Development of the skeleton and feathers of dusky parrots (*Pionus fuscus*) in relation to their behaviour

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A clutch of five dusky parrots (*Pionus fuscus*) was observed from hatching to fully grown. They were examined radiographically from 16 to 45 days of age, a few days before the cessation of bone growth, and the development of their feathers and their behaviour were also studied. It was observed that when growing birds were removed from the nest and placed singly on a flat surface they would stand up and walk about until restrained; normally these birds would move very little and lie in an intertwined huddle that supported their relatively weak growing skeletons. At 50 days old they would climb to the nest entrance, retreating if scared. From day 51 the parrots flapped their wings vigorously inside the nest box, and they emerged at 53 days old when nearly all their large feathers had finished growing. These findings may help to explain the high rate of juvenile osteodystrophy in hand-reared parrots; premature exercise could lead to pathological deformity of the long bones, especially the major weight-bearing bone, the tibiotarsus.

PARROTS are frequently bred in captivity and kept as pets. The baby birds are often hand reared in the belief that parrots that are imprinted on people rather than birds make better pets. However, captive breeding and hand rearing have the potential to produce physical as well as behavioural problems in birds; in a recent study by Harcourt-Brown (2003), 44 per cent of hand-reared grey parrots (*Psittacus e erithacus*) were found to have osteodystrophy.

Osteodystrophy has been defined as a failure of the normal development of bone. Its principle clinical signs are distortion and enlargement of the bones, susceptibility to fracture, and abnormalities of gait and posture (Blood and Studdert 1988). When it affects growing bones it is termed juvenile osteodystrophy and its radiographic signs are permanent. The cause of juvenile osteodystrophy in non-domestic birds is thought to be an imbalance of calcium and phosphorus in the diet, and/or a deficiency of vitamin D (Fowler 1978). A lack of minerals and vitamin D (or inadequate ultraviolet light) are recognised as causes of metabolic bone disease in domestic poultry (Edwards 1992). However, many other factors, such as the bird's rate of growth, have been implicated (Whitehead 1992). In poultry it has also been recognised that genetics plays a part (Kestin and others 1999), as does the amount of exercise the birds are taking (Classen and Riddell 1989); the resulting skeletal deformities are not like those caused in otherwise normal bones by physical means.

One noticeable effect of hand rearing baby parrots is that they appear to be very friendly and active from an early age, when, in normal circumstances, they would still be confined to the nest cavity. In a study in which hand-reared grey parrots were examined radiographically for signs of juvenile osteodystrophy (Harcourt-Brown 2003) it was found that the incidence of bony deformities varied between bones: furcula 0 per cent, keel 25 per cent, ribs 41 per cent, humerus 8 per cent, radius 33 per cent, ulna 33 per cent, pelvis/synsacrum 25 per cent, femur 25 per cent, and tibiotarsus 100 per cent. All the birds affected by osteodystrophy to any degree had a deformed tibiotarsus whereas none had a deformed furcula. Although the cause was probably a nutritional deficiency, the distribution of the lesions could have been modified by the birds' abnormal activity.

The growth rate of birds is related to their final bodyweight, their metabolic rate and their food intake. In wild birds there is a balance between the rate of growth and the period during which the bird is dependent on its parents. There are many reasons why it is advantageous for a young bird to become independent quickly, but the rate is balanced by the risk to the parents (Starck and Ricklefs 1998). Altricial nestlings (such as parrots) are totally dependent on their parents for food and protection as they grow and they are confined to a nest, but they grow rapidly, although parrots are one of the slowest growing altricial birds. In contrast, precocial nestlings hatch from larger eggs which take relatively longer to incubate, but when they hatch they are able to walk, some can even fly (Megapodidae), they have their eyes open and fend for themselves, but they grow more slowly. Altricial birds increase their bodyweight two to three times more quickly than precocial species (Ricklefs and others 1998).

The growth of the skeleton and its relationship with function in a semi-precocial bird (those which are able to walk from an early age but are fed by their parents), the Californian gull (*Larus californicus*), was studied by Carrier and Leon (1990). To overcome the poor weight-bearing ability of relatively soft, growing bone, Californian gulls have relatively thick bones in the pelvic limbs that allow the birds to run around from two days old without being injured or the bones being deformed. The birds do not fly until they are fully grown. The wing bones remain relatively underdeveloped until a few days before they fledge, when they rapidly increase in stiffness in a spurt of growth that corresponds to the start of wing exercise. They found that the stiffness of the bones increased six- to 10-fold during the growth period. In altricial species that do not need to walk or fly until the bird is due to leave the nest, the thickness and stiffness of their bones would be expected to be different from precocial birds, and while the bones are growing they would not be expected to be strong enough for walking.

Most studies of the development of the skeleton of birds have been conducted on dead embryos. The bone growth of budgerigar (*Melopsittacus undulatus*) embryos, but not the larger parrots, has been studied by Starck (1989). There have been few studies of bone growth from hatching to skeletal maturity. There have been morphological studies of ducks (Johnson 1883) and quails (Lansdown 1969, 1970). The centres of ossification and their development in the chicken (*Gallus gallus*) have been described by Hogg (1980). More recently, the skeletal development of birds has been studied with respect to its effects on the developing bird and its parents' survival; much of this work has been reviewed in Starck and Ricklefs (1998). Most studies used dead embryos that were fixed, dehydrated in alcohol, cleared with potassium hydroxide and stained with alizarin red and alcian blue, clearly revealing the red bones and blue cartilage in the trans-

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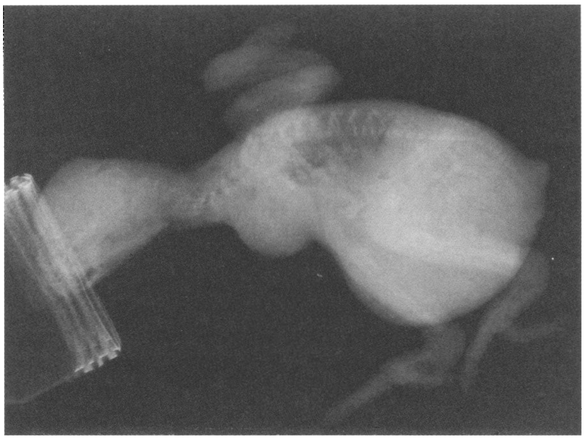

FIG 1: Lateral whole-body radiograph of a 16-day-old dusky parrot (*Pionus fuscus*) with its head in an anaesthetic mask; the significant features are the size of the visceral compartment, the full crop and the lack of mineralisation of the epiphyses; the synsacrum is still in its vertebral segments

parent tissue; this is very useful for embryos and makes it possible to make detailed drawings (Starck 1989). Hogg (1980) used radiography as well as alizarin red stain. In birds less than 21 days old the radiographic appearance of the bones was enhanced by impregnation with silver nitrate. Carrier and Leon (1990) collected 32 Californian gulls from two days old to skeletal maturity; they defleshed the long bones and subjected them to a breaking force (among other tests), then polished the bone at the break and digitised its cross-section. The area was compared with the bird's bodyweight and other parameters.

Kirkwood and others (1989) showed that in adult birds the length of the tarsometatarsal bone was proportional to the bird's weight. They also found that the growth rate of the tarsometatarsus was three times greater in altricial birds than in precocial birds. The long bones lengthen by growing from a zone of proliferation, analogous to a growth plate, and the epiphyseal portion of the bone is unossified cartilage; radiographically there is no formed end to the bone while the bone is growing (Fowler 1981). Kember and others (1990) showed that differences in the rate of elongation of the tarsometatarsus are the result of differences in the height and width of the proliferation zone, the region that is comparable to the epiphyseal plate of mammals. They suggested that the growth rate of the rest of the skeleton could be the same as that of the tarsometatarsus.

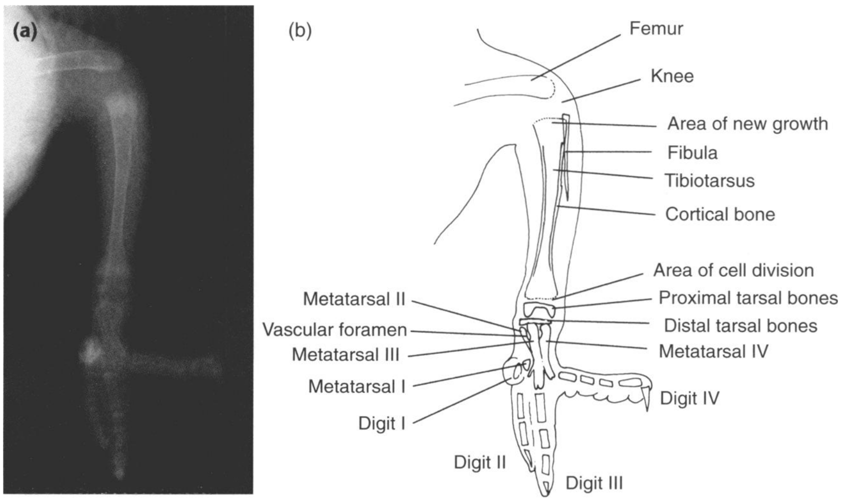

FIG 2: (a) Craniocaudal view of the leg of a 27-day-old dusky parrot (*Pionus fuscus*). The metatarsal bones are fusing but can still be seen as separate entities. Both proximal and distal rows of tarsal bones appear separate. The epiphyses forming the knee joint are not ossified. (b) Line drawing of the radiograph

Radiographic studies of adult female *Pionus* species about to breed showed that, of the long bones, only the humerus was pneumatised. All the other long bones' medullary cavities contained medullary bone that would have made pneumatisation obvious.

The breeding biology of parrots has been reviewed by Collar (1997). In natural conditions, most parrots nest in holes and lay several white eggs. It is uncommon for a parrot to lay only one egg and most lay at least two, and in some cases up to 11; the bigger the bird the smaller the clutch. The eggs are usually laid on alternate days; incubation starts after the first egg is laid, and the eggs also hatch on alternate days. Young parrots are nidicolous (remain in the nest after hatching), ptilopaedic (clad in down when they hatch, although it may be quite sparse at first) and are altricial. They also hatch with their eyes closed. Little is known about their development within the nest but the young birds appear at the nest entrance shortly before they fledge, and interact with their parents.

The aim of this study was to evaluate the growth of the skeleton of dusky parrots (*Pionus fuscus*) and relate it to their behaviour while they were growing in relatively natural conditions, being raised by their parents. The hypothesis was that the bones of an altricial bird would differ from those of a semiprecocial bird and would not be able to support true ambulation until they were skeletally mature.

MATERIALS AND METHODS

The birds used belonged to the author; the adult birds had always reared their own young. They were fed a diet made mainly from chopped apples and carrots with an equal quantity of soaked mixed peas and beans; a vitamin and mineral supplement (Professional Breeder Supplement; Pet Chef) that contained 80,000 iu/kg vitamin D_3, 4·5 per cent calcium and 3·6 per cent phosphorus was mixed into the diet in accordance with the manufacturer's instructions.

A clutch of five dusky parrots was examined radiographically 16, 27, 37 and 45 days after the last bird had hatched. The birds were anaesthetised and whole-body ventrodorsal and lateral views were obtained. Because the eggs hatched on alternate days, this method gave a series of radiographs showing the development of the bones based on alternate day intervals throughout the period of growth. The birds were finally examined radiographically at approximately 90 days of age when they were definitely skeletally mature.

At the end of the study the radiographs were examined to determine the rate of growth and the point of cessation of growth of each bone; in addition, more detailed measurements were made of the ulna and the tibiotarsus. The measurements were of the narrowest part of the bone, the maximum width of the proximal and distal ends, the length of the visible calcified part of the bone, and the length of cortical bone. Some bones are made of a fusion of separate bones, for example, the tibiotarsus consists of the tibia fused to the proximal row of tarsal bones. The formation of these bones from their separate ossification centres was observed, and the onset of pneumatisation of the bones was also recorded.

A one-day-old dusky parrot was also available for radiography; it was from the same parents but had died the year before and had been preserved in 10 per cent formol saline.

The social and physical development of the birds was observed daily for two hours.

The growth of the feathers was recorded, especially in relation to their maturation and pneumatisation. From 16 days of age the parrots were also photographed to record the growth of their feathers. Each bird was removed from the nest box and placed on a table covered by a towel to provide a

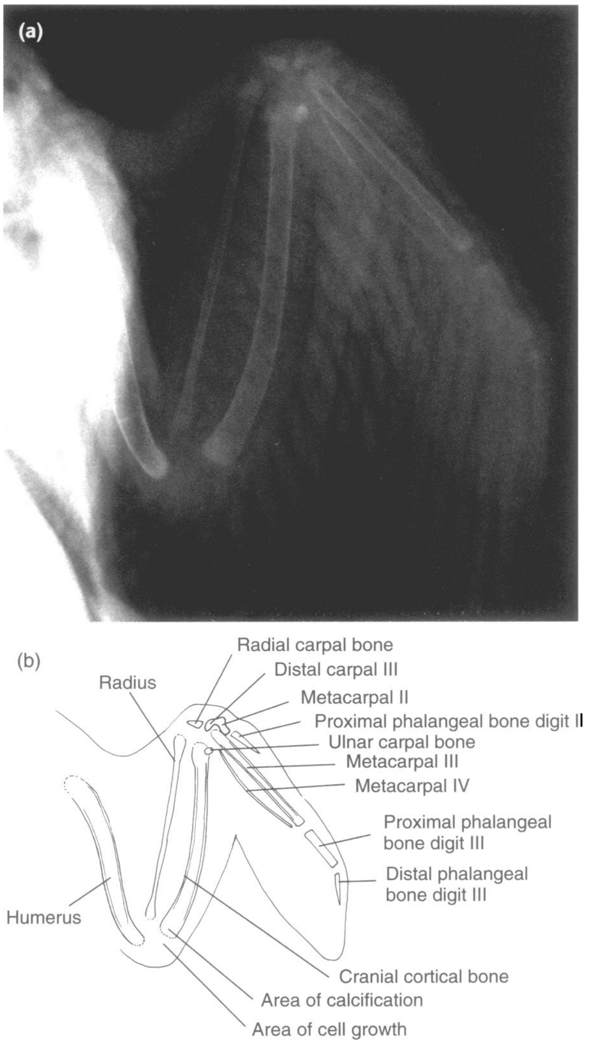

FIG 3: (a) Ventrodorsal view of the wing of a 31-day-old dusky parrot (*Pionus fuscus*). The epiphyses of the elbow and shoulder are not ossified, the metacarpal bones are separate and the distal row of carpal bones is not joined to the metacarpals. The radial and ulnar carpal bones are visible. (b) Line drawing of the radiograph

comfortable, relatively warm surface for it to rest on, and the towel was also used as a backdrop for the photograph.

The radiographs were taken with Trimax T2 screens on HRE film (Fuji), and processed in a RGII automatic processor (Fuji). The dead one-day-old bird was radiographed on HR mammography film in an HR Mammo Fine cassette (Fuji).

RESULTS

Bone development

Very little skeletal development was visible on the radiographs of the one-day-old chick; only some parts of the skull, ribs, femur and tibiotarsus could be detected. By day 16 most of the bones were visible, except for the tarsal and carpal bones (Fig 1). By day 31 the distal tibiotarsus, tarsometatarsus and synsacrum were fully developed. By day 39 the tibiotarsus and femur were fully formed, by day 43 the radius was fully formed, and by day 45 the ulnar carpal bone, humerus and pectoral girdle were fully formed.

Many of the joints, such as the elbow or knee, showed no radiodensity; this was normal. In some birds the carpal and tarsal bones arose as separate ossification centres that eventually fused to an adjacent bone (Figs 2 to 5). While they were growing, the zones of proliferation gave the appearance of a typical mammalian growth plate; these features were seen in the tibiotarsus, tarsometatarsus and carpometacarpus of the growing parrots.

The diaphysis of each growing bone was considerably narrower than the metaphyses, especially in the tibiotarsus (Figs 2, 4, 6). The narrow part of bone had an apparently well developed cortex. During the mid-part of the growth period it was difficult to measure the length of the cortical bone in the tibiotarsus because the beginning and end of the cortex were indistinct.

The synsacrum and notarium grew differently from the long bones and developed as a series of vertebrae that

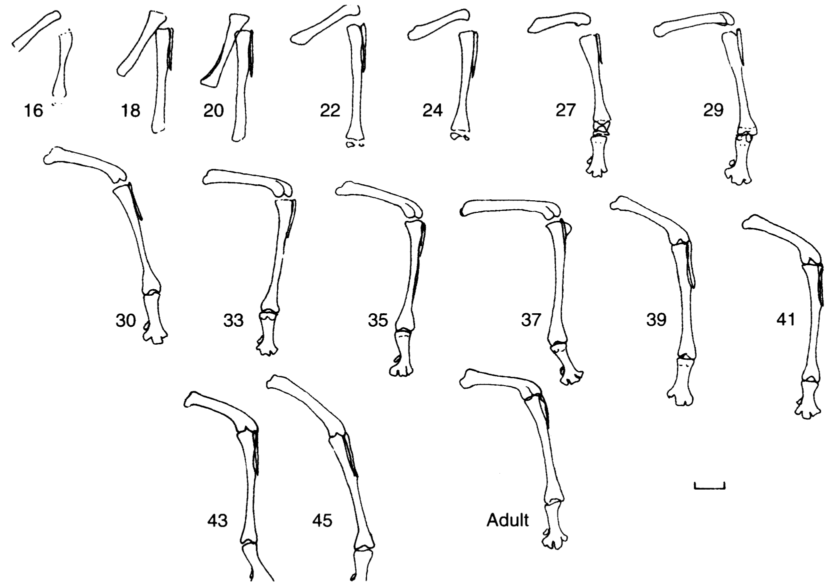

FIG 4: Drawings of the legs of five dusky parrots aged from 16 to 45 days, each examined on three occasions, and one adult parrot, made from the corresponding radiographs of a craniocaudal view. For days 16, 18, 20 22 and 24, the leg was not fully extended so that the tarsometatarsal structure was not visible. Bar=1 cm

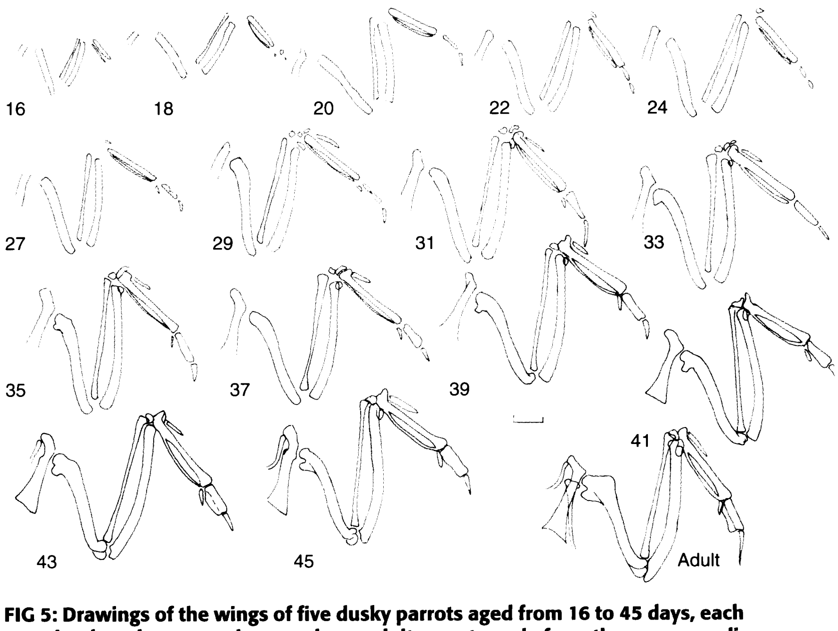

FIG 5: Drawings of the wings of five dusky parrots aged from 16 to 45 days, each examined on three occasions, and one adult parrot, made from the corresponding radiographs of a ventrodorsal view. Bar=1 cm

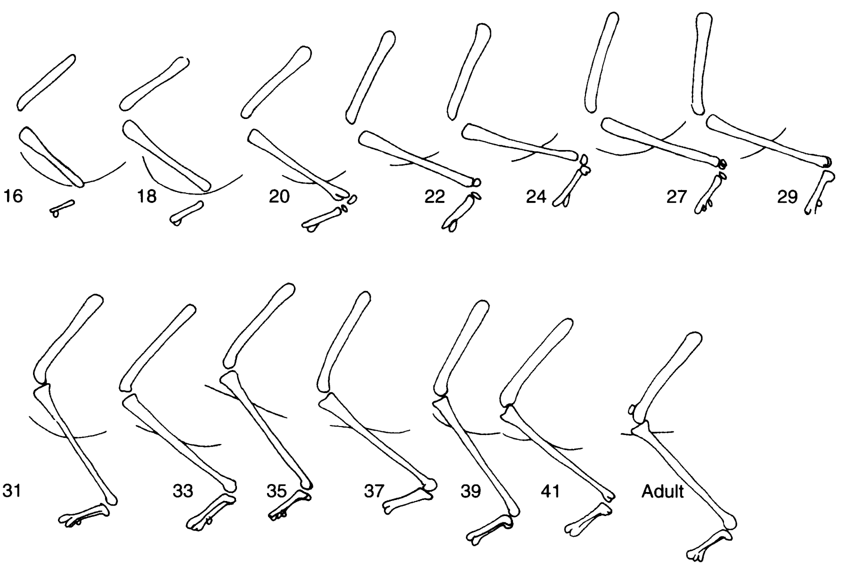

FIG 6: Drawings of the legs of five dusky parrots aged from 16 to 41 days, each examined on three occasions, and one adult parrot, made from the corresponding radiographs of a lateral view. The level of the ventral body wall is shown in relationship to the leg

enlarged and finally fused. Once the bones were fused the synsacrum appeared to stop growing (Fig 7).

The measurements taken from the ulna and tibiotarsus are shown in Figs 8 and 9, respectively.

The birds' humerus appeared to be pneumatised when it was fully formed at 45 days, as its medullary cavity was less radiodense than that of the adjacent radius and ulna.

Feathers

When dusky parrots hatch they are covered with very few down feathers. The eggs were incubated, and the young birds were brooded exclusively by the female almost continuously until the youngest was 16 days old, when it left the nest box for increasingly long periods of time, allowing the young birds to be removed safely to be radiographed and photographed.

By 16 days a few feather follicles had formed, mainly in the feather tracts of the wing (Figs 10, 11), and by 25 days there were considerable numbers of erupting feather follicles of body contour feathers, retrices (flight feathers of the tail) and remiges (primary and secondary wing feathers) (Fig 12). By 33 days, 5 to 10 mm of feather had emerged, especially on the wings, and there had been a second growth of down feathers so that the bird was nearly fully covered by either down or contour feathers (Fig 13). The birds no longer required brooding. When the baby birds emerged from the nest box nearly all their contour feathers and wing feathers were fully grown; primary feathers 9 and 10 (at the wing tip) and all the retrices were almost fully-grown.

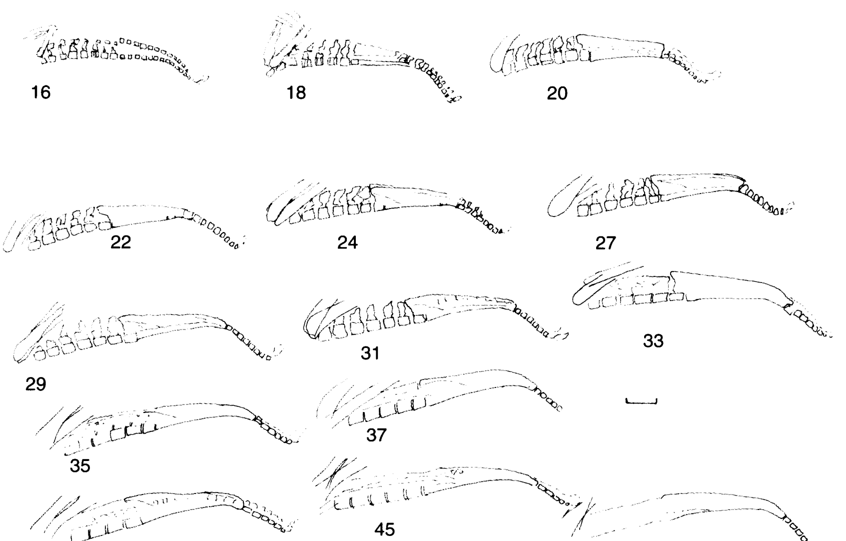

FIG 7: Drawings of the notarium and synsacrum of five dusky parrots aged from 16 to 45 days, each examined on three occasions, and one adult parrot, made from the corresponding radiographs of a lateral view. Bar=1 cm

Behaviour

For most of the time in the nest box the baby birds would huddle into an intertwined mass (Fig 10). From 43 to 53 days the huddle became less intertwined and the birds tended to adopt a more upright stance in the nest box. The optimal size of a nest chamber for dusky parrots is 20 cm x 20 cm and, as a result, once the birds were well grown and standing upright their movement was very limited. Their behaviour developed in a consistent way; from day 50 they would leave their siblings and climb to the nest entrance and peer out, retreating if scared; from day 51 they would flap their wings vigorously, standing over the other young birds in the nest box; on day 53 they would emerge and then stay out for increasingly long periods that became permanent by day 56; by day 57 the birds were flying well, and by day 69 they were able to perch on one foot and appeared socially normal and confident; by day 75 the birds were eating on their own (but still happy to be fed by their parents) and appeared normal adolescent parrots. However, unexpected events would induce signs of excitement.

When photographing the parrots a strong reflex behaviour was observed in the birds over 16 days old. When a bird was removed from the nest box, isolated from its siblings, and placed on a flat non-slippery surface it would stand up and walk around (Figs 11 to 13). As soon as this isolated baby was placed in contact with its siblings, in the nest box or out of it, it huddled into the pile of baby birds (Fig 10).

DISCUSSION

These five naturally reared *P fuscus* parrots were prevented by their behaviour from becoming ambulant until their skeletons had matured and until most of their feathers had stopped growing and become pneumatised. The results, together with those of Harcourt-Brown (2003), in which 44 per cent of hand-reared grey parrots had skeletal deformities, suggest that in addition to a dietary deficiency, hand-rearing could predispose parrots to skeletal malformations through the encouragement of abnormal physical activity and premature weight bearing on growing bones.

Harcourt-Brown (2003) found that grey parrots affected by juvenile osteodystrophy to any degree had a deformed tibiotarsus, whereas none of the birds had a deformed furcula. The furcula is a bone that has a role in conserving energy during flight by acting as an elastic, compressible spacer; it also affects the circulation of air between the air sacs and the lungs during flight (Goslow and others 1989). When the bird is not flying this bone will presumably not be stressed and would therefore be less liable to be deformed. In contrast, the tibiotarsus bears the weight of the baby bird as soon as it can stand and walk, even before it can grasp and perch; it is the major weight-bearing bone (Figs 11 to 13). Although the major cause of deformity in grey parrots is probably nutritional deficiency, the distribution and severity of the lesions could be affected by abnormal activity; even a longitudinal rotational deformity of the bones could be produced if the young bird tries to stand unsupported (Fig 11). Carrier and Leon (1990) showed that semi-precocial gull chicks are able to walk from two days old without deforming their growing leg bones because these bones are relatively thick. They found that the strength of the pelvic limb increased gradually, whereas the wing bones remained weak almost until the end of their growth, when they grew rapidly and gained strength; the increase in strength and stiffness coincided with the birds' first wing flapping and then flight.

The size of the bones and their rate of development were different in the parrots' legs and wings (Figs 8, 9), although the difference was not as great as in the Californian gull. The calcified tibiotarsus doubled in length between 16 and 37 days, when it was fully formed, but at its narrowest point the bone did not change significantly after the birds were 18 days old. This narrow region had a radiographically well developed cortex that presumably strengthened it. Because dusky parrots do not have thick tibiotarsi they cannot be considered to be able to walk while their pelvic limbs are growing. The ulna took longer to reach skeletal maturity and at its narrowest point did not seem to vary significantly after 24 days of age. The length of its cortex increased noticeably after 27 days, and the measurements and the radiographs showed that the legs became stronger more quickly than the wings. This difference parallels the changes in the birds' movements. At first the baby birds only beg for food by raising their head; they lay in a huddle that provided a great deal of mutual physical support. Even the smallest baby bird appeared to be well supported in this intertwined huddle rather than being smothered by its older, bigger siblings. As they got older, the birds would stand upright but could not move around much because they were confined by the size of the nest chamber. Finally, they would climb to the entrance of the nest before they started to flap their wings (Fig 14).

Like other altricial birds early in their development, parrots have no ability to conserve body heat and require brooding by their parent. The female *P fuscus* spent less time brooding the clutch once the youngest bird was 16 days old, and it was then easier to remove young birds in batches of two or three (never five at once) for examination.

The weight of the bird's wings was measured. The feathers were growing and full of blood and developing tissue which was replaced by air spaces in the fully developed feathers. As a result, at the beginning of the last third of the period of growth the wings were relatively heavy. They were difficult to weigh accurately but the wing of a two-thirds grown baby appeared to be heavier than the wing of a fully grown bird. The pneumatisation of the feathers and the humerus significantly reduces the weight of the wing. Walking about while the developing wings dangle would tend to deform the distal humerus, and if the wing were hung over the edge of a bucket or bowl the proximal radius and ulna would also tend to be deformed. Juvenile osteodystrophy would also allow the proximal radius to be deformed at the point of insertion of the biceps brachii muscle. During the first half of the period of development, the parrot's viscera constituted a large proportion of its body (Fig 1); the crop was also very large and usually at least half full (Figs 1, 11, 12); all the bones were growing and were well supplied with blood vessels.

Radiographic images cannot be used to assess the weakness or stiffness of bones but they can provide measurements which can be used to assess rates of growth. It is generally accepted that a ventrodorsal and a craniocaudal view of an extended limb give the best indication of the dimensions of its bones. In anaesthetised growing parrots the weight of the wing and the size of the body make extending the wing hazardous. The body is so heavy and the bones relatively so weak that young parrots appear to be quite delicate. Great care was taken not to place too much strain on the body and so a whole-body ventrodorsal view and a lateral view with the legs gently extended and the wings laid back dorsally were taken; these views were also used by Harcourt-Brown (2003) to assess the skeletal morphology of grey parrots. It was possible to recognise bone growth adequately from these views but it was not possible to measure the actual size of the bones, owing to the magnification caused by the bones being different distances from the film; some views would have been

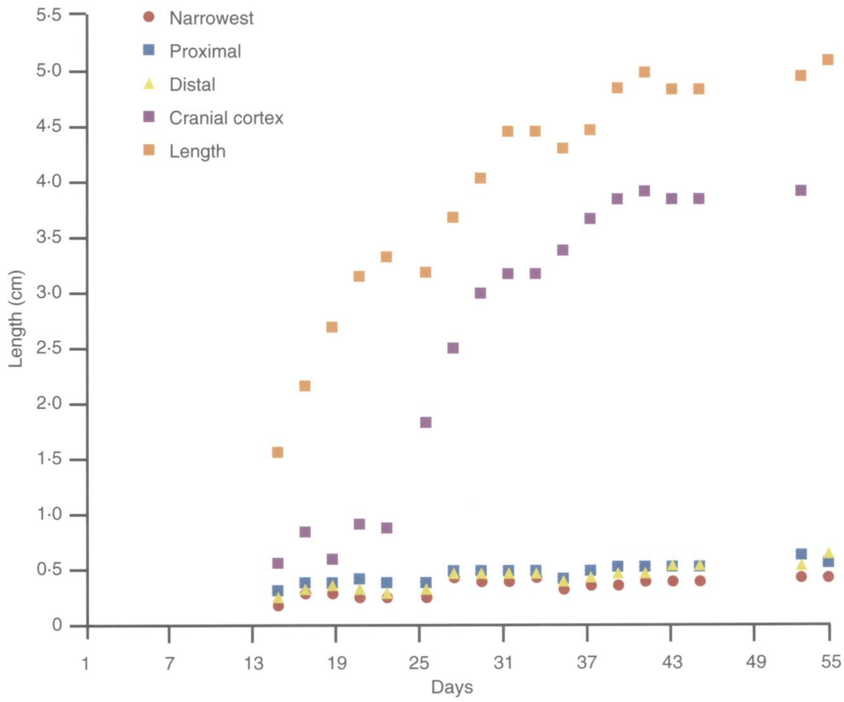

FIG 8: Ulna measured from the ventrodorsal view of the wing. Proximal Widest part of the proximal ulna, Distal Widest part of the distal ulna, Cranial cortex Length of the ulna's cortex on the cranial face of the bone on the radiograph. The final two sets of measurements are from a skeletally mature bird's radiograph and a prepared bone

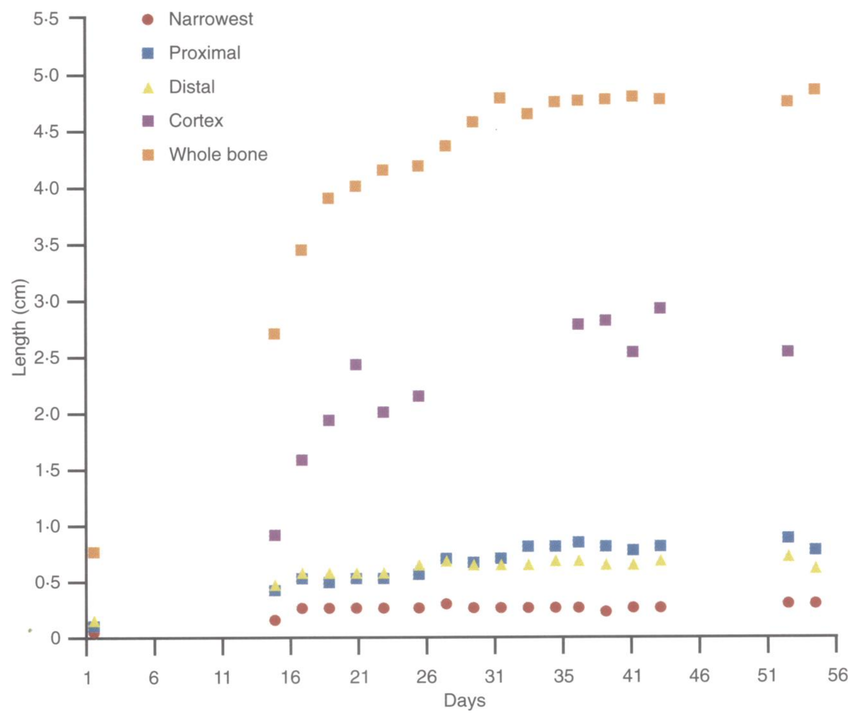

FIG 9: Tibiotarsus measured from the craniocaudal view of the leg. Proximal Widest part of the proximal tibiotarsus, Distal Widest part of the distal tibiotarsus, Cortex Length of the tibiotarsal cortex on the medial face of the bone on the radiograph. The final two sets of measurements are from a skeletally mature bird's radiograph and a prepared bone

FIG 10: Sixteen- to 25-day-old dusky parrots 'huddling'

FIG 11: Twenty-three-day-old dusky parrot, showing the potential for rotational limb deformity

FIG 12: Twenty-five-day-old dusky parrot with a full crop and large visceral compartment

FIG 13: Thirty-three-day-old dusky parrot; the tibiotarsus is still growing and the visceral compartment is decreasing in size

more affected than others because the bones were further from the film. Using radiographs made from an anaesthetised adult dusky parrot, the tibiotarsus (mediolateral view) and ulna (ventrodorsal view) were measured and compared with measurements made from the skeleton of a different dusky parrot; in each case the bone was close to the cassette. For the ulna the bone measured 5·06 cm and the ventrodorsal radiograph 4·94 cm; for the tibiotarsus the bone measured 4·94 cm

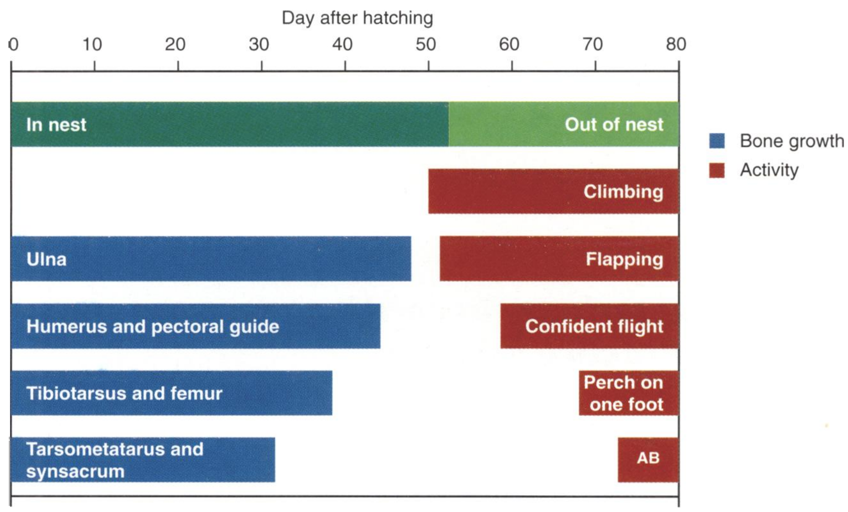

FIG 14: Relationships between the cessation of the growth of various bones and the onset of different activities. The leg bones had finished growing by 39 days, the wing bones by 47 days, and no vigorous activity occurred until the bones had finished growing. AB Adolescent behaviour

and the mediolateral radiograph 4·85 cm. In each case the difference was approximately 0·1 cm in 5 cm (2 per cent), a variation within the normal limits of direct measurements of bones in many species of bird, for example, corvids (Tomek and Bocheński 2000).

It had been found previously that if white-capped parrots (*Pionus senilis*) were removed from the nest a few days before they were due to emerge, they emerged prematurely and did not return to the nest. In one clutch of five birds, three came out together but the remaining two younger birds stayed in for a further eight days. For this reason the last radiographic examination was made at 45 days, and when the ulna had stopped growing had to be estimated. The ulna was examined on radiographs made of the birds at 90 days and compared with radiographs from other *Pionus* species and with skeletons from *P fuscus*; these comparisons suggested that the ulna was fully formed by 47 days.

Dusky parrots were used for this study because they were readily available. Over the past 10 years, various *Pionus* species have been fed the same diet and approximately 100 birds have been raised. Some species have been bred for three generations. The rate of growth of the naturally reared parrots was similar to that of hand-reared *Pionus* species (Sweeney 2001). When these birds' sex was determined endoscopically each year, some or all of them had been examined radiographically, and none of them had been found to have any radiographic signs of skeletal deformity.

The fact that isolated parrots can stand and walk has great advantages in a large nest cavity; a baby bird that has been separated from its siblings will walk around until it bumps into them and then resumes its place in the pile, which provides warmth, protection and skeletal support, as well as an 'even chance' at feeding time. This huddling/walking reflex is shared by other groups of altricial birds; it has been observed in raptors (Newton 1978) and some small passerines, such as reed warblers (*Acrocephalus scirpaceus*) (A. Radford, personal communication).

The age at which a young bird can be removed from the parent's care and hand-reared varies, but it is possible from the day it hatches. Younger babies are easier to train to hand-feeding than are older babies. It is very difficult to keep the birds clean. To combat this problem the babies are kept in plastic boxes, which are of various sizes and may be relatively large; they are usually lined with absorbent paper such as kitchen roll. As a hygienic measure, the birds are usually removed from their box for feeding; while they are being fed they often have to be restrained manually, which can force their legs into abnormal positions. As the birds grow they try to get out of their boxes and will frequently use their wings to climb. They rest on their sterna, and in small boxes they lie with their wings hanging over the side. When the birds are half to two-thirds grown they are often placed, as a group, in a large box that allows them to walk about. Young pet parrots are often sold to their new owners before their feathers are fully grown and while they are still being hand-fed. From an early age the young birds respond vigorously to feeding, and to the feeder; it is common for baby birds to be allowed to run around after the feeding-spoon or syringe.

Hand-rearing encourages abnormal physical behaviour in growing parrots that may exacerbate the effects of a deficient diet and encourage the development of skeletal deformity. In some birds with mild signs of juvenile osteodystrophy it is possible that over-exercise is a major factor in the development of their bone deformity.

Their movements can be limited by mimicking their natural nesting conditions as closely as possible: a limited nest area with high, solid sides and a soft floor that moulds to the shape of the body, for example, wood shavings covered with kitchen roll; the presence of siblings, other similar sized parrots, or adequate padding for single birds; subdued lighting between feeds; and considerable care should be taken when moving and feeding the young birds. Until the birds' bones have stopped growing, adequate confinement and the provision of support if there is only a single chick are as important as a correct diet. In *Pionus* species the pelvic limbs are fully formed three-quarters of the way through growth (Fig 14), a stage which can be assessed on the basis of feather formation. Similar treatment could be important in other genera of parrots and limiting their movement until after their bones have stopped growing should help to decrease the risk of tibiotarsal deformity. Ideally, full movement should be prevented until the wing feathers are completely grown, and some of the young birds should be examined radiographically at the end of growth.

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