Body mass and Abdominal Profile Index in captive Hawaiian Geese

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It is often not practical or desirable to collect birds to assess their body mass. The Abdominal Profile Index (API), developed by Owen (1981), is an alternative method that can be used without capturing or collecting animals. The weight and API scores (from 0 - 4 points) of captive Hawaiian Geese *Branta sandvicensis* were recorded every two weeks for a year. API was significantly correlated with mass and mirrored even minor changes in this parameter. The corresponding mass change per half point on the AP index was 85g for females and 115g for males during the non-breeding season. This is equivalent to 4.0 % of the female and 4.8 % of the male mean body mass during the non-breeding season.

Key Words: Abdominal Profile Index, API, body mass, *Branta sandvicensis*, endangered species, England, goose studies, Hawaiian Goose, mass variation

The quantification of an animal's likelihood of surviving and reproducing is a common goal for animal ecologists. This likelihood is often measured in terms of an estimate of the animal's health or condition. There are a number of indirect methods available for estimating body condition, including the assessment of energy reserves such as mass (by weighing, Ebbinge, 1989), protein reserves (via ultrasound scans, Sears 1988), lipids (with total body electrical conductivity, Roby 1991) and/or steroids and nutrients through blood or tissue sampling (eg Butler, 1991). Weighing body mass is probably the most widespread and most easily accomplished indirect method. A common problem with these methods is that the animals have to be caught and-

handled. This can have a temporary negative effect on overall condition (eg Westneat *et al.* 1986; Williams *et al.* 1993).

Owen (1981) introduced an alternative method to determine body mass in geese without repeated interference with the animal: the Abdominal Profile Index (API). This index is thought to reflect the amount of accumulated abdominal fat. Since abdominal fat is a good indicator of overall body fat (Thomas & Mainguy 1983), Owen argued that the API probably gives a useful estimate of the overall body mass of individual geese. The method allows repeated assessments of individually marked birds, so that variation in 'fatness' can be tracked on a temporal and spatial scale. The non-invasive nature of this method makes it particularly useful for situations when direct assessment of body mass, fat and condition is not desirable or possible.

Over the last 15 years the usefulness of the API has been shown in many aspects of waterfowl ecology, for instance in describing the profitability of foraging within a season (Owen 1981; van Eerden *et al.* 1991), between years (Owen & Black 1989; Bowler 1994) and habitats (Black *et al.* 1991; Mayes 1991; Boyd & Fox 1995), in different social classes (Black & Owen 1989) and in relation to specific energetic requirements (Loonen *et al.* 1991) or examining other aspects with respect to site management (Madsen 1994/5). However, one of the reasons why the API has been questioned by some workers, is the fact that it is a subjective assessment, not a direct measurement of body mass.

In spite of the method's widespread use, the assumed correlation between API and body mass has not been verified. The first aim of this study was to establish a correlation between API and body mass throughout the annual cycle in a goose. The second goal was to describe the nature of the correlation, thus providing a stepwise method for fieldworkers to calculate mass (grams) from API data collected in the wild. The study was carried out on a captive flock of Hawaiian Geese (or Nene), where size data were available, and the nature of which made it possible to obtain mass measurements without handling the study birds. Assuming that the data collected in captivity are representative of the species, the method for converting API scores into grams described here can be used as a ground rule for calculating body mass from API in the wild.

Methods

The captive flock of Hawaiian Geese at The Wildfowl & Wetlands Trust, Slimbridge, Gloucestershire, UK, consisted of about 200 individually marked birds. The geese roamed a 44 ha predator-proof enclosure and spent 10.3% of their day eating grain and 10.4% grazing grass lawns *Lolium sp.* and *Poa sp.* (Black *et al.* 1993; unpubl. data). At the beginning and middle of each month from November 1992 to October 1993

the geese were weighed to the nearest 10g by coaxing individuals onto a portable scale (Marsden Digital Weighing Scale, model DI-10) using grain or bread as bait. The API was taken, without handling the birds, by examining the full lateral view of the goose in a head-down posture, making sure that the body of the goose was not tilted downward (Owen 1981). API scores were always taken before weighing to avoid bias.

Owen (1981) describes the four point index as straight (1), convex (2), rounded (3) and sagging (4). Another major point was introduced where concave abdomens were attributed with a (0). Abdominal profiles between these five major points were given an intermediate minor point, resulting in a total of nine index points (**Figure 1**). In this study and those conducted in Helgeland, Norway (Black *et al.* 1991; Prop & Black, in press), where the birds were close and seen on a near daily-basis, it was possible to detect changes in profile development on an even finer scale, with 10 intermediate points between each of the major index points (0 to 4).

Profiles were also independently taken by two observers within two days of the mass measurement. In the analysis, the mean of the ratings by both observers was used. In 90% of the cases the difference between APIs scored by two observers was 0.6 and a Spearman rank test of bi-monthly means for both observers was significant in both sexes (r_S=0.63, P<0.02, n=16 for females; r_S=0.776, P<0.001, n=16 for males). It was not always pos-

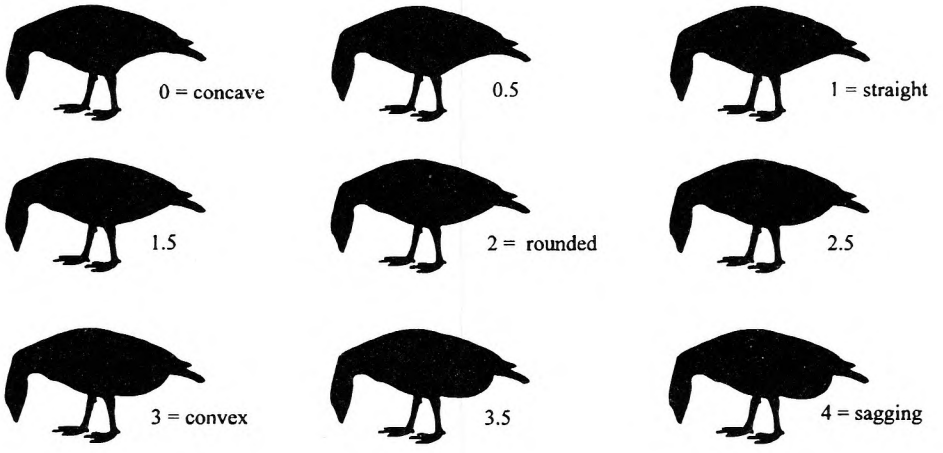

Figure 1. The nine main Abdominal Profile Index scores for Hawaiian Geese (after owen 1981).

sible for observers to take the API on the same day (within two days of each other) which might account for some of the differences in scoring.

Size was determined by Principal Component Analysis using the first principal component (PC1) comprised of tarsus and skull length (Rising & Somers 1989; Freeman & Jackson 1990). To correlate mass and API independent of body size, in a first step mass was regressed against size for each measurement taken. In a second step the resulting residual mass was regressed against the corresponding API value, giving a correlation between mass and API that was corrected for individual size. This regression allowed attribution of a residual mass value to each API score. To achieve a 'realistic' mass measurement, the mass of an 'average' Slimbridge Hawaiian goose was added to the equation. The 'average' male and female mass was calculated by regressing the mean annual mass (for each individual) against size (of each individual) for each sex.

The resulting equation for converting API values into mass thus consisted of two regression terms added together; the first describing the regression between residual mass and API, and the second describing the regression between the 'average' mass and size of individuals in the study population.

Differences in response over time were fitted in general linear models with mass as the response variable, time as factor and API as covariant.

Results

The mean API and mean mass (corrected for size) for each two-week interval were highly positively correlated for both sexes (r_S=0.755, P<0.001, n=24 for females; r_S=0.611, P<0.002, n=24 for males). The API appears to match even minor changes in mass on a temporal scale (see **Figure 2**). Mass and API were also significantly correlated in individuals for both males (binomial test, 12 of 14, P<0.01 (11), P<0.05 (1)] and females (binomial test, 13 of 14, P<0.001).

Due to the great variation in body mass associated with reproductive activities, the data were divided into breeding (January to May) and non-breeding seasons (June to December) for both sexes. At Slimbridge, female Hawaiian Geese increased in mass in January in preparation for nesting; first eggs were laid at the beginning of February, and last clutches were completed around mid-March (Kear & Berger, 1980). The hatching period lasted from mid-March to mid-April. During the breeding season male mass peaked approximately two weeks before that of females and changes were not as pronounced as those in females, but the changes were different from changes in male mass in the non-breeding season (analysis of covariance; F_1=9.26; P<0.002; r^2=0.404). The relationship between mass and API was linear for males and females during the non-breeding season (June to December) with no differences between

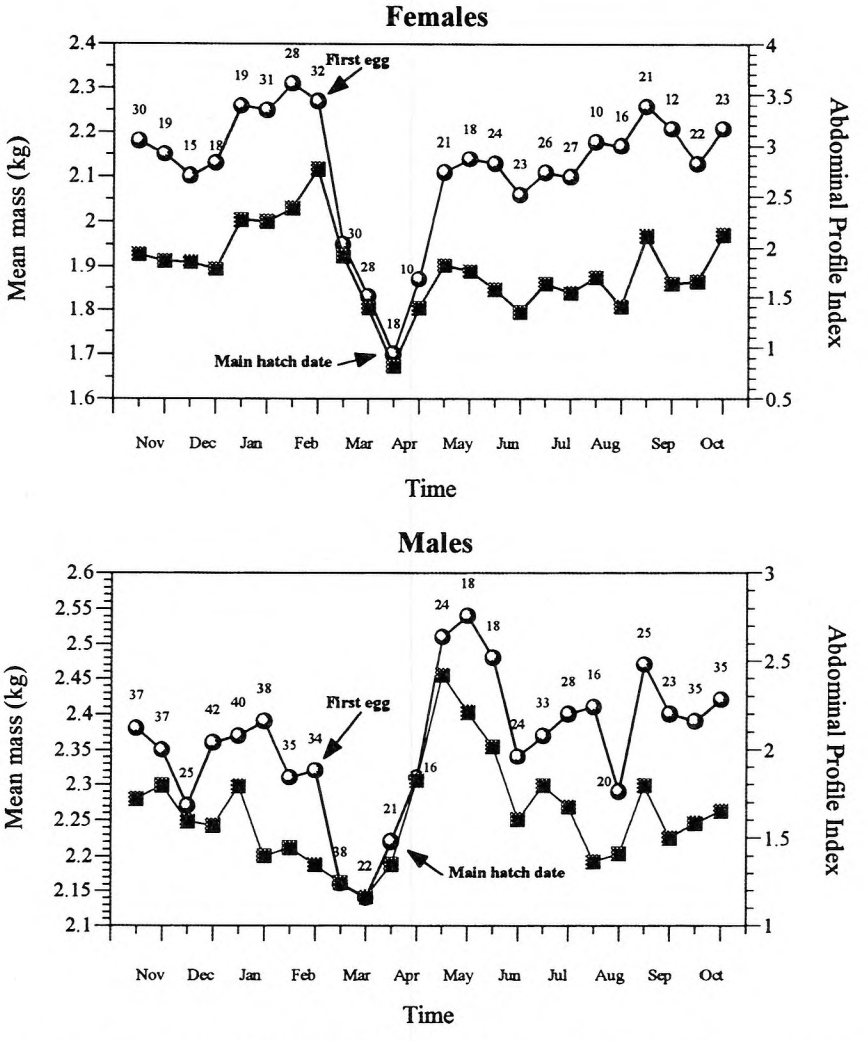

Figure 2. Mean mass (circles) and mean API (squares) for each half-month for female and male Hawaiian Geese at Slimbridge (sample sizes are indicated above each point and apply to both mass and API).

months (**Figure 3**). During the breeding season the relationship was quadratic for females and the curve levelled out at API score of four. This asymptote means there was very little actual gain in mass between scores 3.5 and 4. Although the relationship for males remained linear during the breeding season, slopes differed between the first two months (January and February) and the rest of the breeding season (March to May) (analysis of covariance; F_1=29.28; P<0.0001; r^2=0.616).

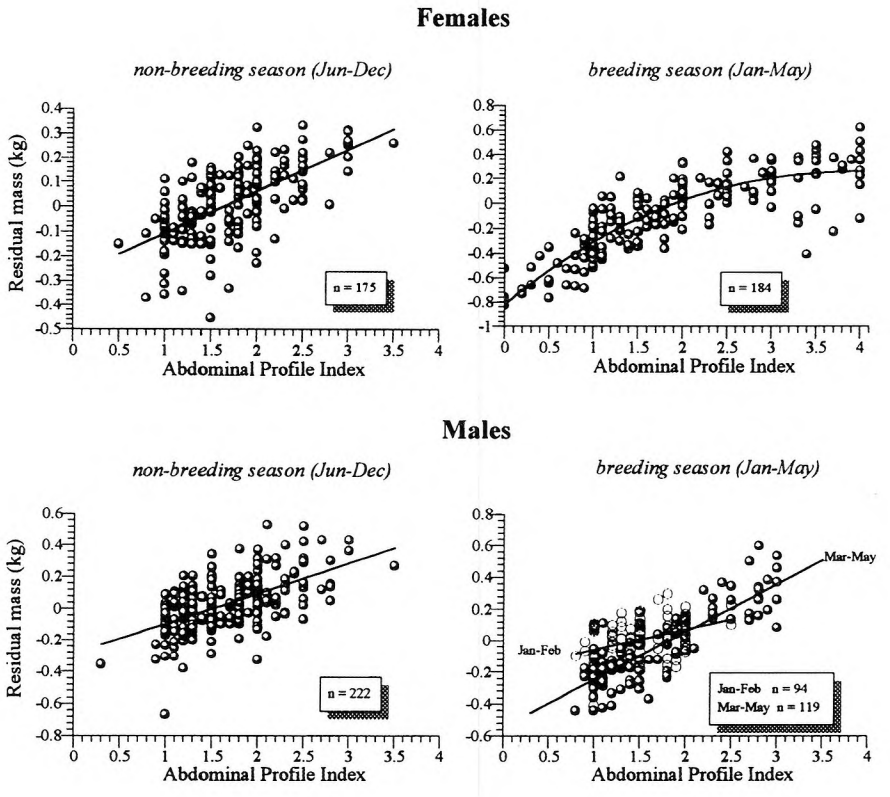

Figure 3. Corelation between API and residual mass (ie mass corrected for size) for females and males. Individual birds can be represented more than once in each graph.

The change in mass (g) associated with each of the nine minor and major unit changes in the API scale were estimated for both sexes at different times of the year (**Table 1**) using an equation consisting of two terms: one describing the regression between residual mass (mass corrected for size) and API, and added to this, a second term describing the regression between the 'average' mass and size of individuals in the study population (see Methods). This allows the calculation of mass from known profiles and includes a general size correction.

The calculated average gain in mass for males was 115g per 0.5 API step and 85g for females in the non-breeding season (**Table 2**). During the different parts of the breeding season the calculated mass gain per API step covered a wide range in both sexes; eg

Table 1. Expressions used to calculate body mass from API scores for both sexes of Hawaiian Geese using the formula: Total mass=(residual mass regressed against API)+(mean annual mass regressed against size); eg for average sized males and the API score of 2.5 during the non-breeding season: Mass=(0.0266 x 126.51 - 1.04)+(0.23 x 2.5-0.367)=2.53kg. Standard errors for the regression coefficients are shown in parentheses.

	Males		Females	
Time of year	Residual Mass regressed against API	Mean Annual mass regressed against size	Residual Mass regressed against API	Mean Annual mass regressed against size
Non-breeding	0.23xAPI-0.367 (±0.006)	0.0266xsize[a]-1.04 (±0.008)	0.172xAPI-0.286 (±0.010)	0.0241xsize[a]-0.704 (±0.011)
	(±0.008)	(±0.093)	(±0.013)	(±0.102)
Breeding				
Jan-Feb	0.112xAPI-0.161	0.0266xsize[a]-1.04	0.0769xAPI^2+0.572xAPI-0.807	0.0241xsize[a]-0.704
(pre-laying)	(±0.017) (±0.021)	(±0.008) (±0.093)	(±0.008) (±0.016) (±0.016)	(±0.011) (±0.102)
March	0.307xAPI-0.555	0.0266xsize[a]-1.04	0.0769xAPI^2+0.572xAPI-0.807	-0.003xsize+2.26
(incubation)	(±0.012) (±0.016)	(±0.008) (±0.093)	(±0.008) (±0.016) (±0.016	(±0.022) (±0.15)
April	0.307xAPI-0.555	0.0266xsize[a]-1.04	0.0769xAPI^2+0.572xAPI-0.807	-0.0481xsize+7.55
(hatching)	(±0.012) (±0.016)	(±0.008) (±0.093)	(±0.008) (±0.016) (±0.016	(±0.031) (±0.301)
May	0.307xAPI-0.555	0.0266xsize[a]-1.04	0.0769xAPI^2+0.572xAPI-0.807	-0.0068xsize+2.95
(post-hatching)	(±0.012) (±0.016)	(±0.008) (±0.093)	(±0.008) (±0.016) (±0.016	(±0.027) (±0.247)

[a] Average size of Slimbridge Hawaiian Geese: PCI = 126.51 ± 0.098 (n=88) for males
PCI = 119.49 ± 0.11 (n=62) for females

in females from 30g (3 to 3.5 in March) to 380g (0.5 to 1 in March).

In males the general relationship between mass and size ('average goose') was linear and remained the same throughout the year (small males weighed less than large males). The same regression term was therefore used to describe the 'average' male in both seasons (**Table 1**). In females, the relationship between mass and size varied significantly in March, April and May (Zillich & Black, unpublished data) from the rest of the year, necessitating separate regression analyses for these months to describe the 'average' female (**Table 1**).

Discussion

This study supports Owen's original assessment that the API can be a useful and accurate tool to monitor mass

Table 2. Estimated body mass (kg) for nine API scores for Hawaiian Geese raised at Slimbridge. Scores/masses that are unlikely to occur in the field are shown in parentheses.

	Males			Females				
	Non-	Breeding		Non-	Breeding			
API	breeding	Jan-Feb	Mar-May	breeding	Jan-Feb	March	April	May
0	[1.95]	2.16	1.77	[1.89]	[1.37]	1.09	1.00	1.33
0.5	[2.06]	2.19	1.92	[1.98]	[1.64]	1.36	1.30	1.62
1	2.18	2.27	2.08	2.06	1.86	1.74	1.64	1.83
1.5	2.29	2.34	2.23	2.15	2.05	1.78	1.68	2.02
2	2.41	2.41	2.38	2.23	2.21	1.93	1.83	2.17
2.5	2.53	2.47	2.54	2.32	2.31	2.04	1.94	2.28
3	2.64	2.53	2.69	2.41	2.39	2.12	2.02	2.35
3.5	[2.75]	[2.59]	[2.84]	[2.49]	2.43	2.15	[2.06]	[2.39]
4	[2.87]	[2.65]	[3.00]	[2.58]	2.43	2.15	[2.05]	[2.39]

variation. Although the sampling error with the API technique is greater than with actual body mass measurements, the API mirrors variations in body mass closely and it is also suitable for assessing mass change over shorter periods of time (eg several days). The close correlation between API and mass is evident on both the population/flock level and the individual level.

A possible explanation for the quadratic relationship between mass and API for breeding females is that this was the only time that the full range of API scores (0 to 4) was observed. API scores of males throughout the year and females during the non-breeding season were normally limited to the scale between one and three.

The fact that there was little or no gain in mass from API score 3.5 to 4 may be due to the formation of the eggshell in the oviduct (between 12 to 18 hours in birds in general). The data supports the prediction that the increase in abdominal profile in females is not only due to accumulation of fat but also to the enlargement of the reproductive tract (Owen 1981; Boyd & Fox 1995). Ankney (1984) reported that ovary and oviduct mass in Brant declined by 92% and 55% respectively from prelaying to postlaying. In the study, one female was classed as API 4

in the morning and, after laying an egg, as API 2 in the afternoon. This suggested that the increase in API higher than three indicated the laying status of a goose rather than an increase in body mass, which would also explain the fact that males never seemed to acquire an API higher than three. It should also be considered that an API larger than three would only occur prior to the first two eggs a Hawaiian Goose lays. After that the weight loss was reflected in the API and a sagging abdominal profile was seen only immediately prior to egg laying.

It remains unclear why male Hawaiian Geese gain significantly less mass per API category during the first two months of the breeding season (pre-laying and laying) than the last three months. One possible factor contributing to this phenomenon may be a change in the body composition during this time. It has been shown that the body composition of geese changes during the different phases of their annual cycle (eg Ankney 1984; Gauthier *et al.* 1992). Generally the amount of stored fat varies more than the amount of protein and/or muscle (Hobaugh 1985; Gauthier 1992), although changes in both might be equally important during the breeding season (Raveling 1979). Further research is needed to determine the correlation among abdominal fat, total fat and API.

The API can be applied to other species if variances in body shape and ecology (migration, short breeding season etc.) are taken into account. A study on Barnacle Geese (Prop & Black 1998) suggests that the increase in mass per half point on the AP index in other species of geese is similar to that of the Hawaiian Goose. Female Barnacle Geese gained on average 85g of body mass per half point (20g per day, increase of 3.5 steps in 15 days) when feeding on agricultural land. These conditions could be compared to the ad. lib. feeding conditions in the study population.

In conclusion, it is problematic to obtain an assessment of mass, and thus indirectly of condition, in wild Hawaiian Geese because of the small number of birds and difficult geographical features of their habitat. With the API method, birds do not have to be approached and can be assessed from long distances. It is a useful tool to provide information for instance about reproductive status of individuals and the general 'condition' of a population. This information can be vital to determine the management of both the species and their habitat.

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