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Morphometric comparison of the epidermis in several cetacean species

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Summary

Epidermal thickness and relative papillary height of the skin from the urogenital region were compared with values from the ventral aspect of the flipper and the mid-dorsal body wall. Data are from seventeen animals of seven species. Values were also compared among different species. Regional variations were not consistent among the animals of one species. The epidermis was thicker in the harbor porpoise, beluga whale and humpback whale than in the bottlenose dolphin, striped dolphin and pilot whales. The reason for this is unknown. The height of the papillae generally remained at 40–50% relative to epidermal thickness in the three areas from each animal. The significance of this in respect to epidermal cell proliferation is discussed.

Introduction

The structure of cetacean skin has been described in a number of investigations (Giacometti, 1967; Simpson & Gardner, 1972; Greenwood *et al.*, 1974; Harrison & Thurley, 1974; Ling, 1974; Sokolov, 1982; Grills *et al.*, 1984; Haldiman *et al.*, 1985; Geraci *et al.*, 1986; Stromberg, 1989; Pfeiffer & Jones, 1993). Although a wide range of integumentary features have been studied, some areas remain unexplored. Many authors have noted the extreme thickness of cetacean skin. Some have discussed regional differences in thickness (Sokolov *et al.*, 1973; Harrison & Thurley, 1974; Sokolov, 1982), but very few (Harrison & Thurley, 1974; Sokolov, 1982; Grills *et al.*, 1984; Geraci *et al.*, 1986) have compared epidermal thickness among cetacean species. Also, the height of dermal papillae relative to epidermal thickness may be an important comparator due to the role of basal folding in increasing the surface area of the germinative layer, affecting increases in the proliferative capacity and in the thickness of the cetacean epidermis (Brown *et al.*, 1983). The objectives of the present investigation were, therefore, to compare epidermal thickness and relative papillary height of skin from the urogenital region (a rarely studied location) with that from other areas of the same cetacean, and to compare values among several different cetacean species.

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Material and Methods

Skin samples were obtained from deceased cetaceans that had stranded or were net caught. From each animal, whenever possible, fourteen samples were taken of skin in the urogenital region in a standardized array (Fig. 1), with six lateral to the urogenital slit on each side (1, 2, 3, 6, 9, and 12 cm from the urogenital slit), and one each 6 cm cranial (P6) and 6 cm caudal (D6) to the slit. Also, skin samples from the ventral aspect of the flipper and from the mid-dorsal body wall were taken for

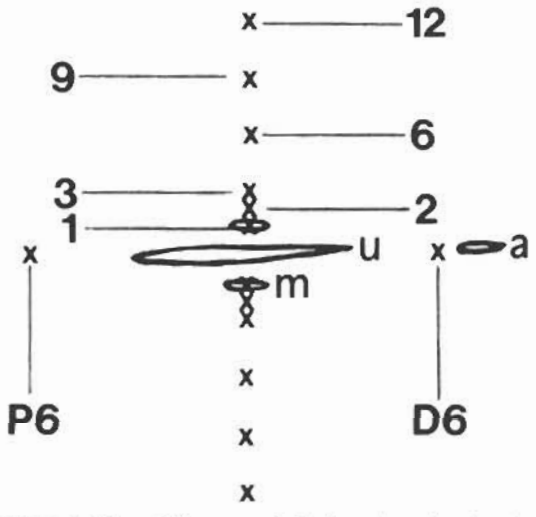

Figure 1. View of the urogenital slit region showing the locations of samples taken: 1, 2, 3, 6, 9, and 12 cm laterally, and 6 cm cranially and caudally (P6 and D6, respectively). u=urogenital slit, a=anal slit, m=mammary slits.

Table 1. Data on specimens of cetaceans used in this study.

Animal	Scientific Name	Sex	Length (cm)	Weight (kg)
BD1	*T. truncatus*	F	216	119
BD2	*T. truncatus*	F	248	261
BD3	*T. truncatus*	M	202	76
BD4	*T. truncatus*	F	265	210
BD5	*T. truncatus*	M	203	122
BD6	*T. truncatus*	M	158	62
BD7	*T. truncatus*	—	—	—
BD8	*T. truncatus*	—	—	—
BD9	*T. truncatus*	—	—	—
SD1	*S. coperuleoalba*	M	223	131
HP1	*P. phocoena*	M	151	48
HP2	*P. phocoena*	F	158	65
HP3	*P. phocoena*	M	141	44
PW1	*G. macrorhynchus*	M	410	785
PW2	*G. malaena*	M	241	—
BW1	*D. leucas*	—	—	—
HBW1	*M. novaeangliae*	M	857	—

comparison purposes. In total, samples were collected from seventeen animals of seven species (Table 1), including the bottlenose dolphin (*Tusiops truncatus*), striped dolphin (*Stenella coeruleoalba*), harbor porpoise (*Phocoena phocoena*), short and long finned pilot whales (*Globicephala macrorhynchus* and *G. malaena*, respectively), beluga whale (*Delphinapterus leucas*) and humpback whale (*Megaptera novaeangliae*).

Tissue samples were fixed in 10% neutral buffered formalin and processed by standard histological methods (Carlson, 1990). Tissues were doubly stained with Verhoeff's elastica and Masson's trichrome. Smaller samples were separately fixed in glutaraldehyde in 0.1 M sodium cacodylate buffer at pH 7.4 for 12 hours. These samples were than washed, post-fixed in 1% osmium tetroxide in 0.1 M sodium cacodylate buffer at pH 7.4 for one hour, washed again and dehydrated in graded alcohols (Jones, 1993). Specimens were cleared in propylene oxide, embedded in Poly/Bed 812 resin (Polysciences, Inc., Warrington, Pennsylvania) and sectioned at 1 μm for high resolution light microscopy. Sections were stained with Humphrey and Pittman's tri-stain (1974). The freshness of the samples also allowed for examination by electron microscopy in another study (Jones and Pfeiffer, 1993).

Using a calibrated ocular micrometer, measurements were taken of the thickness of the epidermis and the height of the dermal papillae (Fig. 2). Approximately six replicate measurements were made for each of the sixteen locations sampled from an individual. For each individual, values from the urogenital region were averaged as a group and compared with the averages for the two non-genital slit sites. Two-tailed Student's t-tests (Daniel, 1991) were employed to test differences in the average epidermal thickness and the average papillary height among the urogenital region and two sites of comparison in an individual. In order to see relative differences in the height of papillae, values were expressed as a percent of epidermal thickness. Differences within an individual as well as species differences were examined and analyzed as above. In order to see absolute differences in the thickness of the epidermis among the species, the values from all sixteen sample locations on each individual were averaged. The averages for the animals were compared using two-tailed Student's t-tests.

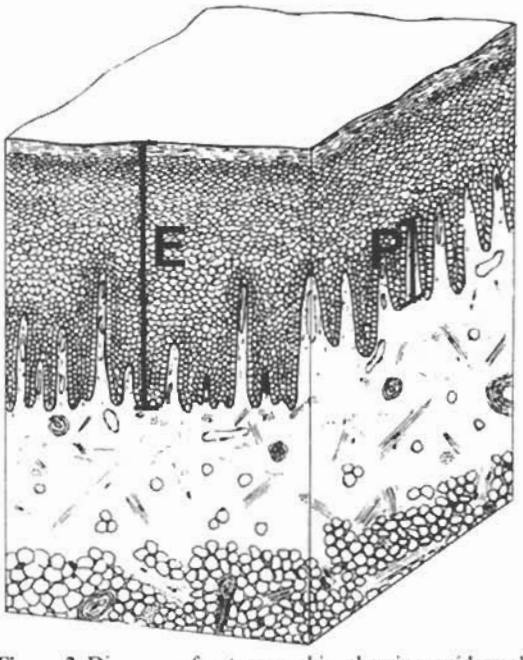

Figure 2. Diagram of cetacean skin showing epidermal measurements that were taken: Thickness of epidermis (E), and height of papillae (P).

Results

Epidermal thickness (Fig. 3) varied among the three areas in some individuals (BD1, BD3, BD4, BD6, SD1, HBW1). The epidermis tended to be thinner in skin from the ventral aspect of the flipper in three individuals (BD4, BD6, HBW1), thinner in skin from the mid-dorsal body wall in one individual (BD3), and thinner at both non-genital slit sites in two individuals (BD1 and SD1). The height of the dermal papillae (Fig. 4) also varied among the three areas in some individuals. Three individuals (BD1,

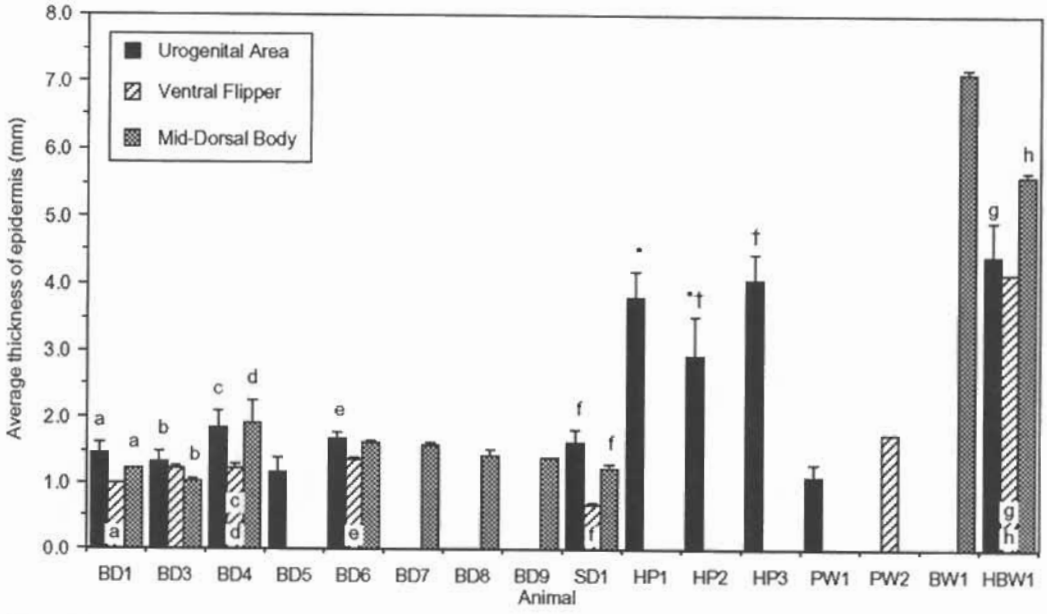

Figure 3. Bar graph showing the average thickness of the epidermis in the urogenital area, ventral aspect of the flipper and mid-dorsal body wall for each animal. P-values identify significant differences among data from the three regions or among individual animals. a: $p<0.0005$; b: $p<0.0005$; c: $p<0.0005$; d: $p<0.005$, e: $p<0.001$; f: $p<0.0005$; g: $p<0.01$; h: $p<0.0005$; *: $p<0.0005$; †: $p<0.0005$; BD=bottlenose dolphin, SD=striped dolphin, HP=harbor porpoise, PW=pilot whale, BW=beluga whale, HBW=humpback whale.

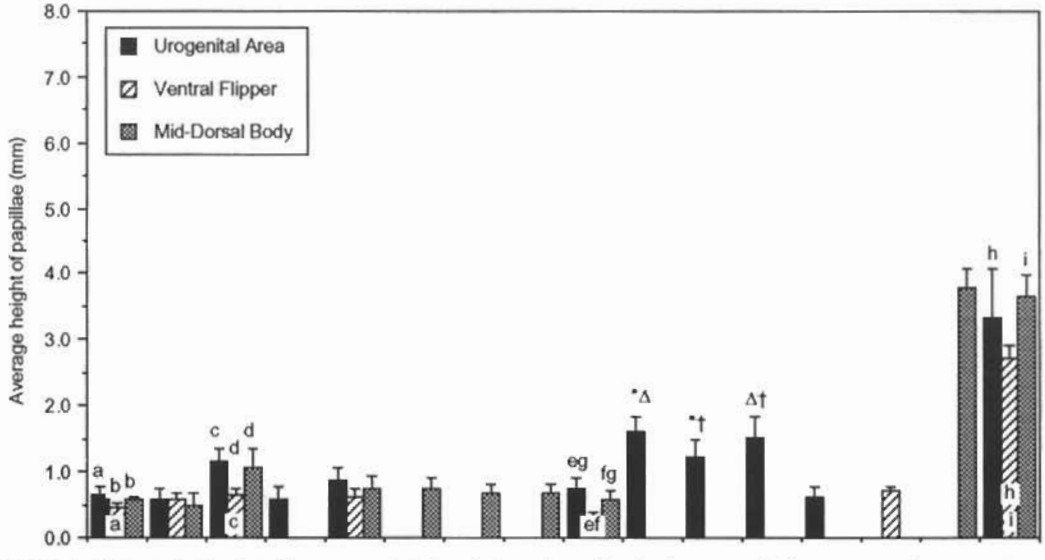

Figure 4. Bar graph showing the average height of dermal papillae in the urogenital area, ventral aspect of the flipper and mid-dorsal body wall for each animal. a: $p<0.0005$; b: $p<0.005$; c: $p<0.0005$; d: $p<0.025$; e: $p<0.0005$; f: $p<0.005$; g: $p<0.025$; h: $p<0.0005$; i: $p<0.0005$; *: $p<0.0005$; †: $p<0.0005$; Δ: $p<0.025$.

BD4, HBW1) had shorter papillae in skin from the ventral aspect of the flipper, and one (SD1) had shorter papillae in skin from both non-genital slit sites. These variations did not follow any pattern but rather seemed random by individual. The height of the papillae with respect to the thickness of the epidermis (Fig. 5), however, remained relatively constant in all three areas (40–50%),

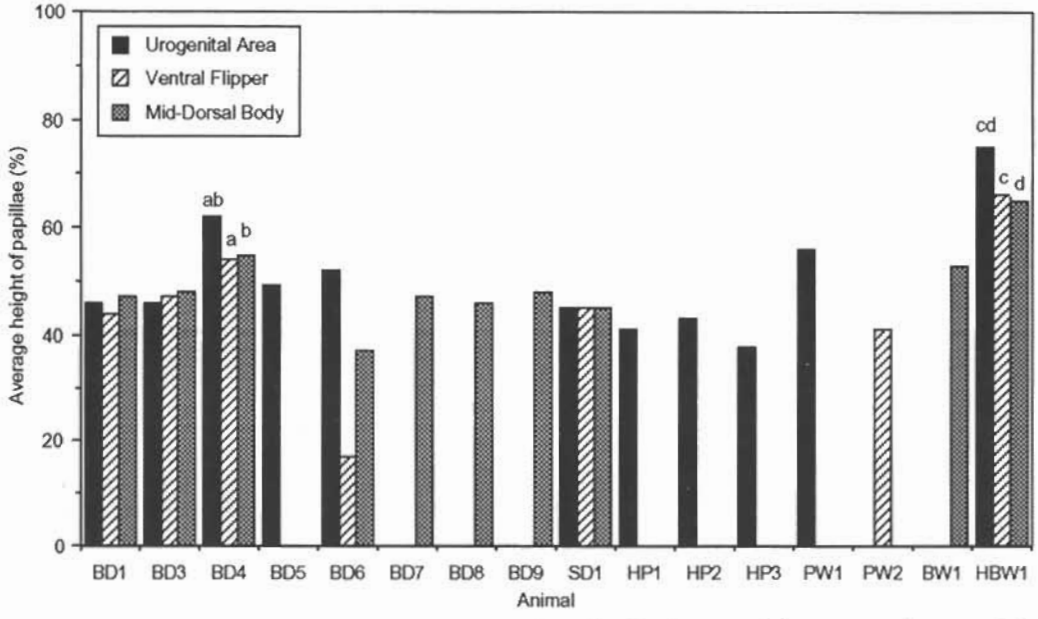

Figure 5. Bar graph showing the average height of dermal papillae in the urogenital area, ventral aspect of the flipper and mid-dorsal body wall expressed as a percent of epidermal thickness. a: $p<0.01$; b: $p<0.025$; c: $p<0.01$; d: $p<0.01$.

except in Bottlenose Dolphin 4 and Humpback Whale 1 where the height of papillae increased by 10% in the urogenital area.

When comparing grouped values, differences among individuals of a single species were evident. Measurements of epidermal thickness and papillary height for the urogenital area varied among the three harbor porpoises (Figs. 3 and 4), but relative to epidermal thickness, the heights of dermal papillae were the same (Fig. 5). Differences in epidermal thickness and papillary height among species were also evident (Figs. 3 and 6).

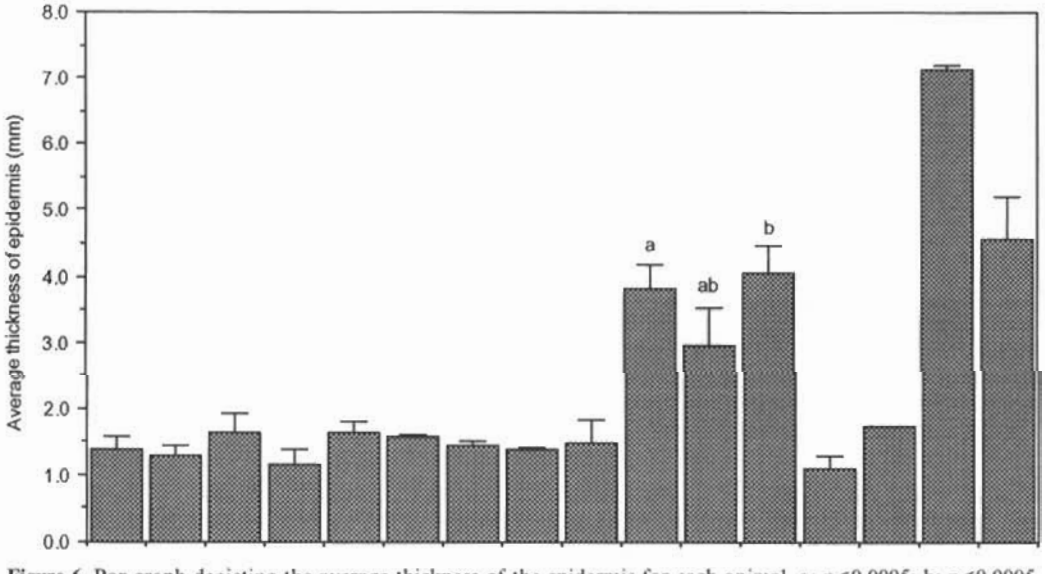

Figure 6. Bar graph depicting the average thickness of the epidermis for each animal. a: $p<0.0005$; b: $p<0.0005$.

Discussion

In three individuals the epidermis was thicker in the urogenital area than in the mid-dorsal body wall, and in five individuals the epidermis was thicker in the urogenital area than in the ventral aspect of the flipper. No conclusions can be drawn from these variations.

Regarding species differences, the epidermis was thicker in the harbor porpoise, beluga whale and humpback whale. These differences cannot be accounted for by differences in size, habitat or diving ability, and measurements from only one humpback whale cannot confirm Gray's (1930) notion that epidermal thickness varies between baleen and toothed whales. The relative height of dermal papillae was higher in the humpback whale than in the other species. The loss of surface layers, not uncommon during tissue processing (Harrison & Thurley, 1974; Stromberg, 1989), could account for an increase in the relative height of papillae in this case. Interestingly, in spite of individual variations (harbor porpoises) and even species differences (harbor porpoises, beluga whale and humpback whale) in the thickness of the epidermis and the height of dermal papillae, the relative height of dermal papillae was generally constant (40–50%). This range is consistent with those reported for the bowhead whale (*Balaena mysticetus*) (Haldiman *et al.*, 1985), Blue whale (*Balaenoptera musculus*), beluga whale (*Delphinapterus leucas*) (Grills *et al.*, 1984), and black finless porpoise (*Neophocaena phocaenoides*) (Liu Renjun *et al.*, 1986).

Although the extensive folding of the basal layers of the cetacean epidermis may facilitate rapid replacement of the surface (Grills *et al.*, 1984; Hicks *et al.*, 1985; Geraci *et al.*, 1986), and the number of papillae per square millimeter may be inversely related to epidermal thickness (Haldiman *et al.*, 1985), there has been no mention in the literature of a consistent relative papillary height and its possible advantages in terms of the proliferative capabilities of the cetacean epidermis. The importance of basal folding to cetacean epidermal cell proliferation and thickness is made evident by comparison with the human epidermis which has few basal foldings, a lower proliferative capacity, and is noticeably thinner (Brown *et al.*, 1983). If form follows function, our finding may suggest that cell proliferation and surface replacement in cetacean skin is most efficient when papillae reach 40–50% of the epidermal thickness. Further investigations on comparative epidermal proliferation will be warranted for diverse cetacean species.

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