2.2 Devices

Even though, the two projects involved in this study wanted to answer different questions, they were using the same methodological approach by using remote sensing devices.

2.2.1 The dead-reckoners

The dead-reckoner (140 g, 90 x 65 x 28 mm, Fig. 5) consisted of a multi-channel logger capable of storing up to 32 mbytes of data in a flash RAM with 16 bit resolution at sampling intervals of between 1 s and 24 h (Driesen und Kern GmbH, Germany). The unit was potted in resin, which incorporated a titanium turned battery housing containing 2 X 3.6 V Saft Lithium cells (SAFT, Bagnolet, France) as well as an infra-red interface for communication with a computer. Depending on the different configurations of the dead-reckoners (which had been further improved during this study), they could be connected to the following sensors:

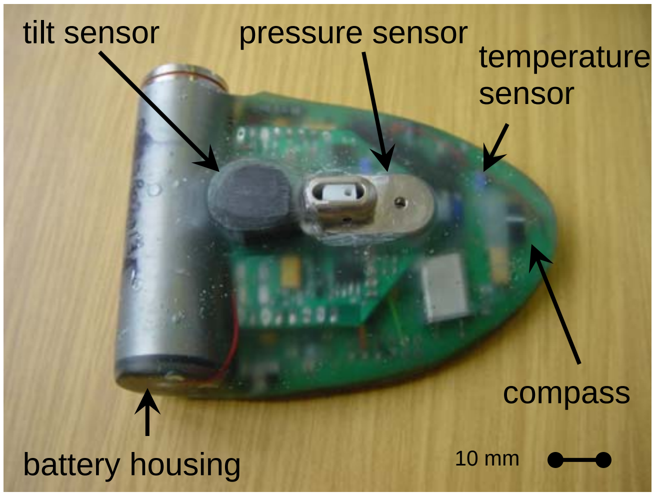

Figure 5. The dead-reckoner from Driesen und Kern, capable of recording 12 different channels.

- Depth (1 channel): This was sensed by a medium-separated Keller 10 bar (harbour seals) or 50 bar (Weddell seals) pressure sensor (Keller, Germany) and corrected for temperature effects via integration with a temperature sensor (see Temperature 1 internal below). Nominal accuracy gave a resolution of better than 2 cm water depth.
- Speed (1 channel): This was also sensed by a medium-separated

Keller 10 or 50 bar pressure sensor (Keller, Germany) and corrected for temperature effects via integration with a temperature sensor (see Temperature 1 internal below). However, in this application, the sensor was placed immediately adjacent to the depth sensor so that it recorded both hydrostatic pressure as well as speed. The speed component was sensed by having a paddle (~ 20 x 20 mm) protruding into the water column, leading at its proximal end to an axle, and a moment arm (~ 3 mm - leading away at 90° to the original paddle arm - Fig. 6) which terminated in a ball and socket arrangement so that the

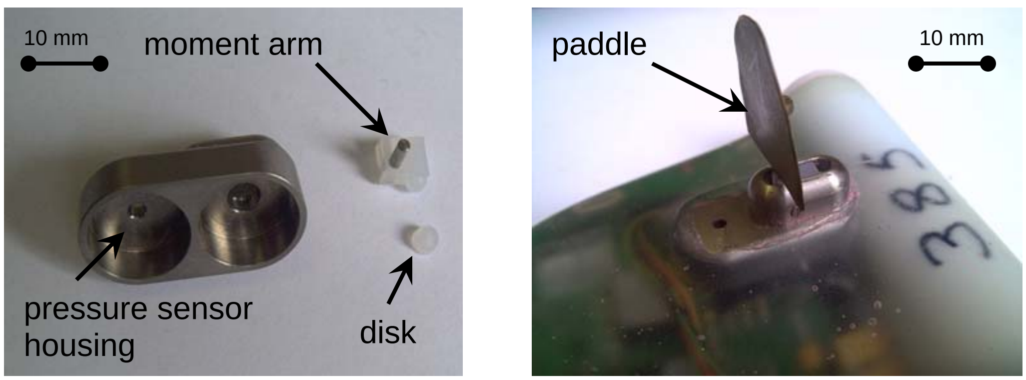

Figure 6. The paddle arm system used for the speed measurement.

socket, which consisted of a small disk (Ø 3 x 1.5 mm), rested on the membrane of the pressure transducer. Thus, forward speed produced a force on the paddle, which was transferred via the moment arm onto the membrane on the pressure transducer. For details of this system see Wilson et al. (2004). The transducer recorded the sum of the pressure due to hydrostatic pressure and that due to the force generated by swimming. Subtraction of the output of depth from this channel output (see above) produced an output corresponding to speed. The calibration for speed could be carried out on the animal by consideration of the sensor output in relation to speed calculated using dive (or return-to-surface) angle in relation to rate of change of depth for periods where there was an appreciable rate of change of depth (see later). This is a refinement of the method suggested by Blackwell et al. (1999) and accords with that used by Mitani et al. (2003) and Sato et al. (2003).

- Heading (3 channels): Heading was determined using a solid-state compass (Honeywell, USA) which resolved the 3 components of the earth's magnetic field into vectors according to the known orientation of the sensor (determined by the body orientation with respect to gravity - see below). The procedure for doing this is detailed in Caruso (2000). This gives a resolution of better than 1° in animal heading.
- Body orientation with respect to gravity (2 channels): An angle-sensing system (VTI, Sweden) was used here, which was so orientated within the package that it resolved pitch and roll, both within the range +90 to -90°, to within 1° after calibration. In order to determine when the animal was swimming or lying on its back, which led to the system giving spurious results, consideration of the output of this sensor had to be combined with the mercury orientation switch (see below).
- Body position (inverted or otherwise) (1 channel): For technical reasons the pitch/roll sensors (see above) were unable to determine body angles exceeding 90° from the horizontal. Thus, an animal swimming on its back, could not be perceived as such by the sensors. For this reason a single channel was devoted to determining whether the device (seal) was inverted or not. The sensor for this was based on a mercury switch and although rather primitive (on or off) it was more than adequate for us to resolve the issue.
- Temperature 1 (internal) (1 channel): In order to correct for temperature-related inconsistencies in pressure transducer outputs, the dead-reckoner had a PT 1000 (Heraeus, Germany) temperature sensor placed directly adjacent to the pressure sensor. This sensor enables temperatures to be measured to 0.03° C accuracy. Correction of the pressure and speed values occurred in the software after the data had been accessed by the computer.
- Temperature 2 (external) (1 channel): This sensor, also a PT 1000

(Heraeus, Germany) was used to measure ambient water/air temperature. Although it measured temperature to within 0.03° C (absolute accuracy) and was placed close to the surface of the logger, it suffered considerable lag due to the thermal inertia of the logger itself. This had to be borne in mind when data were assessed.

- Light 1 (red wavelengths) (1 channel): This sensor, from Tropas (Tropas, USA) measured red light intensity within the range ca. 0.01-100,000 lux (absolute daylight wavelength values) to the nearest 2 lux. As expected, it was highly sensitive to orientation (although this could be corrected by consideration of sun angle with respect to animal/logger angle) and thus values should be taken as approximate.
- Light 2 (blue wavelengths) (1 channel): This sensor, from Tropas (Tropas, USA) was covered with a Schott blue filter (BG-28) and thus measured blue light intensity within the range ca. 0.01-100,000 lux (absolute daylight wavelength values) to the nearest 2 lux. It was highly sensitive to orientation (although this could be corrected by consideration of sun angle with respect to animal/logger angle) and thus values should be taken as approximate.

Over time, different versions of the dead-reckoner became available with different channel and memory configuration. During the first part of the MINOS project, a 12 channel logger was used with all the channels mentioned above and an 8 MB memory. Later, during the follow up project MINOS+, the channel configuration was reduced to 10 by leaving out the external temperature sensor and one light sensor. At the same time the memory capacity was increased to 32 MB. During the Antarctic cruise, a 12 channel 32 MB version was used on the Weddell seals.

2.2.2 The satellite transmitter

The satellite transmitters (also known as PTT - Platform Terminal Transmitters) are termed as the SPOT 2 and 3 models, produced by Wildlife