Growth and morphology of captive female Common Eider *Somateria mollissima* ducklings

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Five female Common Eider ducklings taken under licence from a population at the Isle of May, Firth of Forth, Scotland, were reared from eggs. Weekly measurements were made of the tibiotarsus, ulna, head, ninth primary, body mass, wing and foot area. The body components attained adult size in the following order: tibiotarsus (six weeks), ulna (seven weeks), foot area (eight weeks), body mass and head (nine weeks), wing area and wing loading (ten weeks) and ninth primary (eleven weeks). Paddle index (the ratio of foot area to body mass) remained relatively constant throughout development. Up to and including seven weeks old, body mass could be used as an estimate of age according to the relationship $A = 0.005\ M_B + 0.015$, *where* A = *age (weeks) and* M_B = *body mass (g)* ($R^2 = 0.98$). *'Feathering up' began by the second week and was completed during weeks seven to eight. There was no noticeable trough in the body mass curve when the ducks fledged at nine to 10 weeks.*

Keywords: Growth, Development, Morphology, Eider Duck, Sea Ducks

The Common Eider Duck *Somateria mollissima* is a large-bodied sea duck which is distributed across most of the Arctic, Northern America and Northern Britain. It breeds at latitudes between 44°N and 80°N (Madge & Burn 1988), and the largest British breeding colonies occur at the east coast of Scotland and Northumberland (Owen *et al.* 1986). The species comprises six races *(mollissima, faeroeensis, borealis, dresseri, sedentaria* and *v-nigrum)*, with differing body mass and morphometrics. British and South Norwegian Eider Ducks are of an intermediate type, falling between *S. mollissima mollissima* and *S. mollissima faeroeensis* (Cramp & Simmons 1977).

S. mollissima produces a small brood of large ducklings (Owen & Black 1990). The precocial young leave the nest as soon as they are dry, six to 12 hours after hatching (Mendenhall 1979) and can swim, eat and dive as soon as they reach the water (Steen & Gabrielsen 1986). Post hatch growth rates of ducks are influenced by feeding habits, with dabblers gaining body mass and fledging earlier than diving species (Kear 1970, Lightbody & Ankney 1984). The leg usually develops quickly in waterfowl, as an adaptation for the journey from the nest to the water and subsequent aquatic locomotion (Lack 1968, Kear 1970, Siegfried 1973, Brown & Fredrickson 1983, Leray & Yésou 1989, Bowler 1992), with flight muscles and wings developing more slowly (Sedinger 1986, Düttmann 1993, Bishop *et al.* 1996).

Body growth in the Common Eider duckling has been partly examined by Leray & Yésou (1989), who measured the body mass, culmen, tarsus and 'bent wing' in two captive ducklings for 13 weeks. Body mass in Eider ducklings for the first 10 days post-hatch has also been measured by Swennen (1989). The aims of the present study were to monitor skeletal growth to adulthood in a group of five captive Eider ducklings, and to describe the morphology of the ducks when they attained adult size. All the hatchlings turned out to be female, so this paper may not be applicable (at least quantitatively) to male ducks, as all races of the Eider are sexually dimorphic (Milne 1976). Difference in size between the sexes of another dimorphic species, the Tufted Duck *Aythya fuligula*, arise within the first few weeks of life (Kear 1970), although sexual dimorphism in Lesser Scaup and Canvasback ducklings is 'minimal' until they are around 71 days old (Lightbody & Ankney 1984). There are also likely to be quantitative differences in size between hand-reared and wild birds (Swennen 1989, Bowler 1992, Sedinger 1992) and this should be borne in mind when considering the results presented here.

Method

Twelve Eider duck eggs were collected from a colony on the Isle of May, Firth of Forth, with the permission of Scottish Natural Heritage. Eggs were taken from nests containing four or more eggs, and only one egg was taken from each clutch. Five female birds hatched (sexed by later plumage development) in the laboratory during May and June 1994, but the remaining seven eggs unfortunately failed to hatch. The ducklings were imprinted on the experimenter for ease of handling and reduction of stress. Up to eight hours a day were spent with the birds during the first month of life, and they were taken for a daily walk for the first six weeks. Although Eider ducklings rarely walk far in the field, walking provided them with supplementary exercise and enabled them to habituate to the outdoor compound in which they would eventually live. Initially, the ducklings were housed in an indoor pen of 2.1 x 3.6 m, containing a pool (2.1 x 2.2 m and 0-22 cm deep). A brooder lamp was fitted, but only used by the birds on the first day. Mean indoor temperature was 14.5°C and relative humidity 60% over the six weeks. Lighting was controlled by a time switch that was set to coincide with outside daylight hours.

The ducklings were fed commercial grower's chick crumbs at first, introducing SDS 'Diet A' sinkers during the second week. By the third week, the ducklings were fed 'Diet A' alone and grit was supplied on the bottom of their pool. Their indoor environment was enriched by submerging rubber bungs, mussel shells, pebbles and bricks in their pool and fastening chains and plastic cable ties to the side of their pen (Hawkins 1998).

At six weeks old, the birds had grown too large for the indoor pen and were sufficiently feathered to be kept outdoors. They were moved to an outdoor enclosure of 18m x 7.4 m x 2m high, with an area of grass, an area of gravel and a pond (8.1m x 3.8m, 0.7m deep). The pen was fully enclosed by netting but was not covered. In July 1994, mean temperature was 18°C and mean rainfall was 56.6mm. In August, mean temperature was 15.5°C and rainfall 48.4mm.

Each duckling was weighed and measured on the day of hatching, then at weekly intervals until their morphology had stabilised. Measurements were taken using callipers of the ducklings' tibiotarsus, ulna, head length and ninth primary. The measurements were made by the same observer throughout the study. Wing and foot area were measured by drawing around the fully extended wing or foot and weighing the paper, having first weighed pieces of paper of known area to correlate area with mass. Paddle index and wing loading were calculated according to Raikow (1973); the square root of the area of both wings (or feet) divided by the cube root of the body mass. The hallux was included in the foot area (Raikow 1973). After studies involving the ducks had finished, it would not have been humane to release them into the wild as they had not learned to forage for themselves. However, they were certified fit by a veterinary surgeon and rehomed in a private bird collection.

Means are presented ± 1 S.E., and differences between means were tested using Student's t-tests, at a 5% level of significance. Although complex growth curves are often used to describe increases in body components with age (Ricklefs 1967, 1973, 1983) these are not always applicable to fledging waterfowl (Sedinger 1986, Bishop *et al.* 1996). In the present study, the growth of each variable with time was best quantified using linear ($y = a + bx$), power ($y = a\,x^b$), logarithmic ($y = a + b \ln x$) and exponential ($\ln y = a + bx$) regressions. Only the regression that afforded the most accurate fit for each variable is presented.

Results

Figures 1 to **3** show the mean values of all the variables measured at hatch and thereafter. The power regression of body mass vs. age [M_B (g) = 178.23 $A^{1.04}$, where A = age in weeks] fitted the data best between one and eight weeks (**Table 1**). The increase in mass could also be described by a linear equation between weeks one and seven (M_B (g) = 197.01 A + 7.91) (**Table 1**). The slope of 197 reflects the assimilation rate of the birds, *ie* they were putting on 197 g in body mass per week during this period. All measurements were constant after 14 weeks, when the ducklings were morphologically identical to adult birds (t-test results, in **Table 1**). The measured variables were also checked six months later and had not increased.

Body components attained adult size in the following order: tibiotarsus (six weeks, **Figure 2**), ulna (seven weeks, **Figure 2**), foot area (eight weeks, **Figure 3a**), body mass and head length (nine weeks, **Figures 1a** and **1b**), wing area and wing loading (10 weeks, **Figures 3a** and **3b**) and ninth primary (11 weeks, **Figure 2**). All the birds had begun to fly during their tenth week, when they had attained 97% adult mass.

Ulna length increased exponentially between one and seven weeks, while tibiotarsus length increased logarithmically from one to six weeks (**Table 1**). The limb bones thus reached adult size by seven weeks. The growth of the head and foot area were both described by power curves from one to eight weeks. Wing area, wing loading and the length of the ninth primary all increased logarithmically between six and ten or eleven weeks. The paddle index was not correlated with the age of the birds (**Figure 3b**). It was highest at hatch (0.98 ± 0.03 $cm^{1/2}$ $g^{-1/3}$), lowest at 1 week (0.86 ± 0.01 $cm^{1/2}$ $g^{-1/3}$), and levelled at 0.91 ± 0.01 $cm^{1/2}$ $g^{-1/3}$ in the adult birds.

Up to and including seven weeks, body mass could be used as an estimate of age according to the relationship: A = 0.005 M_B + 0.015, where A = age (weeks) and M_B = body mass (g) (R^2 = 0.98). During the first eight weeks, head length could also be used as an estimate of age. (ln A = (ln H - 4.05) ÷ 0.35; R^2 = 0.98, where A = age (weeks) and H = head length (mm)).

'Feathering up' began by the second week, with emerging contour feathers along the ducklings' flanks (**Figure 4**). By the third week, contour feathers were beginning to grow on the upper tail coverts, and could also be felt on the abdomen. The primaries were erupting by the fourth week, and contour feathers had emerged on the sides of the head, mantle and abdomen. Feathers were present all over the birds except for the rump by the fifth week, and down continued to be shed throughout the following week. By week seven, there was one small patch of fluff remaining near the tail, which was shed over the next few days, and the primaries were well developed.

Discussion

Differential growth of body components

In general, the legs and feet developed to adult size before the head, bill and mass, and the wings were last to develop, which is in agreement with other reports on growth in Anatidae (Kear 1970, Siegfried 1973, Brown & Fredrickson 1983, Sedinger 1986, Bowler 1992, Düttmann 1993). A previous study on two Eider ducklings also concluded that the ability to walk, swim and dive (for food and to escape predation) and the capacity to feed had priority over wing development, so that the duckling could then satisfy the energetic demands of producing adult plumage and gaining muscle mass (Leray & Yésou 1989).

The delayed development of the breast musculature in Canada Goose *Branta canadensis* goslings reduces competition for protein with the other developing organs, thus allowing maximal early development of the legs and gastrointestinal tract for locomotion and feeding (Sedinger 1986). Following growth of the hind limbs in the Barnacle Goose *Branta leucopsis*, there is only a small increase in leg muscle mass between fledging and migration,

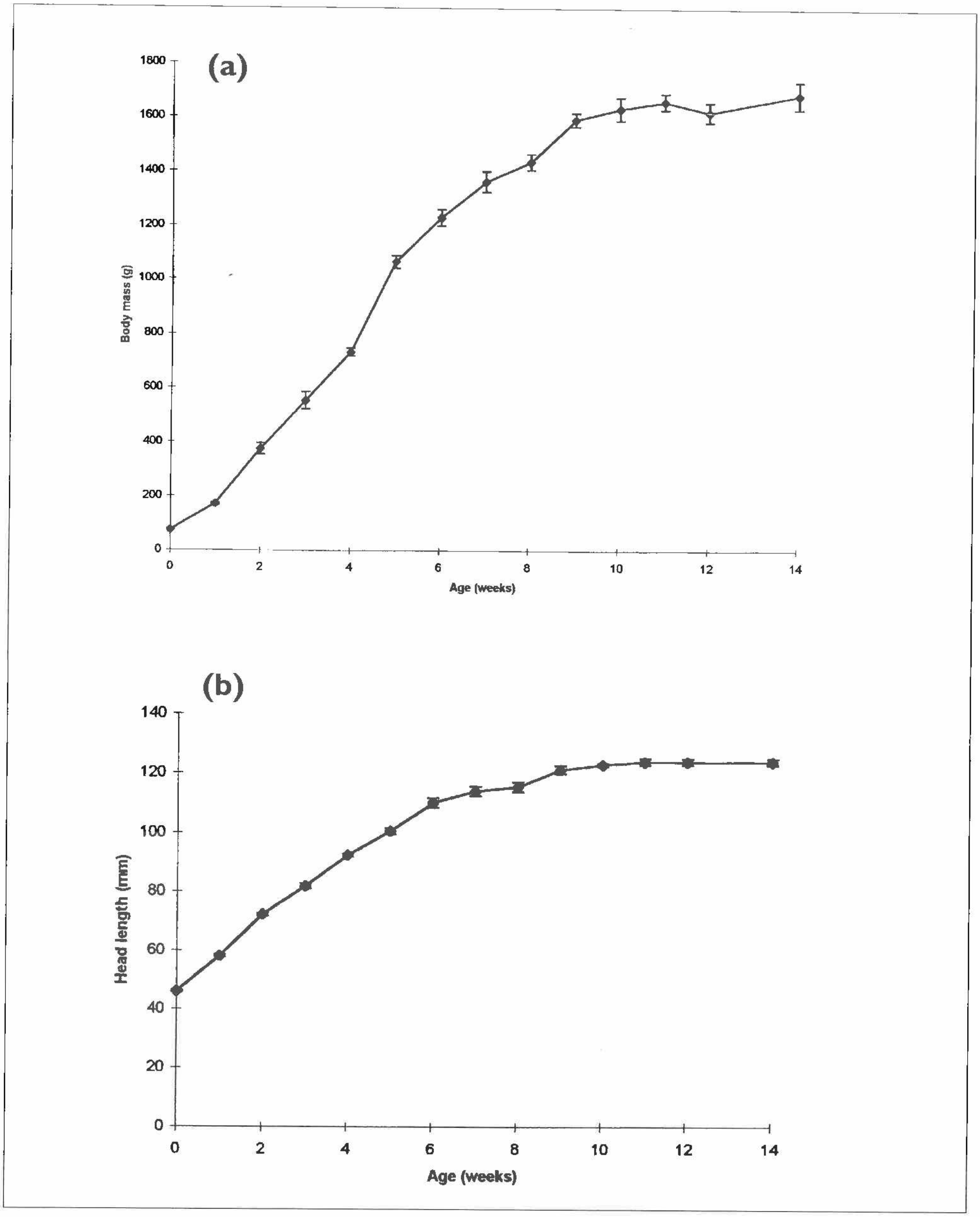

Figure 1. The increase in: (a) body mass; and (b) head length with age in captive female Common Eider ducklings. Vertical bars are ± 1 S.E. (n = 5).

despite a 100% rise in body mass due to lipid deposition and flight muscle hypertrophy. This is indicative of a shift in commitment to flight as the primary form of locomotion (Bishop *et al.* 1996), and a similar shift is likely in juvenile Common Eider, as body mass continues to increase after fledging, but tibiotarsus length does not (**Figures 1** and **2**). In both the captive Eider ducklings and wild Barnacle Goose goslings (Bishop *et al.* 1996), limb bones

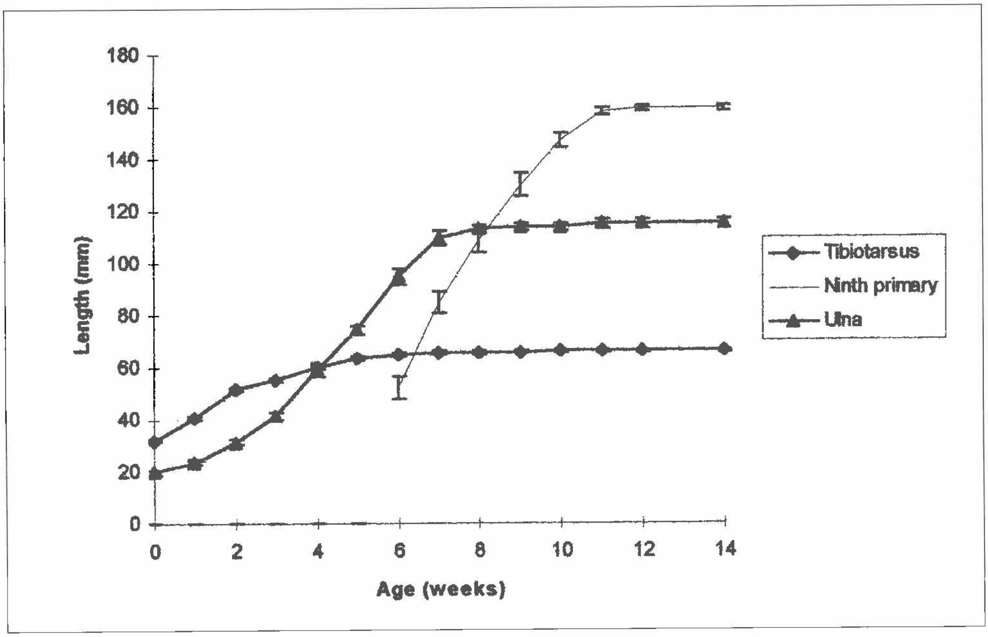

Figure 2. Growth of the tibiotarsus, ninth primary and ulna in captive female Common Eider ducklings. Vertical bars are ± 1 S.E. (n = 5).

had ceased to grow by week seven.

Of the variables measured in the present study, head length approached an asymptote latest and most steeply, so this parameter could possibly be of use in estimating duckling age in the field up to eight weeks (**Table 1**). However, this requires the assumption that wild and hand-reared populations are identical (see below). Sedinger (1986) attempted to use tarsus length in Canada Goose goslings, but this was unsatisfactory after 30 days, as the relationship between tarsus length and age approached an asymptote. It may be easiest to use body mass for Eider ducklings, as this variable may be correlated with age up to seven weeks and is more commonly measured than head length.

Paddle index and wing loading

Although Lack (1974) described ducklings' feet as 'disproportionately large', the paddle index remained relatively constant throughout development. This seems logical, as the growing paddle is likely to increase in area in proportion to the skeleton and leg musculature which has to push it against the water. The adult value for paddle index (0.91) is far greater than the paddle index of 0.79 determined for *S. mollissima* by Raikow (1973). However, it is difficult to interpret the significance of the data presented in Raikow (1973), which was taken from one duck of unknown subspecies, age and sex, at an unstated time of year. The six races of Eider have differing mean body masses (Cramp & Simmons 1977), the sexes are dimorphic (Milne 1976) and the body mass of many birds can vary greatly throughout the year (Milne 1976, Mead 1983, Tuite 1984). Information on the subspecies and sex of an individual, and the date when measurements were made, is therefore of great importance when describing avian morphology.

The small wing area relative to body mass (*ie* high wing loading) found in the Eider is a characteristic of diving ducks, which enables the birds to fly at high speed but necessitates open waters for take-off and landing (Raikow 1973). This high wing loading is not necessarily an

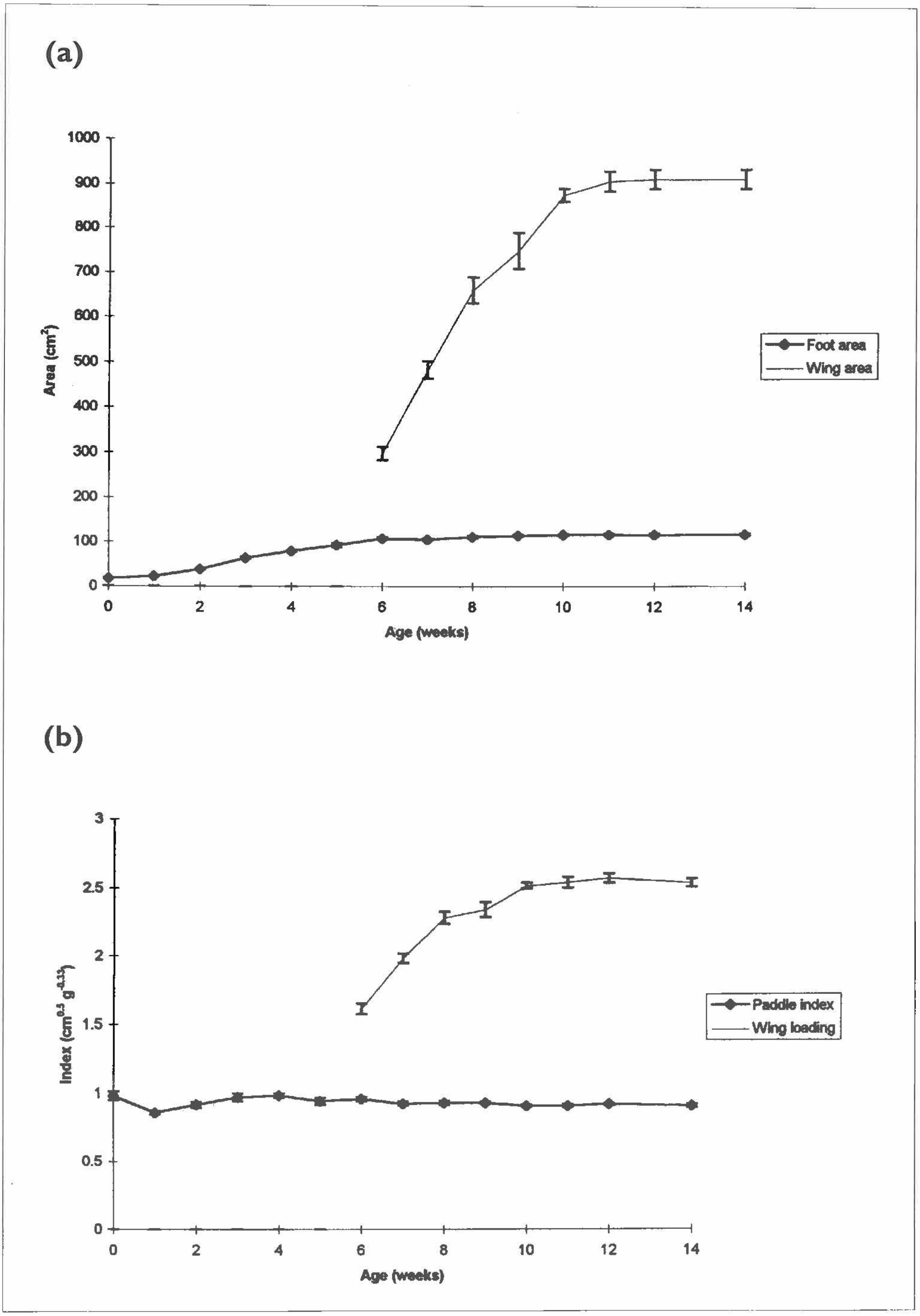

Figure 3. Increase in (a) foot and wing area and (b) paddle index and wing loading with age in captive female Common Eider ducklings. Vertical bars are ± 1 S.E. (n = 5).

Table 1. The relationships between body mass and body components and age in growing captive female Common Eider ducklings.

	Adult size (weeks)	t (one tailed)	*P*	Relationship with age in weeks (A)	R^2	Range of A (weeks)
Tibiotarsus	6	1.97	0.1>*P*>0.05	Length (mm) = 13.65 ln A +40.86	0.97	1 - 6
Ulna	7	1.76	0.1>*P*>0.05	ln Length (mm) = 0.26 A + 2.94	0.97	1 - 7
Foot area	8	0.54	*P*>0.1	Area (cm^2) = 24.11 $A^{0.79}$	0.96	1 - 8
Body mass	9	1.56	0.1>*P*>0.05	Mass (g) = 178.23 $A^{1.04}$	0.98	1 - 8
				Mass (g) = 197.01 A + 7.91	0.98	1 - 7
Head length	9	1.61	0.1>*P*>0.05	Length (mm) = 57.40 $A^{0.35}$	0.98	1 - 8
Wing area	10	1.38	*P*>0.1	Area (cm^2) = 1119.02 ln A-1695.70	0.94	6 - 10
Wing loading	10	0.55	*P*>0.1	Loading ($cm^{1/2}$ $g^{-1/3}$)=1.73 ln A-1.42	0.90	6 - 10
Ninth primary	11	0.63	*P*>0.1	Length (mm) = 184.69 ln A -276.43	0.94	6 - 11

Each component attained adult size at the age shown in the second column of the table and the mean values were compared to adult values using Student's t-tests at a 5% level of significance. The dependent variables were regressed over a range of ages, and the ranges which afforded the most accurate fit (highest coefficient of determination, R^2) are listed in the last column.

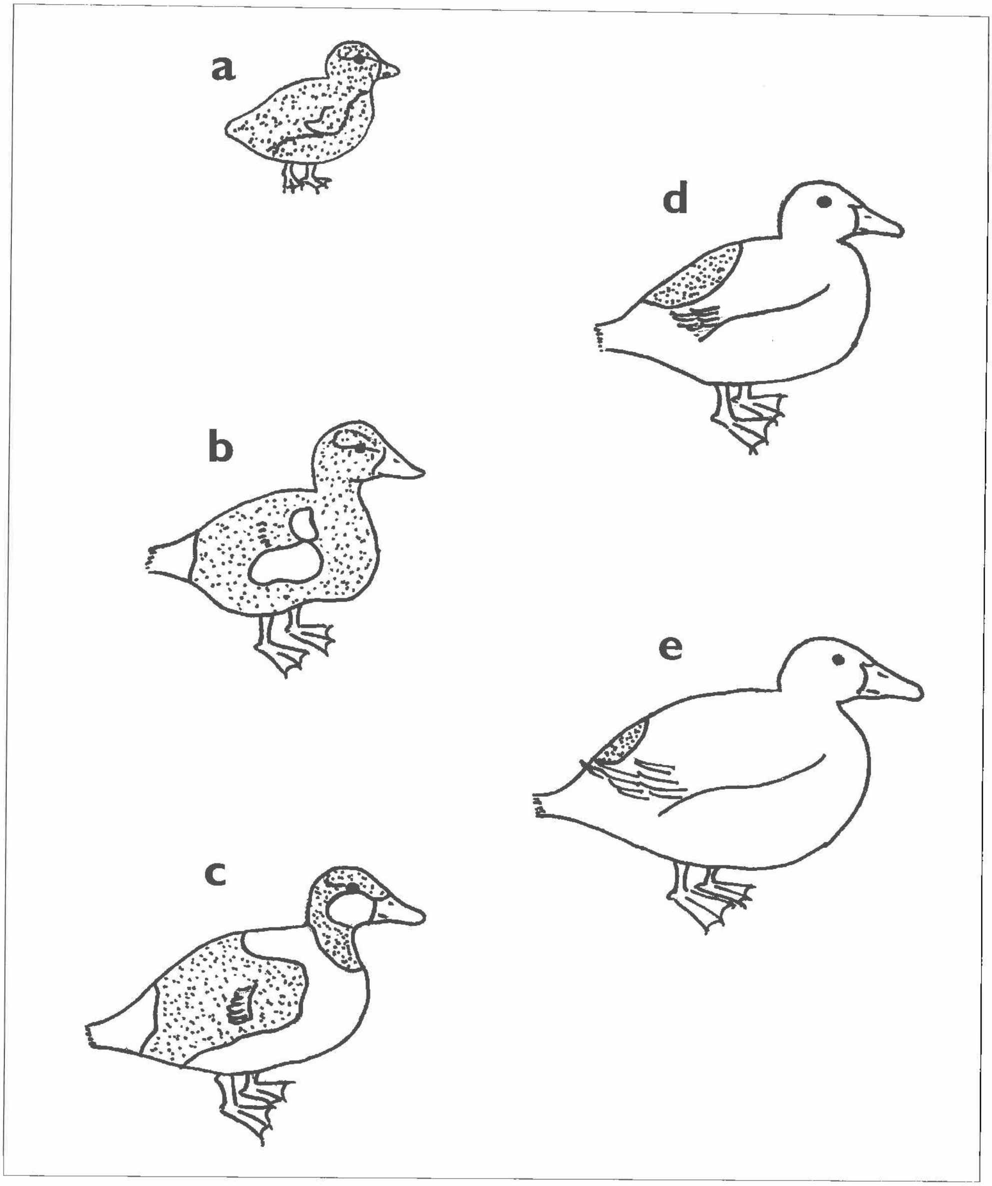

Figure 4. Plumage development of captive female Common Eider ducklings. (a) 0-1 week; covered with down (stippled areas), (b) 2 - 3 weeks; contour feathers emerging on flanks and tail coverts (plain areas), (c) 3 - 4 weeks; primaries erupting, (d) 4 - 5 weeks; most of body feathered apart from rump, (e) 6 - 7 weeks; covering of contour feathers almost complete and primaries well developed.

adaptation to diving, nor does it reflect a particular need for high speed flight; it may be engendered by the relaxation of selective pressure acting against high speed wings - predators are less able to conceal themselves, and the ducks can escape by diving in addition to flight (Lovvorn & Jones 1994).

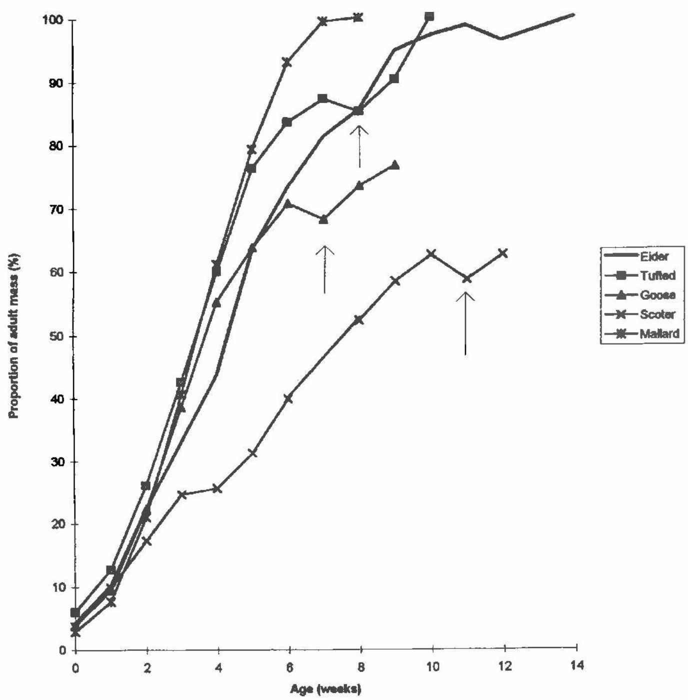

Figure 5. Body mass increase with age in five species of Anatidae and measured in captive populations. The three arrows indicate mass loss associated with fledging in the Tufted Duck, Barnacle Goose and White-winged Scoter.

Fledging and body mass

The data from the present study agree with those of Leray & Yésou (1989) regarding the sequence of 'feathering up', and lack of a noticeable trough in the body mass curve at the point of fledging. A temporary loss of mass during the period when flight first occurs has been noted in captive Tufted Duck (Kear 1970), White-winged Scoter *Melanitta fusca* (Brown & Fredrickson 1983) and Barnacle Goose (Deaton 1998), but not in captive Mallard *Anas platyrhynchos* (Sugden *et al.* 1981). Body mass during development in these birds is compared in **Figure 5**. The Mallard was the first to attain adult body mass (Kear 1970, Lightbody & Ankney 1984), while the White-winged Scoter grew very slowly. The significance of this long growth period was not known, but the authors suggested that it may spread energy demands over a long period in a niche where energy is not readily available and the cost of foraging is high.

The fledging age of 10 weeks for the Eiders in the present study was at the midpoint of the age range of 65 to 75 days quoted for wild Eider ducklings by Ogilvie (1975), by which time the skeleton of the captive ducks had attained adult size. In contrast, Tufted Duck ducklings could make short flights at seven weeks, before the wings, tarsus and head were fully grown (Kear 1970), which could be related to a greater risk of predation. The trough in body mass at fledging may also be an adaptation to enable the Tufted ducklings to fly earlier by reducing wing loading. Many adult

Anseriformes lose body mass during the flightless period of the moult, even though food may be abundant (Owen & Black 1990). Such a mass loss, which reduces the flightless period, may not be necessary in the fledging Eider duckling, as they are relatively safer at sea. This is also suggested by the fact that adult female Eider ducks gain mass during moult at sea, while males 'lose only a small amount' (Milne 1976).

Captive and wild populations

A possible problem with physiological and morphological studies of hand-reared birds is that they may not be identical to wild populations. Growth rates are ultimately under genetic control, as they are the result of natural selection, but are also strongly influenced by environmental factors (Kear 1970, Brown & Fredrickson 1983, Swennen 1989, Bowler 1992, Sedinger 1992). Waterfowl growth rates are often submaximal in the wild, such that most species grow faster in captivity (review in Sedinger 1992) or where supplementary food is provided (Swennen 1989, Austin & Serie 1994). Swennen (1989) reported that hand-reared Eider ducklings provided with commercial chicken pellets put on more mass than those given live marine invertebrates in trays for the first nine days but not on the tenth and final day on which the birds were weighed (no statistics presented). However, there may have been a behavioural explanation for this, as it took several days for the ducklings to learn how to catch the small crustaceans and polychaetes provided for them (Swennen 1989).

Kear (1970) found that wild, 10 week old Tufted Ducks were heavier than her hand-reared birds by 2% in males and 5% in females. When mean body mass and tibiotarsus length measured from wild Barnacle Goose goslings (Bishop *et al.* 1996) at one, three and five weeks, were compared with data taken from hand-reared goslings (Deaton 1998), the captive birds were significantly larger and heavier at three and five weeks old. However, Sedinger (1986) found only a small number of differences (with no consistent pattern) in measurements taken from imprinted and wild Canada Geese.

Overall, mean measurements taken from hand-reared birds are likely to be larger than those obtained from wild birds, and variation around the means is also likely to be less in captive birds. This is due to a number of factors including uniform environmental conditions, *ad lib* feeding regimes (Austin & Serie 1994), reduced exercise and thermo-regulatory requirements (Bowler 1992, Sedinger 1992), and, in the case of sea ducks, access to fresh water (Swennen 1989). Although the ducklings in the present study were moved outside as soon as possible and made to dive for their food, it is possible that they were larger than wild Eiders. However, measuring captive animals is the only method which guarantees that data will be obtained from the same individuals and at the required intervals.

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