

## Relationship Between Total Body Electrical Conductivity and Lean Mass in Wild Captive Dunlins *Calidris alpina*

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**Abstract.** The use of total body electrical conductivity (TOBEC) to measure the body composition of live birds has progressed from the use of cross-species relationships to the use of calibrations based on individual species. The present investigation showed that calibrations can differ significantly even within a species when there are differences in organ size. This means that care should be taken when applying the technique to birds that show substantial changes in organ size in the field e.g. long distance migrants.

**Key word:** Dunlin, TOBEC.

### Introduction

Total body electrical conductivity (TOBEC) has become a popular technique among ornithologists for estimating lipid reserves in birds (e.g. Asch & Roby 1995; Bachman & Widemo 1999). The method was developed in the early 1970's and has been widely used in animal production and medicine as well as by ecologists. Its use for measuring the body composition of live birds and mammals was pioneered by Walsberg (1988), who derived a single calibration equation based on 15 species of birds. Scott, *et al.* (1991) found that calibration equations differed significantly in four different species of wading birds. In a study of waders, involving both calibration and test samples of four species, Lyons & Haig (1995) found that TOBEC was an efficient predictor of lean mass, but not of lipid mass and advised to use a predictive equation derived from the species under investigation.

The TOBEC method has been subject to a number of criticisms. First of all, care is required to ensure that a chamber of the right size is used (Asch & Roby 1995; Golet & Irons

1999), that the subjects are consistently positioned within it (Walsberg 1988), that subject do not differ in shape (Robin *et al.*, 2002), are not contaminated with water, and the temperature does not change (Scott *et al.*, 1991). Even when all these factors are properly controlled, TOBEC may be no more accurate than morphometric methods when estimating the fat content of small birds and mammals (Wirsing *et al.*, 2002; Parker & Krockenberger 2002), or only marginally so (Lyons & Haig 1995; Purvis *et al.* 1999).

The present investigation describes a situation in which the calibration was found to differ significantly even within a species; as a result of keeping a sample of birds in captivity for a period of two years, during which time significant changes in organ size occurred.

### Materials and Methods

Using the same instrument and methodology as Scott *et al.*, (1991) in the same laboratory, I measured the TOBEC indices of eleven individual dunlins that had been housed in captivity for 23-24 months. I compared these with the dunlin measured by Scott *et al.*, (1991).

Any differences in the calibration must therefore have been due either to differences in the birds as a consequence of laboratory confinement, or to unidentified differences in procedure. There were none of the latter to the best of our knowledge. The measurement protocol was the same, the cylindrical chamber in which the birds were held was the same (385 mm long and 75 mm in diameter) and the birds were restrained by the same plastic jacket.

After measurement, the birds were killed and the left pectoral muscle block (pectoralis major and supracoracoideus), stomach, liver, intestine and heart were dissected out. The birds were then sexed by gonadal inspection, and the measurements of intestines and four skeletal measurements were taken to the nearest 0.1 mm using a vernier callipers. A further sample of 11 wild birds (captured under licence at the same time of year as the captives) was measured similarly.

The carcass and organs were weighed and each was dried to a constant mass in a vacuum oven at 40 °C. Once dry, the lipid from each carcass and organs was extracted using a Soxhlet apparatus with petroleum ether as solvent. After all the lipid had been extracted, the carcasses and the organs were dried once again to a constant mass in a vacuum oven at 40 °C. The total lean dry mass of the carcass was calculated and subtracted from the total dry body mass to obtain the lipid mass. Lipid mass was subtracted from live body mass to give total mass.

Following Siegal & Castellán (1988) runs tests were performed to determine whether the relationship between total lean mass and TOBEC index was significantly non-linear or not. Analysis of covariance (ANCOVA) was used to determine whether regression lines differed significantly in the two groups of birds, following Quinn & Keough (2002). The tests were carried out using Minitab 12.2. Two-tailed Student's *t*-test were used to compare the organ weights of wild and captive birds.

## Results

There was no departure from linearity in the relationship between total lean mass and TOBEC index in captive or wild birds (run tests,  $P > 0.500$  in both cases). There was no significant difference in the slopes of the regression lines in the two groups ( $F_{1,18} = 0.77$ ,  $P > 0.200$ ). When a common slope was forced, however, there was a highly significant difference in the elevation of the regression lines ( $F_{1,17} = 21.35$ ,  $P < 0.001$ ). The regressions explained 68% of the variance in wild birds and 87% in captives.

The captive birds gave TOBEC readings that were about 7 units (at least 20%) higher than wild birds of the same lean mass (Fig. 1). This means that if Scott *et al.* (1991) formula for wild birds were applied to captives it would overestimate their lean mass by about 10%. This would in turn have led to calculations that grossly underestimated their lipid content (giving negative values in several cases). The mean  $\pm$  SE of the error in the lipid mass calculated from the formula for captives was only  $1.6 \pm 0.01\%$ . Lyons & Haig's (1995) dunlin calibration line was markedly steeper and more elevated than either of the lines in Fig. 1, but was obtained on a different scanner, using a

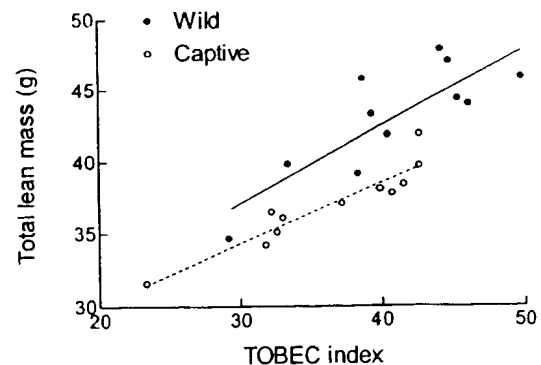


Fig 1. Relationship between total lean mass and TOBEC index in wild and captive Dunlins. Completely separate fitted regression lines are shown, to enable their slopes to be compared, even though they differed significantly in elevation alone (see text).

**Table 1.** Body composition (mean  $\pm$  SE) of wild and captive dunlins.

Component	Wild	Captive
Body mass (g)		44.2 $\pm$ 2.1
Total lean mass (g)		37.0 $\pm$ 0.8
Lipid mass (g)		7.2 $\pm$ 1.5
Water content (%)		66.2 $\pm$ 0.4
TOBEC index		36.1 $\pm$ 1.8
Gut dry mass (g)	0.74 $\pm$ 0.07	0.29 $\pm$ 0.01
Intestine length (cm)	31.1 $\pm$ 1.2	22.2 $\pm$ 0.8
Liver dry mass (g)	0.51 $\pm$ 0.04	0.33 $\pm$ 0.02
Heart dry mass (g)	0.24 $\pm$ 0.02	0.17 $\pm$ 0.01

different protocol.

Our captive birds differed significantly from wild birds in several respects (Table 1). Their intestines were 29% shorter ( $t_{20} = 6.3$ ,  $P < 0.0001$ ). Their guts were 61% lighter ( $t_{20} = 6.3$ ,  $P < 0.0001$ ), and their hearts were 29% lighter ( $t_{20} = 3.3$ ,  $P = 0.0059$ ). Their pectoral muscle masses did not differ significantly. These differences may have resulted in differences in both body shape and lipid distribution. Both factors were reported to affect TOBEC readings (Robin *et al.* 2002; Unangst & Merkley 2002). The reduction in the size of the gut and other organs of our Dunlins were similar to those recorded in captive waders by Piersma (1994), Mitchell (1996) and Selman (1998).

## Discussion

If the differences reported here were restricted to birds kept in captivity, this would merely require that separate TOBEC calibrations be carried out in order to measure the lipid masses of such birds. However, the changes in body composition of our captive Dunlins were similar in type to those recorded in Knots and Bar-tailed Godwits at various stages of migratory fattening in the field by Piersma, *et al.*, (1993) and Landys-Cianelli *et al.*, (2003). These authors found that shorebirds arrived at migratory fattening sites with a reduced gut mass. The gut (gizzard and intestine) hypertrophied as the birds began to

feed and fatten, before reducing in size again prior to departure. For example, in Bar-tailed Godwits, the guts of newly arrived birds were 22% lighter, the livers 18% lighter and hearts 12% lighter (Landys-Cianelli *et al.* 2003). Although these differences were only half as great as those observed in our captive birds, the risk clearly exists that the TOBEC calibrations might differ.

Under such circumstances, care should be taken to ensure that the birds in a calibration sample are representative of the birds for which it is desired to measure the body composition. The use of a calibration based on newly arrived migrants to estimate the body composition of those about to depart may significantly overestimate their lipid masses and consequently risks exaggerating their potential migratory ranges.

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## العلاقة بين التوصيل الكهربائي الكلي للجسم و الهبر يختلف في الطيور الطليقة عن المأسورة

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**الملخص :** تطور استخدام التوصيل الكهربائي للجسم الكلي في قياس مكونات أجسام الطيور الحية من استخدام العلاقات بين الأنواع المختلفة إلى استخدام المعايير لكل فرد من هذه الأنواع. هذا البحث أوضح أن المعايير قد تختلف حتى في أفراد النوع الواحد عندما يكون هناك اختلافات في حجم الأعضاء الداخلية. هذا يعني أنه يجب توخي الحذر عند استخدام هذه التقنية في الطيور الطليقة التي تظهر اختلافات كبيرة في أحجام أعضائها الداخلية كما يحدث في الطيور المهاجرة لمسافات طويلة على سبيل المثال.