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Sexing Monomorphic Birds by Vent Measurements

P. DEE BOERSMA^{1,2} AND EMILY M. DAVIES¹

¹Institute for Environmental Studies and ²Department of Zoology, University of Washington, Seattle, Washington 98195 USA

Sexing monomorphic birds in the field historically has presented serious difficulties to biologists. The technique of sexing birds by examination of minute differences in cloacae is well known among professional aviculturalists (Stromberg 1977) and has been proposed for wild birds (Mason 1938, Hochbaum 1942, Wolfson 1952, Samour et al. 1983). The distinguishing characteristics of cloacae differ among species, which affects the ease and reliability of discrimination (Stromberg 1977); many of these characteristics are also difficult, or impossible, to find under poor field conditions.

Early in the season female vents dilate to allow the passage of the disproportionately large egg. Serventy (1956) described a simple method to sex birds based on a comparative examination of birds' external cloacae, or vents. The studies of Cole (1913), Serventy (1956), and Richdale (1957) did not quantify the accuracy and reliability of the method, however, nor did they address its general applicability. Serventy (1956) and Richdale (1957) identified the limitations inherent in the technique: only females that had recently laid eggs, and their known mates, could be sexed by examining their vents.

We measured the vents of Fork-tailed Storm-Petrels (*Oceanodroma furcata*) on the Barren Islands, Alaska, in 1981-1983; American Coots (*Fulica americana*) at Turnbull National Wildlife Refuge, Washington, in 1982; and Magellanic Penguins (*Spheniscus magellanicus*) at Punta Tombo, Argentina, in 1983 and 1984. These species were selected incidentally during other research projects.

Birds were measured during their breeding seasons and, except for a sample of Fork-tailed Storm-Petrels mist-netted and laparotomized in 1981, only known

breeders were used. For all species two measurements of the vent were made with needle-nosed calipers; the transverse, or lateral, length; and the cranio-caudal width (Fig. 1).

We analyzed the data by discriminant analysis by SPSS, and by K-mean clustering by BMDP statistical packages. In addition, we tested our ability to sex birds correctly by using 40% of the sample to calculate the discriminant functions and the remaining 60% to assess the validity of sex determination.

We swabbed the birds' vents with 10% alcohol, which wet the surrounding feathers so the raised fleshy lips of the vents could be seen clearly and measured. The stimulation and cooling effect of the alcohol uniformly caused the birds to contract their sphincters. Females that had recently laid eggs could not contract their vents as small as males, so by stimulating contraction maximum differences in vent size between the sexes was measured.

To verify sex identification by vent measurements, we laparotomized 42 Fork-tailed Storm-Petrels mist-netted between 12 and 30 July 1981. In 1982 and 1983 we measured only known breeders captured in burrows. In 1982 we measured the vents of 182 birds; 158 were members of known pairs (79 pairs) in which both individuals were measured. In 1983 we measured 161 birds, 142 of which formed mated pairs (71 pairs). Because the results of the laparotomies corroborated what intuitively and deductively seemed true, we categorized the individual of a mated pair with the larger vent as female and the bird with the smaller vent as male. We were not present any year between May and mid-June when the majority of eggs were laid (Boersma et al. 1980). Because female vents regress in size after laying (Serventy 1956, pers. obs.),

TABLE 1. Differences (χ^2) in mean vent sizes (mm) for females and males of three species of birds and the percentage of females and males correctly sexed by vent dimensions, using entire samples. Values were derived from discriminant analysis.

| Species | Sex | n | Vent length | | | Vent width | | | Percentage correctly sexed by: | | |
|--|-----|-----|--------------|---------------|------|--------------|---------------|------|--------------------------------|-------|------|
| | | | Mean (SD) | χ^2 (df) | P | Mean (SD) | χ^2 (df) | P | Length | Width | Both |
| Fork-tailed Storm-Petrel (laparotomized, 1981) | F | 19 | 6.90 (0.94) | 18.6 (1) | 0.01 | 4.49 (0.57) | 26.4 (1) | 0.01 | 74 | 68 | 84 |
| | M | 23 | 5.66 (0.70) | | | 3.59 (0.37) | | | 87 | 78 | 91 |
| Fork-tailed Storm-Petrel (pairs, 1982-1983) | F | 150 | 7.58 (0.87) | 346.7 (1) | 0.01 | 4.83 (0.59) | 164.8 (1) | 0.01 | 73 | 90 | 93 |
| | M | 150 | 5.47 (0.52) | | | 3.99 (0.36) | | | 89 | 96 | |
| American Coot | F | 14 | 5.98 (0.53) | 61.2 (1) | 0.01 | 3.85 (0.48) | 27.5 (1) | 0.01 | 86 | 100 | 100 |
| | M | 8 | 3.36 (0.49) | | | 2.93 (0.29) | | | 94 | 100 | 100 |
| Magellanic Penguin | F | 31 | 17.99 (4.45) | 51.2 (1) | 0.01 | 17.50 (3.04) | 47.8 (1) | 0.01 | 87 | 77 | 87 |
| | M | 31 | 10.18 (1.81) | | | 11.86 (2.03) | | | 90 | 100 | 100 |

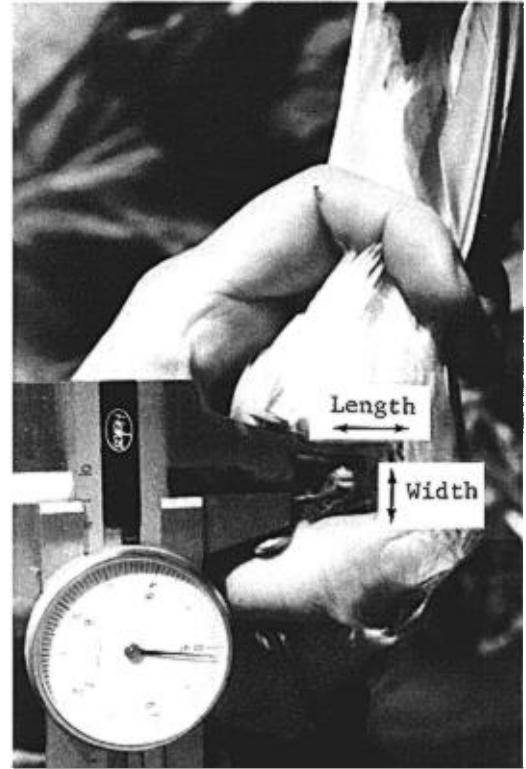


Fig. 1. Length and width measurements of an avian vent, showing the contracted vent of a female Fork-tailed Storm-Petrel.

the birds were measured as soon as possible after we arrived on the island to minimize the length of time between egg laying and sexing the bird. Petrels were measured between 18 June and 10 July (\bar{x} = 28 June, n = 182) in 1982, and 23 to 29 June in 1983 (\bar{x} = 26 June, n = 161).

We measured the vents of 32 banded, breeding American Coots near the end of incubation (2-3 weeks after egg laying) in spring 1982. Individuals were sexed independently by behavior and vocalizations (Hill 1984).

In October and November 1983 and 1984 we measured the vents of 62 breeding Magellanic Penguins within 2 weeks of egg laying, and again a month later. We independently sexed these birds by bill length and depth, a technique that is 94% reliable (Scolaro et al. 1983).

Eggs and adults of all species were weighed with 100- and 6,000-g spring scales, respectively, to determine egg size relative to body size.

Nineteen of the Fork-tailed Storm-Petrels laparotomized in 1981 were females and 23 were males. Female vents were significantly larger than males' for both length and width values (Table 1). We compared a discriminant function that additively combined both

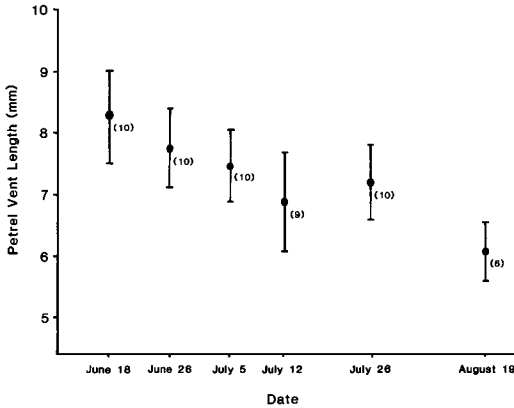


Fig. 2. Regression of female Fork-tailed Storm-Petrel vent sizes (mean \pm SD [n]) following egg laying in 1982. Most eggs are laid in May and June, although a few eggs are laid in July.

values (vent length plus width, L + W). L + W differed significantly between the sexes and was the best predictor of sex ($\chi^2 = 31.83$, $df = 2$, $P = 0.01$). Length-plus-width values correctly sexed 88% of the Fork-tailed Storm-Petrels (Table 1): 3 of 19 females (16%) were incorrectly identified as males, and 2 of 23 males (9%) incorrectly identified as females. The vents of nonbreeding females and male vents were similar in size. One laparotomized female was definitely a nonbreeder, as evidenced by her completely feathered brood patch and lack of well-developed follicles. Several other storm-petrels with immature gonads were incorrectly sexed by vent size and may also have been nonbreeders.

The degree of overlap between female and male storm-petrel vent sizes was influenced by two factors. First, the birds were mist-netted so nonbreeders were included, as evidenced by birds with completely feathered brood patches. Second, the birds were measured relatively late in the breeding season—between 1 and 2 months after egg laying—by which time many female vents had relapsed (Fig. 2). We were more successful measuring American Coots and Magellanic

TABLE 3. Mean vent sizes for "female" and "male" Fork-tailed Storm-Petrels as determined by K-mean clustering analysis.

| | Cluster means | Minimum | Center | Maximum | SD |
|---------------------------|---------------|---------|--------|---------|------|
| "Females" (n = 146 cases) | | | | | |
| Length | 7.80 | 5.99 | 7.50 | 10.49 | 0.80 |
| Width | 5.01 | 4.92 | 6.00 | 7.84 | 0.61 |
| "Males" (n = 197 cases) | | | | | |
| Length | 5.59 | 4.64 | 5.95 | 7.19 | 0.50 |
| Width | 3.97 | 3.15 | 4.30 | 5.69 | 0.49 |

Penguins because we measured only known breeders within 3 weeks of egg laying.

Unstandardized canonical discriminant function coefficients were used to sex petrels in the field (Table 2).

Female and male vent sizes of mated petrel pairs did not differ significantly between 1982 and 1983 (females: $t = 1.13$, $df = 148$, $P > 0.05$; males: $t = 0.94$, $df = 148$, $P > 0.05$). These data from the two years were combined.

Mean vent measurements for mated female storm-petrels (1982–1983) were significantly larger than for males (Table 1). Vent-length measurements correctly sexed 93% of the birds; only 15 females and 6 males were incorrectly classified (Table 1). Because we knew the vent measurements for the mates of these 21 birds, however, we were able to deduce the correct sex of some of them. For example, if we considered a bird to be a female but discriminant analysis indicated it should be sexed as a male, we measured the vent size of its mate. If the mate's vent length was less than the mean value for males, we considered our original sex determination to be correct. In this manner we "confirmed" the sex of 9 of the 21 misclassified individuals. By measuring both members of a pair we sexed correctly 96% of the birds.

We used BMDP K-means clustering as an independent method to classify into two groups all petrels measured in 1982 and 1983. The two groups had vent sizes similar to the groups used in discriminant anal-

TABLE 2. Unstandardized canonical discriminant function coefficients (DFC) for sexing birds by vent measurements. Vent measurements are multiplied by the DFCs given, then added to the constant. If the resulting $\bar{x} > 0$, the bird is female; if $\bar{x} < 0$, the bird is male.

| Species | Width | | Length | | Length + width | | |
|--------------------------|-------|----------|--------|----------|----------------|----------|--------|
| | DFC | Constant | DFC | Constant | DFC | Constant | |
| Fork-tailed Storm-Petrel | | | | | | | |
| Laparotomized, 1981 | 2.11 | -8.47 | 1.23 | -7.65 | 1.58 | 0.63 | -10.21 |
| Pairs, 1982-1983 | 2.06 | -9.07 | 1.40 | -9.14 | — | — | — |
| American Coots | 2.62 | -8.75 | 1.96 | -8.86 | -1.74 | 2.78 | -6.74 |
| Magellanic Penguin | 0.39 | -5.68 | 0.29 | -4.15 | 0.24 | 0.20 | -6.29 |

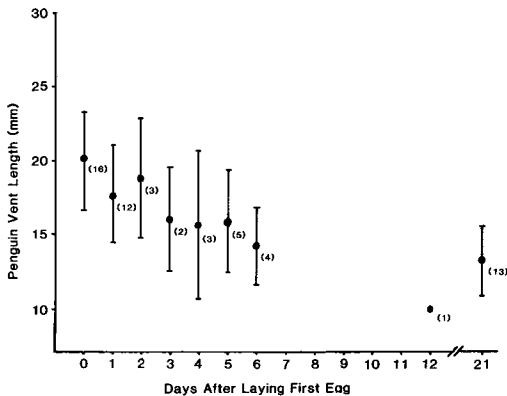


Fig. 3. Regression of female Magellanic Penguin vent sizes (mean \pm SD [*n*]) following egg laying in 1984.

ysis (Table 3; cf. Table 1). Vent length overlapped less than vent width for the two clusters, which is consistent with the discriminant analysis findings that length was the more powerful predictor of sex.

Finally, we used the sample of laparotomized Fork-tailed Storm-Petrels to determine discriminant functions for each sex and then analyzed the mated pairs for 1982–1983 with these values to determine individual sexes. Two hundred sixty-seven of the 300 storm-petrels (89%) were sexed correctly according to these criteria. Similarly, we used 40% (120 birds) of the 1982–1983 samples to determine discriminant functions and the remaining sample (60% or 180 birds) to validate reliability. Again, 89% of the storm-petrels were sexed correctly.

In 1982 we measured 35 randomly selected Fork-tailed Storm-Petrels 2–5 times on different days to determine measurement variability. The standard error of the mean of standard deviations was ± 0.08 mm for both length and width measurements for females ($n = 15$), and ± 0.06 mm (length) and ± 0.04 mm (width) for males ($n = 25$).

Vents of female American Coots were larger than those of males (Table 1; for L + W, $\chi^2 = 65.20$, $df = 2$, $P = 0.01$). Both vent width and length were good predictors of sex; vent length and L + W, however, discriminated sex better than width (Table 1). Discriminant analysis showed that both vent length measurements and L + W values sexed coots with 100% accuracy (Table 1). Birds with vent lengths greater than 4.6 mm were females (Table 2).

Female Magellanic Penguins had significantly larger vents than males (Table 1; for L + W, $\chi^2 = 67.81$, $df = 2$, $P = 0.01$). Both length and width measurements discriminated between the sexes, although L + W values best distinguished females and males (Table 1). Female vents were longer than 14.3 mm (Table 2).

To test validity we divided vent measurement data

into two groups: 40% to determine discriminant functions and 60% to test validity. By this method L + W correctly predicted the sex of 34 of the 37 penguins (92%).

Female penguin vents regress quickly after egg laying (Fig. 3). Female vent lengths measured near the time of egg laying (\bar{x} days after first egg = 2, range = –2 to 12) were significantly larger than those taken later (\bar{x} days following first egg = 28, range = 16–35) ($t = 5.99$, $df = 62$, $P = 0.01$). Male vents were not significantly date dependent ($t = 1.12$, $df = 58$, $P > 0.05$). Vents of females measured a month or more after their first eggs were laid were still significantly larger than male vents measured at that time ($t = 4.17$, $df = 75$, $P = 0.01$).

In all species measured females were less reliably identified than males. The low standard error of the mean of standard deviations for repeated measurements on individual birds suggests that measurement variability had little impact on identifying sex. The problematic sexing of females appears related to the regression of female vents after egg laying. It is therefore important to know when egg laying occurred relative to the date vents were measured.

The period after egg laying during which birds can be reliably sexed depends on the rate of regression, which in turn may be a function of egg size relative to body size. For example, a female Fork-tailed Storm-Petrel's single egg represents approximately 21% of her body mass (Boersma et al. 1980), and female vents relapse slowly over a period of several months (Fig. 2). Magellanic Penguins lay two eggs representing less than 6% of their body mass, and their vents relapse significantly within three weeks after laying the first egg (Fig. 3).

The predictive power of vent length, width, and L + W measurements varied between species and over time. Width was a better predictor of sex for petrels in 1981, but in 1982 and 1983 length was better. Female vent length for all species was the most variable vent dimension, and early in the breeding season it was the most accurate measure of sex. The use of both length and width measurements increased the reliability of the technique.

Nonbreeding birds cannot be sexed reliably by this technique because nonbreeding females have vents similar in size to males. Observations on brood-patch size, feathering, and vascularization can provide clues to a bird's breeding status and the time since egg laying. Measuring birds immediately before or after egg laying is likely to improve accuracy. Secondary indicators of gender such as behavior and morphological differences also help distinguish sex.

This technique can be simplified. In the field we accurately sexed approximately 80% of the Fork-tailed Storm-Petrels by simply graphing their measurements and computing means and standard deviations. We could visually distinguish with 100% accuracy female and male American Coots and Magellanic Pen-

guins within a few days after egg laying. More sophisticated analysis is necessary to sort out individuals with vent sizes in the overlap zones, but individuals of questionable sex can be identified in the field. Once the size ranges for female and male vents have been delineated for a particular species, field researchers can easily sex individual birds to investigate sex-specific behavior and biological patterns that historically have been difficult to study.

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Density Effects on Reproduction of Cavity Nesters in Northern Arizona

JEFFREY D. BRAWN¹

Department of Biological Sciences, Box 5640, Northern Arizona University, Flagstaff, Arizona 86011 USA

Reproductive success of noncolonial passerines was traditionally thought to decline with increasing intraspecific breeding density. This perception obtained from the classic long-term studies of Great Tits (*Parus major*) in Holland (Kluijver 1951) and England (Lack 1954). More recently, studies of Great Tits and other species have questioned the commonness of negative density effects on fecundity (Tompa 1967, Järvinen 1983, Orell and Ojanen 1983) and the importance of such effects on population dynamics (Perrins 1979, Klomp 1980, van Balen 1980). Data on the frequency of negative density effects are useful for understanding many aspects of avian biology. For example, an assumed inverse density-fecundity relationship underlies certain models of habitat selection and territoriality that relate habitat quality to local conspecific densities (Brown 1969, Fretwell and

Lucas 1970). The general applicability of such models is doubtful if negative density-fecundity relationships are not universal. Here I present evidence suggesting that the reproductive success of secondary cavity nesters in northern Arizona is not affected by intraspecific density.

To study density effects, I sought to increase breeding densities of secondary cavity-nesting birds with nest boxes on three 8.0-ha treatment plots (Brawn 1985). The plots were in northern Arizona's ponderosa pine (*Pinus ponderosa*) forests at approximately 2,200 m in the U.S. Forest Service Coconino National Forest, Coconino Co. I installed 60 nest boxes on each plot before the 1980 breeding season (see Brawn and Balda 1983 for details of box installation). All boxes were the same size (approx. volume = 1,900 cm³).

The treatment plots differed in habitat structure because of silvicultural activity (Szaro and Balda 1979, Brawn and Balda 1983). The Dense treatment plot had not been logged recently and included numerous large, mature pines interspersed with thickets of small

¹ Present address: Smithsonian Tropical Research Institute, Box 2072, Balboa, Republic of Panama.