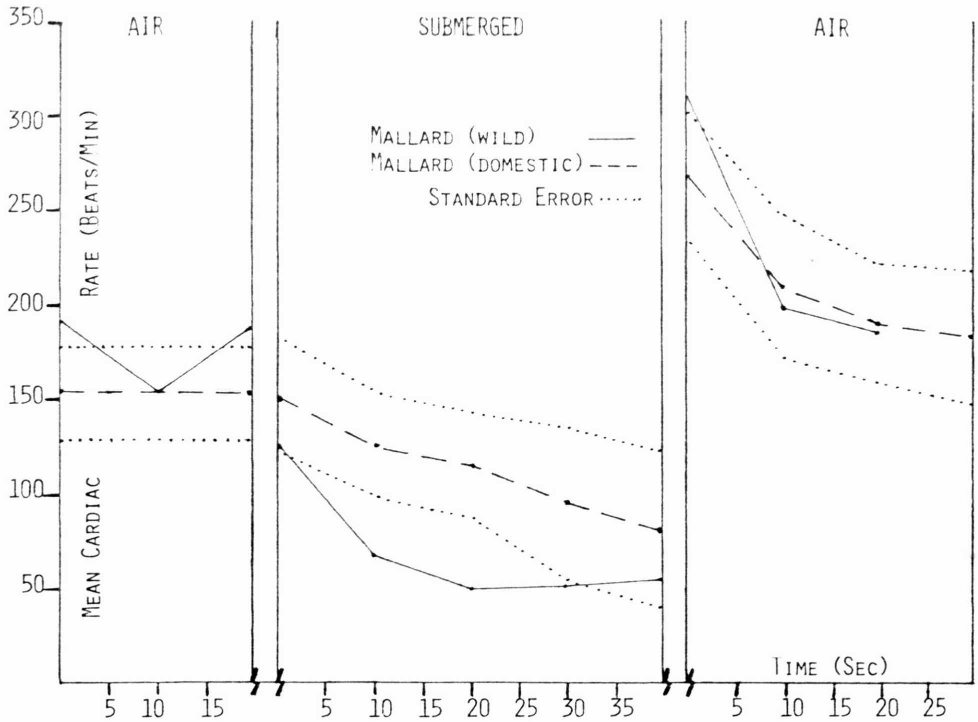

Fig. 3. MEAN INSTANTANEOUS CARDIAC RATE IN WILD AND "DOMESTIC" MALLARDS WITH HEAD IN AIR, SUBMERGED IN WATER AND RETURNED TO AIR.

Pre-dive heart rates for the domestic Mallards stayed consistently near the 150 beat/minute level, this being very similiar to pre-dive rates obtained from wild ducks (Bond et al., 1961). Post-dive heart rates for the domestics also showed striking similarities to results from wild Mallards (see Figure 3).

DISCUSSION

Though the domestic Mallards did no diving to acquire food, a significant bradycardia (.05) developed during submergence. The diving bradycardia of the wild and domestic ducks cannot be statistically compared, however, since Bond (et al., 1961) chose not to include his animal's standard error in his paper. If one assumes a simiiiar error for both groups of Mallards then the differences in the means between the wild and domestic ducks could be explained by random error.

What is possibly different is the way in which bradycardia develops within the two groups. In the wild Mallards, submergence appears to cause a rapid reduction in the pre-dive cardiac rate. Within 20 seconds the wild ducks have reached their most sustained bradycardia and are efficiently extending their circulatory oxygen.

In the domestic Mallards, bradycardia appears to develope at a slower rate. The maximum reduction in heart rate has not been reached even after 40 seconds of diving and, therefore, oxygen must be used to sustain the heart that otherwise could be used to prolong submersion.

This study supports the conclusions of Catlett and Johnston (1974), that diving bradycardia is an adaptive mechanism for tolerance to asphyxia. The present investigation could have been strengthened by enlarging the sample size of ducks tested. Increased sampling could have reduced variances and aided in determining statistical similarities and differences between the wild and domestic ducks.

ACKNOWLEDGEMENT

The author wishes to thank Dr. Dorthea Mangum, Jeffrey Giles and Steven Lehr for their welcomed assistance in the completion of this study. A further word of thanks is extended to Sea-Arama Marineworld which generously supplied the ducks for this investigation.

REFERENCES

Anderson H. T. (1966) Physiological adaptations in diving vertebrates. Physiol. Rev. 46, 212-243.

Bert P. (1870) Lecons sur la Physiologie Comparée de la Respiration, Baillière, Paris, pp. 526-553.

Bond C. F., Douglas S. D. & Gilbert P. W. (1961) Effects of submergence on cardiac cycle and rate in aquatic and and terrestrial birds. Am. J. Physiol. 200, 723-726.

Butler P. J. & Taylor E. W. (1973) The effect of hypercapnic hypoxia, accompanied by different levels of lung ventilation, on heart rate in the duck. Resp. Physiol. 19, 176-187.

Catlett R. H. & Johnston B. L. (1974) Cardiac response to diving in wild ducks. Comp. Biochem. Physiol. 47A, 925-931.

Irving L. (1939) Bradycardia in diving mammals. Physiol. Rev. 19, 112-134.

Richet C. (1894) La resistance des canards a l'asphyxie. Compt. Rend. Soc. Biol. 1, 244-245

Scholander P. F. (1961-1962) Physiological adaptations to diving in animals and man. Harvey Lect. 57, 93-110.