## SUMMARY

Amongst cetaceans, the southern right whale integument is second in skin and blubber thickness only to that of the bowhead whale, *Balaena mysticetus*. Its histological structure has not been previously described. The development of a deep-core biopsy system allowed for the collection of integumentary samples from southern right whales that have been used in the multi-disciplinary research presented in this study.

Histological analysis has revealed the general structure of the integument of southern right whales to be typically mammalian and comparable with that of other cetaceans. The interdigitation of the dermal papillae and epidermal rete (papillomatosis) is particularly marked in this species, as in other balaenids so far studied. This study supports previous findings that the integument of this family, possessing an almost "fat-free" dermal layer, is more like that of odontocetes than that described for balaenopterids. The transition from the dermis to the hypodermis is defined by a gradual increase in the amount of adipocytes in a proximal direction. Unlike bowhead and sei (*Balaenoptera borealis*) whales, southern right whales possess an uninterrupted hypodermal layer that is connected to the muscle layers by a connective tissue layer (superficial fascia).

Scanning electron microscopy (SEM) techniques exposed a typically mammalian pattern of exfoliation of the superficial epidermis. The acquisition of samples from (non-calf) southern right whales in the Antarctic provided the opportunity to determine whether there were seasonal differences in exfoliation between animals in the summer and wintering grounds. Superficial exfoliation was detected on samples from the Antarctic indicating a continuous rather than seasonally-restricted exfoliation in southern right whales. SEM also revealed various microbial aggregations on skin biopsies taken in Antarctic as well as South African waters, including samples that were collected from stranded animals. These microbes included unidentified yeast colonies, various species of fungal mycelia and spores, an unidentified species of cyanobacteria and bacterial cocci. The increased presence of these microbes on cows and calves in October/November when compared to reduced amounts on Antarctic animals, seems to suggest that these microbes are acquired in the coastal waters

around South Africa. An invasive infestation of the skin of a stranded neonate by a *Candida*-like fungus could possibly have contributed to the mortality of this animal. This is the first account of microbial aggregations on and fungal infestations of the skin of southern right whales.

No diatomaceous films were found on any of the stranded whales sampled, and *Bennettella* [*Cocconeis*] *ceticola* (usually associated with films on southern hemisphere cetaceans in cold water) was not present on any of the samples. The unique ultrastructure of southern right whale stratum corneum cells, described previously by other researchers, may allow for high cellular proliferation rates in this species. This suggests that even at higher latititudes, diatom films may not have sufficient time to form on the skin of southern right whales.

Differences in the macroscopic appearance of the skin of neonatal calves were noted during the collection of samples in August. Calves possessed either a characteristically light grey and "rough" skin texture or a dark, smooth skin. Histological analysis of samples from stranded neonates revealed a distinct "double" epidermis, demarcated by a transition line that occurred distal to the tips of the dermal papillae. In noticeably "rough-skinned calves, this line became characterised by intercellular oedema, which caused the cell layers above the line to separate from those below it, essentially forming an ecdysal plane. A similar, although pathological, process known as "spongiosis" has been described in humans, but not before in cetaceans. Although a thick outer epidermal layer ("baby skin") has been noted in bowhead whale calves, this is the first thorough description of this type of moult (ecdysis) in any species of cetacean.

From a combination of aerial and boat-based observations, southern right whale calves complete this ecdysal process approximately one week after birth. This may be an archaic character in balaenids, vestigial evidence of which is found in the more modern balaenopterids.

The extensive and well-developed blubber layer, so characteristic of balaenids, played an important role in fuelling the whaling operations around the South African

coastline. The quantitative and qualitative properties of right whale blubber have remained, until now, relatively uninvestigated. The current study made use of analytical methods that did not exclude the possibility of coelution, but which were supported by trial analyses on more accurate systems. These systems indicated that all the major fatty acids (> 5% of total) were detected, and revealed previously unidentified peaks. Blubber samples were collected from various positions along the bodies of stranded southern right whales in order to determine whether there was any significant variation in the fatty acid composition from one region to the next. Such samples were also sub-divided into three macroscopically distinct layers and analysed for the same purpose. Statistical tests revealed no significant differences between positions around and along the body of a neonate. Differences in fatty acid composition between the layers of individual samples, the layers from various positions and between the layers of samples from animals of different ages (neonates, a juvenile, a subadult and an adult) were also not significant. Noting sample sizes as a limiting factor, these results seemed to indicate that random and relatively superficial (i.e. outer third/half) sampling of southern right whale blubber is acceptable for the purposes of qualitative fatty acid analysis, although clearly deeper core samples would minimize the effects of any possible stratification. The fatty acid composition of this exceptional energy and insulation depot provides possible indications of the prey species consumed by these whales as well as reflecting physiological processes within the digestive system of the southern right whale. For example, the polyunsaturated fatty acid (PUFA), C18:3, is derived originally from plant sources and is recorded in small amounts in *Euphausia superba*, but not at all in copepods, the other prey species consumed by southern right whales. This fatty acid may therefore serve as a good indicator of euphausiid consumption. The low levels of C20:1 and C22:1 (as well as the levels of C16:1, C18:3 and C20:5) seem to allow for speculation that the southern right whales sampled for this study were possibly feeding on herbivorous euphausiids rather than copepods, although confirmation of this requires further analysis of additional samples on capillary column gas chromatographs.

Thirteen major fatty acids were detected in the blubber of the southern right whales sampled for this study. Although this composition was generally consistent in all the seasonal and age classes, significant differences in the proportions of fatty acids were

detected between these groups which were predominantly related to changes in diet/available nutrients over time.

To date, the fresh biochemical contents of southern right whale stomachs have not been studied and evidence for microbial fermentation in this species has therefore not been found. The presence of the medium-chained, saturated fatty acid, C15:0, which has not been detected in southern right whale prey species, but which is usually of dietary origin, suggests that it may have been acquired from microbial sources. This fact, together with the extensive biohydrogenation of various fatty acids evident, may suggest that microbial fermentation occurs within the digestive system of southern right whales.

The general pattern of monounsaturated fatty acids (MUFA) composing the highest proportions of triacylglycerols (TAGs), followed by saturated fatty acids (SFA) and then PUFA, in non-neonatal southern right whales, follows that seen in some rorqual species. Although there are doubts about the comparability of analytical techniques, the values for North Pacific right whales, provided in the literature, do not conform to this pattern and have PUFA occurring in higher proportions than SFA. It was important to note that the slow-swimming North Pacific and southern right whales had higher proportions of SFA (for storage) and lower proportions of metabolically accessible MUFA in their blubber compared to the faster-swimming rorquals described in the literature. Differences in specific fatty acids between the North Pacific and southern right whales are detectable, possibly indicating the consumption of different prey species, however the high MUFA (especially C20:1) and low SFA content of the North Pacific right whale blubber seemed to indicate less biohydrogenation or less endogenous synthesis and possibly less efficient microbial fermentation in this species, compared to southern right whales.

The first description of total fatty acid values from southern right whale blubber tissue is given. The results presented are bracketed by results obtained from bowhead whales. The comparison of results from late season cows and calves revealed no significant differences and a linear regression revealed that the total fatty acid values were not correlated to length of sample in either of the age groups. However the

shortest sample obtained from a cow, consisting predominantly of dermal tissue, possessed the lowest total fatty acid values which indicated that very superficial sampling of blubber tissue for quantitative analysis will probably not provide true representations of the blubber tissue as a whole.

It is well known that certain characteristics of blubber tissue may vary with depth in cetaceans, e.g. histological structure and lipid content/fatty acid composition. These variations have implications for example, for energetic determinations and organo-chlorine analyses. In order to collect representative data, it is therefore important to obtain deep core blubber samples. The generally slow-moving and boat-tolerant behaviour shown by southern right whales allowed for the development of a hand-held biopsy system. This mechanism of delivery is anticipated to have less physical impact on the animal and at the same time enables non-destructive tissue sampling for histological analysis. The system is a practical and cheaper alternative to projectile systems, allowing for the collection of deep core samples from southern right whales that can be used for multidisciplinary research.

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