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Remote-Sensing Technology; an Alternative to Transmission-Telemetry for Determining the Behaviour of Penguins at Sea

Pelagic marine mammals and birds are particularly difficult to study at sea due to their relative scarcity, low profiles and diving habits. Consequently, until relatively recently most research on air-breathing marine animals consisted of work performed during the terrestrial phase of their annual cycle or of distributional data obtained by surveying their numbers at sea. Telemetry, the transmission of data via radio or sonic waves from a package-carrying animal to a receiver based elsewhere, has had limited success in the marine environment due to marked signal attentuation by sea water. Researchers have had to accept that range limitation imposes practical constraints on their ability to monitor telemetrically the activities of smaller marine animals (e. g. Trivelpiece et al. 1986). Even large whales, with the potential to carry considerable power packs, cannot be telemetrically monitored over long distances without aerial or ship-based support (e. g. Ray et al. 1978).

Non-radio-telemetric remote-sensing devices must sense and then store information to be later retrieved when the package-carrying animal is recovered. Although this methodology requires that the study animal be recaptured, there are no range limits and there is no labour, power or cost intensive period when the animal is at sea. Remote-sensing devices for marine animals were initially large (ca. 700 g; e. g. Kooyman et al. 1971) and therefore could not be deployed on animals smaller than medium sized seals. Subsequently, with the inception of micro-electronics, devices could be made small enough (ca. 95 g; Kooyman et al. 1982) to be carried by penguins (e. g. Lishman & Croxall 1983). Concomitant with size reduction, however, the cost of electronic devices increased (ca. $ 3000 per unit), an undesirable facet with the potential for losses being so high.

In 1971 Kooyman et al. utilized a non-electronic maximum depth gauge weighing ca. 1 g and costing $ 0.10. Although this device only gives one piece of information (the maximum depth attained during the full period at sea) its low cost and small size have meant that it has been extensively used on animals as small as auks (e. g. Burger & Simpson 1986).

In 1984, we used autoradiography to build an inexpensive (ca. $ 10) depth gauge weighing 20 g (Wilson & Bain 1984a). A beta emitter was attached to the depth indicator in a cheap depth gauge. Radiation sensitive film was placed over the face of the gauge so that indicator position, i. e. depth, was recorded by selective exposure of parts of the film through the beta particles. Furthermore, since the density of blackening on the film was related to expsoure time, the time at depth could be calculated. We employed a similar principle to build a speed/distance meter (mass 5 g, cost ca. $ 0.30; Wilson & Bain 1984b) which consisted of a beta emitter mounted on a moving speed indicator. This device has been subsequently used by a number of authors to determine that most species of penguin normally travel at speeds between 5 and 12 km/h and have foraging ranges between 15 and 500 km (e. g. Wilson 1985, Adams & Wilson 1987, Adams 1987).

Although autoradiography enables cheap, small ('nuclear powered') devices to be built, the usage of radioactive materials is restricted and thus many researchers are unable to utilize this technology.

The concept of recording data on film led us to consider using light as a power source for making exposures. Photographic film responds to light far more readily than X-ray film does to ionizing radiation. Furthermore, the dynamic range of photographic film is more than 100 times that of autoradiographic film. Initially we developed a depth gauge that, like the autoradiographic gauge described above, recorded the total time that the gauge spent at each depth underwater. In this case we modified a normal plastic syringe by sealing the needle end and inserting the bung to produce an enclosed volume of air. With increasing water depth (i. e. hydrostatic pressure) the pressure of the enclosed air increased to compensate by incurring a volume reduction brought about by movement of the bung. Thus, bung position indicated depth. We fitted a small light emitting diode (LED) and battery onto the bung and placed photographic film over the unit. Bung position was recorded by the film. The amount of time that the bung spent at particular positions on the film was also recorded by changes in the optical density of the film. This system can be built for a material cost of ca. $ 2 and weighing approximately 4 g. We used this 'syringe depth gauge' to determine that Rhinocerus Auklets Cerorhinca monocerata in British Columbia, Canada were foraging as deep as 60 m although 90 % of their time underwater was spent at depths of less than 10 m (Wilson et al. in press).

At the Institute für Meereskunde we have been developing a system to enable us to determine where penguins go when they are foraging at sea. Previously, it was thought that this type of information could only be determined by using telemetric devices. As outlined earlier, telemetry has limited application in marine studies. However, we have built a device that functions using 'dead reckoning' to automatically store information on an animal's movements at sea. The device has been designed for penguins and it records the direction that the birds swim and the speed at which they are swimming as a function of time. Thus, if the start position of the penguin is known the movements of the bird during the period at sea can be reconstructed. The direction that the penguins face is sensed by Hall generators (devices sensitive to a magnetic field) in association with a miniature fluid-filled ship's compass. Each Hall generator is linked to a LED and a battery. When the south pole of the magnet comes within a critical distance of the Hall generator, a voltage is produced which caused the relevant LED to become illuminated. Different LEDs indicate different headings. The speed of the penguin is indicated by the position of a spring-mounted arm which lies perpendicular to the normal water flow. Increased speed of the bird through the water causes greater deflection of the arm. The arm has a small magnet glued to the unattached end so that arm position can be sensed by an adjacent linear

Hall generator. Increased water flow causes the arm to move closer to the Hall generator which increases magnetic flux in the vicinity of the sensor. The Hall generator produces a voltage proportional to magnetic flux. This voltage is used to activate a LED which becomes brighter with increasing water flow. The functioning of the LEDs used in determining the penguin's heading and speed is recorded photographically. All LEDs are mounted parallel and encased in transparent plastic and 8 mm cine film is moved over the display as a function of time. Each LED selectively exposes a specific, unique track on the film. The density of blackening on the film is determined by the luminous intensity of the individual LEDs, the length of time that they are illuminated and the speed of movement of the film. The temporal and quantitative functioning of the LEDs can be determined by analysing the film with a densitometer. The whole device has a material cost of about $ 20 and has a mass of 30 g and theoretically should not present a problem even for small penguins (Wilson et al. 1986).

We successfully field tested this dead reckoning automatic sensor on African Penguins (Spheniscus demersus) in September 1987. Such work on a temperate species of penguin enabled us to isolate potential faults which could prevent the system from functioning in more extreme climes. During December 1987 and January 1988 we will be utilizing our dead reckoning sensors on Adelie Penguins (Pygoscelis adelie) in Antarctica. We hope to discover, not only where the birds are going when they leave for the sea to forage, but, by looking at changes in swimming behaviour, specifically where they catch food. This information will be coupled with data on penguin energetics to give us a more comprehensive insight into the energetic costs of living for these birds.

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