Characterisation of limb development and locomotion in the brown kiwi (*Apteryx mantelli*)

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Erica Anne Jones

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Abstract

This thesis covers broad topics concerning limb growth and development and their effects on locomotion in the brown kiwi (*Apteryx mantelli*).

I begin by describing the morphological features of a collection of unknown-age wild kiwi embryos from early development to point of hatch. Using these features, I assign developmental stages to each embryo and compare the progress of development to the same-staged ostrich and chicken embryos. Measurements of the hindlimb, bill and crown-rump length are used to develop an aging scheme based on comparisons with the ostrich and the chicken. The ostrich model and chicken model create age predictions for the unknown aged kiwi embryos. One kiwi embryo was of known age and both models gave identical predictions for this marker embryo, but gave differing predictions for all other kiwi embryos.

Using captive-reared kiwi chicks, I characterise hindlimb, bill and bodyweight growth from the time of hatch to 3 months of age. Growth patterns are very linear within this time period for all measurements but bodyweight. Female kiwi hatch with longer bills than males, but the growth of both sexes converges by the end of the 3-month period. Growth of bodyweight in the males slows earlier than in females. Bodyweight and bill length were then compared to a wild population of kiwi. Captive-reared chicks were found to hatch with shorter bills than the wild birds and to increase in bodyweight at a faster rate than wild birds. Rapid weight gain has been implicated in developmental limb deformities in other precocial and long-legged birds and has the potential to produce similar results in captive kiwi.

I further studied the movement of the hindlimb during locomotion in two adults and one juvenile kiwi by filming them while they were walking on a treadmill. Kinematic parameters were measured from the video recordings and compared to overground parameters from another study. Similarity between the treadmill and overground locomotor parameters validates the use of a treadmill in studying kiwi locomotion. None of the birds achieved the theoretical transition from a walk to a run at a duty factor of 0.5. After normalising for size, the juvenile showed a longer stride length and lower

stride frequency with increasing speed than the adults. Lateral head oscillations were observed during the stride cycle, which I propose having a sensory function as well as a biomechanical one.

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Preface

This thesis has been written and organised as self-contained chapters that will act as submissions to peer-reviewed scientific journals. Therefore, each chapter is written as a fully-referenced paper, causing overlap of some material, but each presents a unique aspect of kiwi hindlimb growth, development or movement.

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