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Cetacean live stranding dates relate to geomagnetic disturbances

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Abstract

Further analysis of the UK cetacean strandings records has revealed more information about the way the animals use the geomagnetic field as part of a travel strategy. Animals make the key mistakes, which result in live strandings, at some distance from shore. The distances implied by the analyses fit well with the distance of major choice points in the geomagnetic topography of the usual migration routes. Live strandings are associated with geomagnetic disturbances. The pattern of magnetic disturbance, not the absolute level of disturbance is the key factor for live strandings at all latitudes investigated. If disturbances occur in that part of the day available for monitoring geomagnetic time information (the second to fourth parts of the Greenwich day), live strandings result. This indicates that the animals are using geomagnetic time information to re-set a 'biological travel clock'. It also implies that the receptor system involved is likely to be multidomain.

Introduction

Earlier studies (Klinowska, 1983; 1985a) have shown that cetacean live strandings can provide information about travel strategies. It was found that the positions of live strandings can be explained as mistakes made while using geomagnetic topography for orientation. The original work was based on the United Kingdom (UK) strandings records, and has now been confirmed for the USA east coast (Cornwell-Huston, 1985; Kirschvink, Westphal and Dizon, 1984), for Canada (Fraser, 1984) and for New Zealand (Dawson, Whitehouse & Williscroft, 1984). More importantly, known cetacean tracks (Evans, 1974) also seem to follow geomagnetic topography in the manner indicated by the strandings data (Evans—personal communication).

Animals using goemagnetic information for travel may be expected to make relatively more mistakes when the geomagnetic field is disturbed. Our first attempt (Easton, 1980) to explore this question was not successful because heterogenous strandings data were used as well as an inappropriate measure of geomagnetic disturbance. However, since homogeneous samples of stranding events had revealed the relationship between live stranding sites and geomagnetic topography, it seemed worthwhile to have another look at the question of possible relationships between live strandings and geomagnetic disturbances, using these samples. (Further information on the first study is summarized in Klinowska, 1985c.)

Data and methods

Geomagnetic disturbances

The earth's magnetic field has two sources (Chernosky *et al.* 1966). The main source is generated within the earth, from electric currents flowing in a molten metallic core. Movements in this core produce slow surface changes, including alterations in the position of the geomagnetic poles. The second, relatively weak, source is generated by the flow of ions in the jet streams of the upper atmosphere. The atmospheric field, however, is the main source of geomagnetic variation at the surface of the earth. The heating of the atmosphere in the daytime and the cooling at night cause the atmospheric ion streams to move north and south in a daily rhythm which changes local field by 30–60 nano Tesla (nT) over a day. There are also tidal variations related to the movements of the sun and moon. These regular variations provide daily and seasonal time information in much the same way as the familiar light/dark cycle (Pittendrigh, 1981). Solar activity creates bursts of ionized particles which can affect the earth's field, creating relatively more disturbance in the auroral zones than towards (but not at) the equator (Lincoln, 1967). During the greatest magnetic storms, as major events of this type are known, changes can be of the order of thousands of nT, although small disturbances of tens to the low hundreds of nT are an almost constant feature of the earth's magnetic environment. These irregular events can be regarded as magnetic 'weather', disrupting the regular field variations in a similar fashion to the disruption of light/dark cycles by meteorological events. Unlike meteorological events, however, geomagnetic weather is a little more predictable. In general, disturbances are greater during the evening and early part of the night, while the early morning is a much quieter time. This is because of the interactions between solar corpuscular radiation and night-side ring currents in the polar zones of the upper atmosphere. Seasonal variations in magnetic disturbances also occur for these reasons.

The dynamic aspects of the earth's magnetic field are known through the network of magnetic observatories. The most usual observations are the declination, horizontal intensity and vertical intensity of the field. These are published as hourly values, but are difficult to interpret, particularly when comparing observatories, and several types of indices are used to describe dynamic magnetic phenomena, the main intent being to separate the undisturbed or quiet-day normal variations from the rest and to compensate for geographical effects. The K index, which is commonly used for general purposes (e.g. Keeton, Larkin & Windsor, 1974; Martin & Lindauer, 1977), is intended to be a measure of solar corpuscular radiation based upon the intensity of geomagnetic activity caused by the electric currents produced in the ionosphere by such radiation. The K index is a measure of the activity during each 3-hour interval of the Greenwich day (which begins at midnight). The index has a quasi-logarithmic scale from 0 (least disturbance) to 9 and is based on the sum of maximum deviations from the undisturbed or quiet-day variations. The conversion of K indices into nT depends on the magnetic latitude of the observatory. K9 represents disturbances of 300 nT and above at low latitudes (except at the equator) and 2,500 nT or more in the auroral zones. Intermediate K values are adjusted accordingly. Several summary K indices are also published, giving geomagnetic activity for larger areas and longer time periods. There are three geomagnetic observatories in the UK, Lerwick in the Shetland Islands, Eskdalemuir near Edinburgh and a southern station which started at Abinger, south of London and moved to Hartland on the west coast in 1956/57. At Lerwick K9 represents disturbances of 1,000 nT and above and at Abinger/Hartland 500 nT.

Normal quiet-day geomagnetic fluctuations are published as the Sq series of indices. We may think of the Sq index as providing information analogous to the regular pattern of light levels (solar and lunar contributions) which would be observed at a point on the earth's surface if there was no meteorological disturbance. The K indices represent maximum deviations from this base but do also show diel and longer term patterns on average, for the reasons mentioned above.

The K indices themselves for Lerwick, Eskdalemuir and Abinger/Hartland are almost identical, because of the inherent latitude compensation. For the present purpose the three hourly K indices for 1929 to 1980 were obtained through the British Geological Survey, since these are the longest set.

Strandings

Of the 137 live strandings of cetaceans recorded in the original report files at the British Museum (Natural History), 89 occurred within the period for which K indices are available. As was shown previously (Klinowska, 1985a, b; Easton, Klinowska & Sheldrick, 1982), there are a number of biases in the UK stranding records, mainly attributable to uneven observer effort. The most important source of longitudinal biases is reduced effort (for obvious reasons) during and possibly just after the wars. The most important sources of regional biases are the distribution of Coastguard establishments (the main primary reporting network) and the more restricted legal reporting requirements in Scotland. These biases, however, affect the recording of passive strandings (at least in the regional dimension); live or active strandings are distributed in accordance with geomagnetic topographical features and have no relation to observer distribution (Klinowska, 1985a). Therefore, if the entire sample for this period of over 900 passive strandings (cases where animals were clearly described as having been dead for some time when first washed up) was taken as a control group, in effect this would compare events mainly recorded on the south and east coasts with live stranding events known to be distributed in a quite different way all around the country. Since the magnetic disturbances are greater at higher latitudes, there must be some *a priori* expectation that any relationship between strandings and magnetic disturbances will have a latitudinal component. Thus a control group heavily biased towards the south will not in fact be an effective control for two reasons. If passive strandings and active strandings are both related to geomagnetic disturbances the reporting biases will obscure any latitudinal relationships. On the other hand, if only live strandings are related to geomagnetic disturbances, the bias in reporting passive strandings will exaggerate the latitude effect. A calculation of