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SEX DETERMINATION OF THE CALIFORNIA SEA LION (*ZALOPHUS CALIFORNIANUS CALIFORNIANUS*) FROM CANINE TEETH

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ABSTRACT

Size of canine teeth from California sea lion (*Zalophus californianus californianus*) carcasses is shown to be useful in determining the sex of animals which have missing genitalia or which are otherwise of unknown sex. A total of 267 canine teeth from carcasses of 68 males and 43 females were measured along five axes. Of root and crown measurements of upper and lower canines, males and females overlapped only in root thickness of upper canines. A multivariate ANOVA showed a significant difference in the size of canines between upper and lower canines, and between males and females. Stepwise discriminant analysis produced discriminant functions for upper and lower canines for determining sex of unknown-sexed California sea lions. A separate set of canine teeth from 39 male and 49 female California sea lions was correctly classified without prior knowledge of sex by visual inspection and by the two discriminant functions.

Key words: California sea lion, *Zalophus californianus*, sex determination, canine teeth.

Sex determination from genitalia is often not possible when soft tissue is badly decomposed. While extracting canine teeth from carcasses of California sea lions (*Zalophus californianus californianus*) to obtain age information, we noted size differences between canines of males and females, and that the size of the crown remained constant through life for each sex (Fig. 1). Other researchers have reported the use of canine or skull measurements for determining sex of other carnivores (Crespo 1984, Fuller *et al.* 1984, Parson *et al.* 1978, Sauer 1966, Flook and Rimmer 1965). In this report, we evaluate canine tooth size as an indicator of sex of California sea lions.

MATERIALS AND METHODS

Several researchers (see Acknowledgments) collected carcasses of California sea lions of various ages and known sex from (1) coastal mainland beaches of

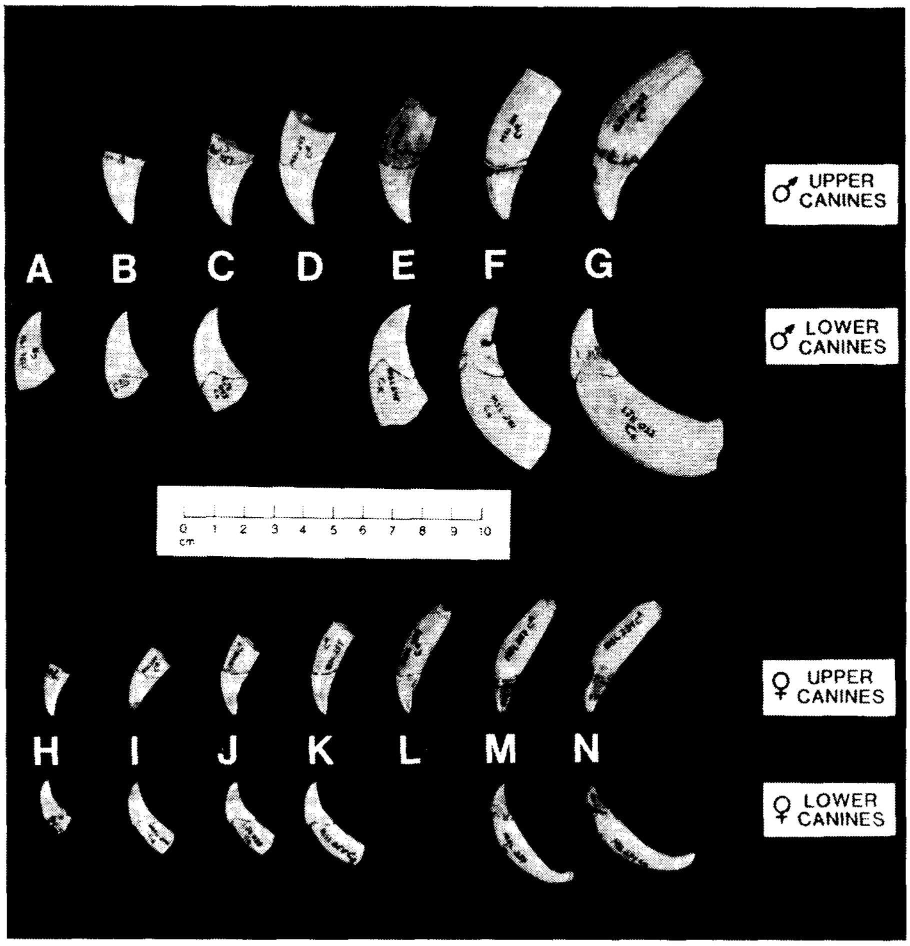

Figure 1. Ontogenetic series of upper and lower canine teeth from known-sex California sea lions (*Zalophus californianus californianus*). The estimated age and standard length of each specimen are: A (5 mo, 87 cm); B (7 mo, 91 cm); C (11 mo, 130 cm); D (2 yr, 145 cm); E (4 yr, 165 cm); F (7 yr, 186 cm); G (12 yr, 232 cm); H (4 mo, 80 cm); I (7 mo, 99 cm); J (11 mo, 116 cm); K (2 yr, 132 cm); L (6 yr, 152 cm); M (10 yr, 165 cm); and N (12 yr, 180 cm).

San Diego County, California; (2) San Clemente, Santa Catalina, and San Nicolas islands, California; (3) Bolsa Chica State Beach, Orange County, California; (4) Farallon Islands, California; and (5) vessels at sea which caught the animals inadvertently during fishing operations. All canines present on the carcass were extracted and the dental position was noted as upper right or left, or, lower right or left. We collected 267 canines from carcasses of 68 males and 43 females.

A sub-sample of canines from various age and length classes of California sea lions was photographed to demonstrate that there is a distinct difference in the size of the canines between males and females (Fig. 1). Ages of sea lions from this sub-sample were either known (animals had been tagged as pups at San Clemente and San Nicolas Islands) or estimated by reading layers from an acid-etched canine from the same animal (Pierce and Kajimura 1980). Counts of dentine growth layer groups (GLG's), as defined by Myrick (1980), were made to estimate age of animals greater than 1 yr old. The deposition rate of GLG's was calibrated from a canine of a captive California sea lion known to be 12 yr old and from sea lions tagged in the wild as pups. Each GLG was found to represent one year. For animals less than 1 yr, an approximate age was determined by taking the difference between the specimen collection date and end of the pupping period, which takes place during the last week of June (Odell 1975).

Canines were used for sex determination only if the crown was completely developed. This criterion eliminates animals which are too young for the tooth measurements to be effective in distinguishing the sex of the animal. We estimate that this criterion will be met at approximately five to six months of age for males and as early as three to four months of age for females. The canine from the youngest sea lion male (specimen A in Fig. 1) was collected from a 5-month-old animal. The lower canine from this young male specimen has a crown that is almost fully developed and with signs of a developing root. A canine from the youngest female specimen (specimen H in Fig. 1) was collected from a 4-month-old animal. The crowns of the upper and lower canines are fully developed and the root has formed in this female.

The canines of pup and juvenile sea lions must be removed from the skull or mandible to determine relative size of the teeth because part of the crown remains embedded in the alveolus. The discolored region evident on the apex of the canines shown in Figure 2 denotes the exposed portion of the fully developed crown of canines from a pup.

All canines collected were measured along five axes. We measured (± 0.01 mm) (1) crown length of upper and lower canines in a straight line from the concave side of the canine (posteriorly) from the neck to apex, (2) crown width and (3) thickness at the widest region of the neck or base of the crown, and (4) root width and (5) thickness at the root's widest and thickest region, respectively (Fig. 3). Some measurements of individual canine teeth were excluded because: (1) the crown was excessively worn (in one animal the crown was flat and level with the gum line); (2) the canine had been sectioned for age determination before all measurements were obtained; and/or (3) the root had not developed (in newborn pups only).

Before testing for sex-related differences we tested for dental-position differences in the measurements taken of each canine for all four dental positions (upper and lower; right and left). Only canines measured at the five previously mentioned locations of the tooth were used. The effect of dental position and sex were tested using MANOVA (Program 4V of BMDP-88; Dixon 1988). Multiple univarite ANOVA's were not used because multiple measurements from the same tooth could not be considered independent.

We also performed stepwise discriminant analysis (Program 7M of BMDP-87; Dixon 1985) to produce a discriminant score function to ascertain the sex

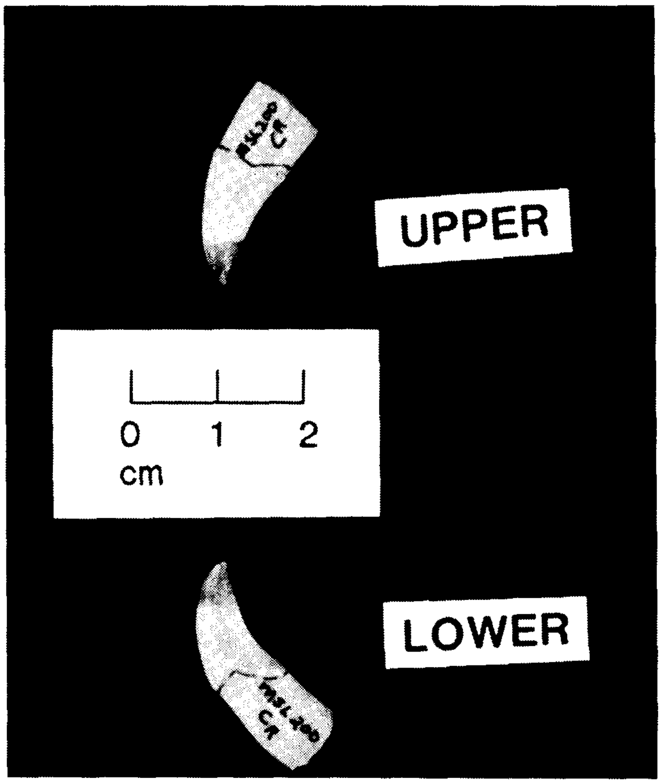

Figure 2. Canine teeth from an approximately 7-mo-old female California sea lion (*Zalophus californianus californianus*) showing exposed region (discoloration) at the apex of a fully developed crown.

of a California sea lion based on the canine measurements performed on any of four canines. This analysis was made because root thickness of upper canines overlapped between sex, and we did not know if other measurements would overlap if a larger sample size was available.

Without knowledge of sex, a second set of canines taken from 39 male and 49 female California sea lions collected from San Miguel Island, California was used to test the two functions and to determine if sex could be determined by visual examination of the canines. For the visual discrimination test, the teeth were examined visually before any measurements taken and separated into male and female. To test the two functions, the teeth were measured along the five axes and the two measurements chosen by stepwise discriminant analysis were used to identify male and female.

Results

Of root and crown measurements of upper and lower canines, males and females overlapped only in root thickness of upper canines (Table 1). For each sex we rejected the hypothesis that mean canine measurement vectors were equal

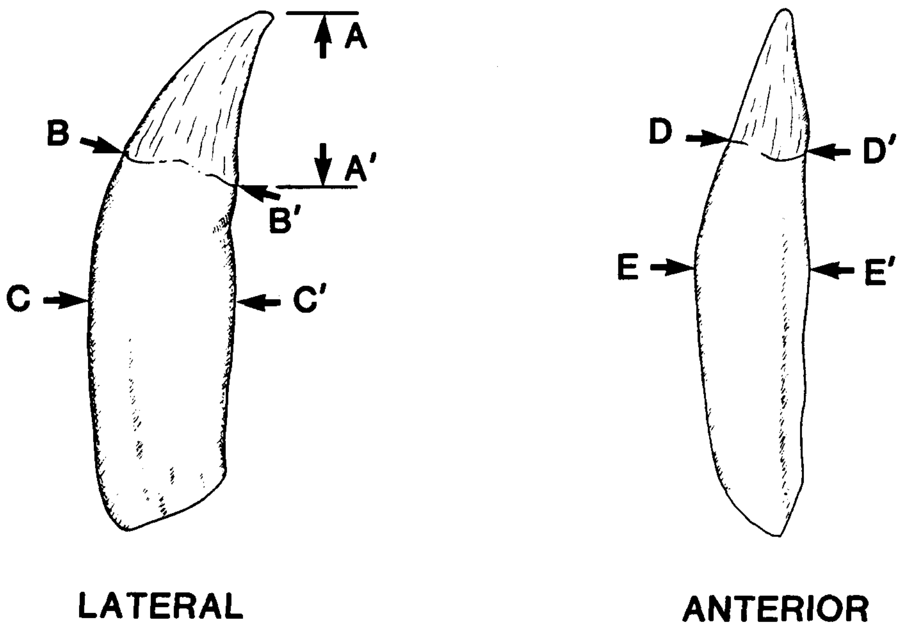

Figure 3. Measurements taken of California sea lion (*Zalophus californianus californianus*) canine teeth (A–A' = crown length; B–B' = crown width; C–C' = root width; D–D' = crown thickness; and E–E' = root thickness).

for upper and lower dental positions ($P < 0.01$), but did not reject the hypothesis of equal right and left dental-position ($P \geq 0.66$). For upper and lower canine positions, we rejected the hypothesis that mean canine measurement vectors are equal for males and females ($P < 0.01$, in each case).

Upper and lower canines were used in two separate stepwise discriminant analysis tests because a significant difference was found between those dental

Table 1. The sample size and range of measurements (mm) for 267 sampled canine teeth taken from known-sex California sea lions (*Zalophus californianus californianus*).

		Female			Male		
Position of canine	Measurement	*n*	Minimum	Maximum	*n*	Minimum	Maximum
Upper	Crown length	49	12.44	16.44	60	19.24	24.74
	Crown width	52	6.36	9.75	70	11.09	15.89
	Crown thickness	51	4.07	7.66	67	8.15	11.95
	Root width	58	8.17	12.40	73	13.78	22.85
	Root thickness	58	5.64	10.42	73	10.41	16.19
Lower	Crown length	54	10.97	14.96	81	17.76	27.26
	Crown width	54	6.03	9.81	84	11.10	17.08
	Crown thickness	54	3.84	6.18	84	7.00	10.47
	Root width	52	7.45	11.40	79	12.35	22.28
	Root thickness	52	4.50	7.52	78	8.06	18.30

positions, and not for left and right dental positions. After stepwise discriminant analysis of upper canines was made, root thickness of lower canines was eliminated from the analysis in order to have the same measures for the two dental positions. Each stepwise discriminant analysis chose root width and crown length as two measurements used in the discriminant function for determining sex of California sea lions from one of their canine teeth. A 100% jackknifed classification was achieved for upper canines of 57 males and 48 females, and for lower canines of 76 males and 51 females. The discriminant function for upper canines is:

$$S = 0.33763x + 0.67752y - 17.20254 \qquad (1)$$

The discriminant function for lower canines is:

$$S = 0.30240x + 0.59720y - 15.91558 \qquad (2)$$

where x = root width, and y = crown length, and S is the discriminant score. If the discriminant score (S) for upper canines is greater than -0.31707, then the canine is from a male; if it is less, then it is from a female. If the discriminant score for lower canines is greater than -0.85475, then the canine is from a male; if it is less, then it is from a female.

Without prior knowledge of sex, a 100% accuracy rate was achieved in identifying the sex of 39 male and 49 female California sea lions. These animals were correctly sexed without any measurements by visually discriminating between the two different sizes of canines. They were also correctly sexed by using measurements of root width and crown length with the discriminant functions. Although crown length is affected in older animals by wear (*i.e.,* the point of the crown is rounded), we found that the formulas correctly determined the sex of animals with this condition.

Discussion

Our results indicate that California sea lions can be sexed by examination of any of their canines. This difference is obvious enough that sex can be accurately determined from visual inspection of a canine. If the identification is in doubt, we have provided two formulas (one for upper canines and one for lower canines) for determining the sex of California sea lions from two measurements of a canine. Unless crown length is abnormally worn, the two formulas should identify the sex of the sea lion. For animals with abnormally worn crowns, we suggest comparing the other measurements to those found in Table 1 to determine the sex of these animals.

This technique may be of use in determining the sex of decomposed or mummified carcasses of other sexually dimorphic pinnipeds such as the Guadalupe fur seal (*Arctocephalus townsendi*), northern fur seal (*Callorhinus ursinus*), northern (Steller) sea lion (*Eumetopias jubatus*), and northern elephant seal (*Mirounga angustirostris*). Possible applications of this technique would be to determine the sex ratio of dead pups and juveniles in rookeries, or to increase the sample size of known-sexed animals for age-determination studies.

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