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Changing occurrence of epidermal lesions in wild bottlenose dolphins

Ben Wilson[1,2,*], Kate Grellier[1], Philip S. Hammond[2], Gary Brown[3,], Paul M. Thompson[1]**

[1]Department of Zoology, University of Aberdeen, Lighthouse Field Station, Cromarty, Ross-shire IV11 8YJ, United Kingdom
[2]Sea Mammal Research Unit, Gatty Marine Laboratory, University of St. Andrews, Fife KY16 8LB, United Kingdom
[3]Department of Mathematical Sciences, University of Aberdeen, Aberdeen AB24 3UE, United Kingdom

ABSTRACT: There are increasing concerns that human activities promote the development of natural diseases in aquatic organisms. Of these, diseases concerning small cetaceans have received increasing attention. Most studies have focused on dead animals and provided information on pathogens, contaminant exposure and probable causes of death. However, our understanding of diseases in living populations, particularly with respect to prevalence during the lives of individuals, and for whole populations in different years, remains limited. This study was designed to provide such information on epidermal lesions (abnormalities not directly attributable to physical trauma that may indicate disease) in a wild population of bottlenose dolphins *Tursiops truncatus*. An 8 yr time series of photographs of 82 free-ranging dolphins from NE Scotland was used to investigate the occurrence and dynamics of epidermal lesions in 7 age classes of young dolphins (from their 1st to their 7th summer of life) and for an adult group. Lesions were found at high prevalence (90 to 100%) in both young and adult dolphins, with 1st-summer calves having the lowest levels. Lesions of different appearance showed 2 patterns of occurrence, either being restricted to young individuals or becoming more common with age. When severity was compared between calves (in their 2nd summer of life) born in 8 different years, a significant decline over time was observed ($p < 0.005$). Comparison of this change with environmental and anthropogenic factors may help identify which factors may be promoting the ubiquitous epidermal lesions in these dolphins.

KEY WORDS: Disease · Cetaceans · Photo-identification · Pollution · North Sea

INTRODUCTION

There is widespread concern for the well-being of numerous species and populations of marine organisms. Small cetaceans are no exception (Klinowska 1991). Many threats arise directly from diverse human actions. These range from activities that remove animals from populations, such as incidental capture in fishing operations and hunts (Read et al. 1988, Northridge 1991) to those which diminish the fitness of individuals through factors such as habitat alteration (Richardson & Würsig 1997) and chemical pollution (Martineau et al. 1988, Béland et al. 1993, Lahvis et al. 1995). Less obvious but equally important are secondary effects which may compromise an organism's immune response to fight new or existing disease. For example, the extreme severity of several recent viral outbreaks amongst marine mammals are believed by some investigators to have been influenced by anthropogenic pollution (Hall et al. 1992, Aguilar & Borrell 1994).

*Address for correspondence: Sea Mammal Research Unit, Gatty Marine Laboratory, University of St. Andrews, Fife KY16 8LB, United Kingdom.
E-mail: ben.wilson@st-andrews.ac.uk
**Present address: Office for National Statistics, 1 Drummond Gate, London SW1V 2QQ, United Kingdom

To understand and address the impacts of human activities, knowledge of the occurrence and development of disease in wild populations is required. Many studies with this aim have been carried out on cetacean carcasses that wash ashore (Cowan et al. 1986, Martineau et al. 1988, Kirkwood et al. 1997) or are recovered after entanglement in fishing nets (Van Bressem et al. 1994, Van Bressem & Van Waerebeek 1996, Kirkwood et al. 1997). These have proved valuable in cataloguing disease types, aetiologies (Kennedy 1996) and relationships with pollutants (Kuiken et al. 1993). However, they have only rarely been used to document the occurrence of disease in *living* small cetacean populations (Van Bressem & Van Waerebeek 1996). This is because of the difficulty in identifying the populations from which carcasses originate and, more importantly, because the information they yield represents a single and potentially biased snapshot of the life of an animal. This problem is likely to occur particularly with diseases not directly associated with the death of the individual. Studies of animals in captivity do permit serial sampling (Dierauf 1990) but, due to the artificial conditions, are unlikely to represent processes occurring in wild populations. Temporary capture-sample-release programmes offer a more direct approach and have considerable potential, allowing serial sampling of known individuals (Scott et al. 1990). However, opportunities for these studies are rare and logistically complex. Consequently, knowledge of the occurrence of natural, non-lethal diseases that occur during the lives of individual small cetaceans and their relationships with the wider behaviour and ecology of these animals remains poorly known. Providing such information remains a considerable challenge and is only likely to be addressed using a combination of approaches.

Photo-identification offers one way to obtain repeated remote measures of a limited range of epidermal conditions in wild cetaceans. Photographs of animals at sea are now taken routinely world-wide (Hammond et al. 1990) and used to repeatedly identify individuals from their natural marks and scars. Thus, these pictures can also be used to document the occurrence of epidermal lesions that may signify epidermal disease (Thompson & Hammond 1992, Harzen & Brunnick 1997). In one study, carried out on a population of bottlenose dolphins off NE Scotland, 14 types of epidermal lesion were defined by their appearance, and prevalence and severity indices calculated for each type *within* the living dolphin population (Wilson et al. 1997a). Furthermore, variations in the prevalence and severity of lesions in different broad age groups and between the sexes were identified. Similar techniques have also been used to compare the occurrence of epidermal disease *between* populations (Wilson et al. 1999a).

In this study, we use an 8 yr photo-identification data-set to document long-term changes in the occurrence of epidermal lesions in a wild population of bottlenose dolphins off NE Scotland. In particular, we examine whether there are age-specific changes in lesion prevalence and extent, and investigate whether their occurrence in the population has remained constant or is changing over time.

METHODS

Data were drawn from a long-term study of approximately 130 free-ranging bottlenose dolphins *Tursiops truncatus* that inhabit coastal waters off NE Scotland (Wilson et al. 1999b). As part of this work, an archive of high-quality photographs of dolphin fins and flanks was compiled so that a record of the survival, movements and associations of uniquely marked individuals could be accumulated (Wilson 1995). These pictures were collected during 308 standardised surveys conducted year-round from small boats, and taken with autofocus SLR cameras and ISO 100, 200 or 400 colour transparency film (see Wilson et al. 1997b for survey details).

Data processing. Archived pictures of dolphins, collected between July 1989 and June 1997, were used to quantify the occurrence of epidermal lesions in different age categories. Because the physical changes that occur in maturing bottlenose dolphins are gradual, reliable ageing of individuals by their appearance is impractical. In this study, the ages of dolphins were accurately known only for individuals that were born during the project and subsequently recognised in later years by their unique marks. In this way, the epidermal condition of calves and sub-adults up to the age of 7 yr could be determined from the 8 yr data-set. Because calves are born throughout the summer months, the approximate age of each calf was defined by the number of summers that it had experienced. Thus, neonate individuals were classed as 1st-summer individuals, and so on.

With sexual maturity in bottlenose dolphins occurring generally more than 7 yr after birth (Perrin & Reilly 1984), it is unlikely that the calves followed in this study could have reached this stage. To examine reproductive individuals, therefore, a group of adults seen at the beginning of the study was chosen, and epidermal characteristics were recorded over the following 8 yr. Although the years in which these dolphins were born is unknown, they all aged during the study period and therefore changes in the overall patterns of lesion occurrence may indicate gross changes as dolphins age.

To quantify the occurrence of epidermal lesions in each age category/group, 2 parameters were measured: *prevalence* (proportion of individuals with lesions at one time: Rothman & Greenland 1998); and *extent* (percentage of each individual's epidermis covered by lesions, equivalent to *severity* in Wilson et al. 1997a, 1999a). Because dolphins only expose part of their bodies above the water when they breathe, only the dorsal fin and variable proportions of the back could be photographed. In this study, only the dorsal fin was considered. Restricting these measures to just 1 part of the dolphin meant that prevalence values represent minima, but using a defined area ensured that valid comparisons could be made between individuals and years. Further, for each individual, only 1 side of the dorsal fin was used, so that pictures in the photo-sequence were directly comparable.

The best picture of the dorsal fin for each individual for each age category (where available) was chosen from the photo-archive. Pictures in which part of the fin was obscured, or which were out of focus or not directly parallel with the plane of the film were rejected. The presence or absence of lesions were not considered in the picture-selection procedure. Chosen images were projected using a slide projector with 70 to 120 mm lens. The presence or absence of lesions of different types (see following paragraph) was scored, and the dorsal fin and area covered by lesions was traced using a pencil and paper. The order of slides in the projector was shuffled, and dates on the slide mounts were covered so that the scorer (always B.W.) could not know when the pictures were taken and therefore which age category of dolphin each picture represented, thus excluding the possibility of observer bias in age-related lesion classification. The area of the dorsal fin and lesions was then measured from the drawing using a digitising tablet and purpose-written software.

Lesion types were categorised following the definitions described by Wilson et al. (1997a). These were grouped by appearance for analysis into 4 categories (dark, pale, cloudy and orange lesions). *Dark* lesions were characterised by patches of epidermis with areas of hyper-pigmentation and included the 'black', 'dark-fringed spots', 'white-fringe spots' and 'lunar' lesions; *pale* featured areas of hypo-pigmentation and included the 'white-fin fringes', 'white' and 'cream' lesions; *cloudy* were characterised by blue-grey patches, and *orange* by orange, yellow or brown-coloured patches of epidermis. Lesions that appeared to result from direct physical injury (such as scratch and bite marks) were not considered.

Analysis of temporal changes. One way in which to investigate whether the occurrence of epidermal lesions changes over time is to take annual photo-samples from the population and quantify changes in lesion occurrence between the samples. However, because the occurrence of lesions is known to vary between different broad age groups in the population (Wilson et al. 1997a), any changes in occurrence could be masked by variation in the age composition of the samples.

In this study, therefore, we restricted analysis to 2 groups of dolphins: the group of adults first seen at the beginning of the study, and calves in their 2nd summer, chosen because they could be aged unambiguously and had lived long enough to develop lesions. In the adult group, any change in lesion occurrence over time is confounded with any change resulting from ageing of the dolphins during the study period. For 2nd-summer calves, any such age effects are eliminated.

For the adult group, the data consisted of 211 photographs of 45 dolphins (16 males, 20 females and 9 of unknown sex) taken over 8 yr. Thus pictures were not available for every individual in each year. The best-recorded individual had 8 photographs taken over 8 yr, but the worst-recorded had only 2 photographs over 3 yr. Because of the incomplete nature of the data, neither analysis of data on individual dolphins nor analyses using repeated measures were possible. Simple regression of lesion extent on date has the problem of lack of independence among data from the same individual. In addition, the constant term of any regression is not of interest. Consequently, a Pearson (product moment) correlation analysis relating the difference between the last recorded and first recorded extent value, and the number of days between these occurrences was conducted using SPSS (Subprograms of the Statistical Package for the Social Sciences) software. This discarded >50% of the recorded data but did address the question of whether there was a trend in lesion extent over time.

For the 2nd-summer calves, 37 individuals were photographed over 8 birth years. The best-sampled birth year was 1994 with 9 calves, and the worst 1993 with 2 calves. Each calf was represented only once, but the constant term of any regression is again not of interest. Consequently, a Pearson (product moment) correlation analysis relating lesion extent to birth year was conducted using SPSS software. Because the question being addressed is whether there was a general trend in lesion extent with birth year, the individual effects of variability among 2nd-summer calves was eliminated by averaging lesion extent at each birth year.

RESULTS

Demographic differences in lesions

Lesions were present and at high prevalence throughout all categories of both the young *Tursiops*

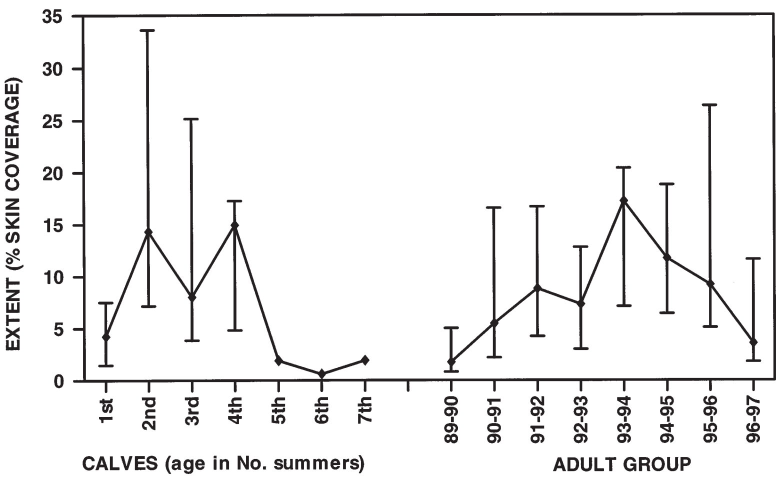

Fig. 1. *Tursiops truncatus.* Changes in extent of all epidermal lesions with age. Calves were in their 1st to 7th summer of life, and adults were followed over an 8 yr period starting 1989. Medians and interquartile ranges are shown

truncatus (1st- to 7th-summer individuals) and the adult group. First-summer dolphins had the lowest prevalence values, with 90.5% of individuals having lesions. Thereafter, prevalence rose to 100% for all age groups and for all years. The extent of lesions showed more variability. Within the young dolphins, median extent values varied from 0.6% for 6th-summer to 14.9% for 4th-summer calves (Fig. 1). These differences between age categories were significant (Kruskal-Wallis ANOVA, $\chi^2 = 20.3$, 4 df, $p < 0.0005$, data for 5th-, 6th- and 7th-summer dolphins were combined because of small sample sizes). For the adult group, lesion extent varied over the 8 yr period from a minimum of 1.7% to a maximum of 17.2% (Fig. 1), and significant differences were found among years (Kruskal-Wallis ANOVA, $\chi^2 = 27.2$, 7 df, $p < 0.0005$).

The occurrence of lesion types varied with age. Dark, pale and cloudy lesions all had similar patterns of prevalence (Fig. 2). Each was uncommon in 6th-summer calves, but then became more prevalent in older age classes of calves and in adults. Whilst dark and pale lesions were present on almost all individuals in each age group, cloudy lesions increased in prevalence but only ever affected approximately half the dolphins in any age group. Orange lesions were different from the other types (Fig. 2). They were most prevalent in the 1st- to 4th-summer calf-classes, and then decreased to become rare in 5th-, 6th- and 7th-summer calves and in adults.

In terms of extent, cloudy and orange lesions covered relatively small percentages of epidermis in most age groups (Fig. 3), with orange lesions only covering broad areas in 2nd-summer calves. Dark and pale lesions covered larger areas of epidermis and affected most age groups. Lowest extent levels occurred in 1st-summer calves. In subsequent age groups, dark lesions rapidly became more prominent, to peak in 2nd-summer calves. Extent then fell, to become relatively constant in older age classes. In all calves, pale lesions followed a similar pattern to that of dark lesions, but with a 2 yr lag. In adults, pale lesions varied in extent considerably between years, but covered greater areas of epidermis than dark lesions.

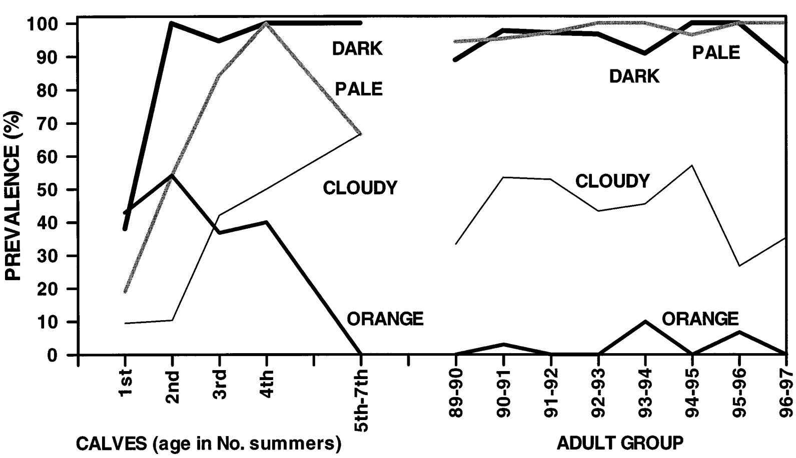

Fig. 2. *Tursiops truncatus.* Changes in prevalence of lesions with age in calves (in their 1st to 7th summer) and group of adults (over 8 yr from 1989). Data from 5th-, 6th- and 7th-summer calves were combined because of small sample sizes

Temporal changes in lesion extent

Adult group

Correlations between the change in extent and the number of days over which these changes took place are shown in Table 1a. All are positive, and those for pale and total lesions are significantly different from zero at the 5% level. Scatterplots of the data revealed no obvious non-linear relationships. We conclude that there was an increase in extent of pale and total lesions in adults over the period of the study, but we cannot differentiate between the confounding effects of a change over time or a change with age.

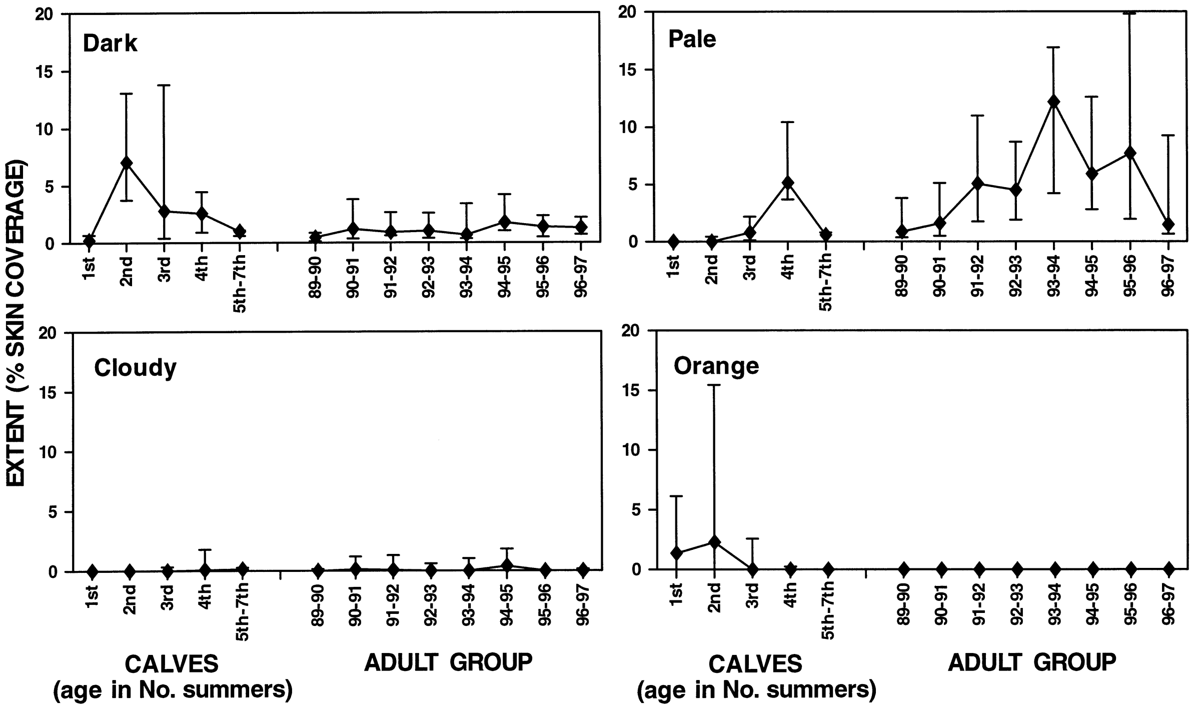

Fig. 3. *Tursiops truncatus.* Changes in extent of 4 lesion types with age of calves (between their 1st and 7th summer) and group of adults (over 8 yr period from 1989). Data for 5th-, 6th- and 7th-summer calves were combined because of small sample sizes. Medians and interquartile ranges are shown

Table 1. *Tursiops truncatus.* Correlation between (a) change in lesion extent and number of days over which change occurred in adults and (b) lesion extent and birth year in 2nd-summer calves. There were insufficient data to allow analysis of cloudy and orange lesions in adult group. Pearson (product moment) correlation was used with SPSS software. *Significant at 5% level; **significant at 1% level

Age group	Lesion type	Correlation coefficient	Significance (p)
(a) Adult group	Dark	0.043	0.780
(n = 45)	Pale	0.369	0.013**
Total		0.295	0.049*
(b) 2nd-summer calves	Dark	−0.745	0.034*
(n = 37)	Pale	−0.035	0.934
	Cloudy	0.159	0.707
	Orange	−0.600	0.166
Total		−0.907	0.002**

Second-summer calves

The extent of lesions plotted against birth year for individual 2nd-summer calves is shown in Fig. 4. Correlations between average lesion extent and birth year are shown in Table 1b. Of the 5 correlations, 4 are negative, including the only 2 that are statistically significant from zero (for dark $p < 0.05$ and total $p < 0.005$ lesions). Fig. 4 and other scatterplots for specific lesion types show no evidence that the relationship is non-linear. We conclude that the severity of dark and total lesions in 2nd-summer calves decreased over the period of the study.

DISCUSSION

The occurrence of epidermal lesions in the Moray Firth *Tursiops truncatus* population is well documented (Thompson & Hammond 1992, Wilson et al. 1997a). However, because the previous studies were based on photo-identification data collected over short time periods (1 and 3 yr, respectively), it was unclear whether the lesions observed were transitory or long-term features within this population. This study has shown that these epidermal lesions are a long-term feature of this bottlenose dolphin population, that they occur in all age groups, and that lesion extent, particularly of dark lesions, has changed over time.

Demographic differences in lesions

Epidermal lesions were found in all age groups of dolphins examined (including calves in their 1st year of

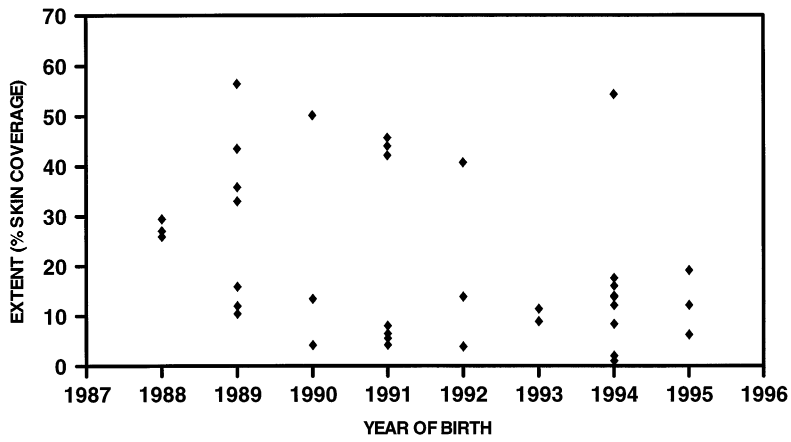

Fig. 4. *Tursiops truncatus.* Extent of lesion coverage for individual calves in their 2nd summer plotted against year in which they were born

life), and are therefore widespread within the population. Furthermore, because almost every individual in each age group examined had lesions (particularly dark and pale), they appear to be long-term features in the lives of individual dolphins. Of the types, dark and pale were both the most common and covered the most epidermis in all age groups. Studies of the development of dark and pale lesions (Wilson 1995) suggest that they are linked, with dark being precursors to pale lesions. This is supported by the present study, where an approximate 2 yr time lag was observed between peaks in the prevalence of dark and pale lesions, respectively, in both the young dolphins and the adult group (Fig. 2), and in extent in the young dolphins (Fig. 3). The relationship between dark and pale lesion extent in adults was less clear. Similar transitions in lesion appearance have been observed in other bottlenose dolphin populations (Harzen & Brunnick 1997).

Sub-adulthood, the time between being a dependent calf and a reproductive adult, is thought to extend in bottlenose dolphins from 4 until 11 or 12 yr of age (Perrin & Reilly 1984, Wells et al. 1987). In this study, lesions on dolphins were only investigated for part of this range (5th-, 6th- and 7th-summer individuals). To cover the whole of sub-adulthood, this study would need to be extended for at least another 6 yr. Results from a cross-sectional study of lesion occurrence in the same population in 1992 suggest that the extent of epidermal lesions in a broad age group of probable subadults was lower than that in either adults or calves (Wilson et al. 1997a). The limited data from the present longitudinal study, where the age of young individuals was known, supports these findings. Of all the age groups examined, dolphins in their 5th to 7th summers had the lowest lesion-extent levels (Fig. 1). Why these non-dependent, non-reproductive individuals should have such low levels is unknown.

Temporal changes in extent

The extent of lesions per individual in adults increased during this 8 yr study. However, because the effects of age and time were confounded, it is unclear whether this was the result of changes in the factors that promote lesion development or a result of lesion accumulation in the dolphins as they aged. The analyses of 2nd-summer calves provide a better measure of changes over time because the effect of age was eliminated. Lesions were present in each of the 8 years (Fig. 4), suggesting that the factors leading to these epidermal anomalies are not transitory but were present in the area for at least the period of this study. Comparisons of the prevalence and extent of epidermal lesions between populations world-wide have shown a strong correlation between occurrence of epidermal lesions and natural climatic factors, principally water temperature and salinity, in dolphins inhabiting different areas (Wilson et al. 1999a). The results presented here confirm that one or more long-term factors are likely to be important for lesion development.

That the extent of lesions in individual 2nd-summer calves has changed over time raises 3 possibilities: the long-term factors promoting lesion development in the Moray Firth dolphins have changed, the susceptibility of the dolphins themselves has changed or the survival of the 1st-summer calves likely to be most affected by their 2nd summer has declined. Pollutants and diet have been suggested as possible influences on cetacean immune-competence, while viral infections (e.g. morbilliviruses) are known to attack the lymphoid tissues in bottlenose dolphins, leading to immunosuppression and secondary infections that can include epidermal lesions (Geraci 1989, Kennedy 1996). The temporal variation found in the development of lesions in the Moray Firth population now provides a baseline gradient against which these possibilities, or any others, can be tested in future.

While climatic factors, other diseases, diet and pollutants may play a part in influencing the development of lesions, they are unlikely to be the primary cause. Despite several post-mortem and histopathological examinations of stranded individuals from this population, the pathogens or immunological mechanisms leading to lesion development have proved elusive (Patterson 1997). Whatever their cause, these epidermal anomalies do not seem to be immediately fatal because of the continued survival of the adults followed in this study. They therefore appear to be a feature of the lives of bottlenose dolphins off NE Scotland and do not simply occur near the time of death. However, because their impacts on the lives of these dolphins and on the well-being of the wider population is unclear, it is not yet possible to determine whether these lesions signify disease (i.e. impairment of the ecological potential of the individual: Kinne 1980) or are more simply benign, anomalous changes in the pigmentation of the epidermis. Extending a longitudinal study, such as that presented in this paper, would provide an opportunity to match long-term epidermal condition with individual survival and therefore allow exploration of this important question.

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