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Refining instrument attachment on phocid seals

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During the 1960s through to the early 1980s, harnesses were used to attach instruments to diving marine animals such as seals and penguins. Such devices were replaced with epoxy and cyan glues and specialist adhesive tapes in the mid-1980s because of chafing and drag issues (Wilson *et al*. 1997, Kooyman 2007). Fedak *et al*. (1983) were the first to glue instruments directly to the fur of a seal. This simple, direct form of instrument attachment has become the norm in pinniped research, though details of exactly how, where, and what specific products are used vary (*e.g*., Fedak *et al*. 1983, Le Boeuf *et al.* 1988, Harcourt *et al.* 1995, Zeno *et al.* 2008).

The attachment of tracking and bio-logging devices has been identified as a particular animal welfare concern (Hawkins 2004), the main concern being that these attachments may cause physical pain and suffering with subsequent changes in behavior or survival. Two recent studies (McMahon *et al*. 2008, Mazzaro and Dunn 2009) have specifically assessed the impacts of attaching tracking instruments to seals. McMahon *et al*. (2008) clearly demonstrated that for southern elephant seals (*Mirounga leonina*), carrying tracking devices produced no detectable differences in overwinter mass gain nor in long-term survival. In a study conducted with two captive harbor seals (*Phoca vitulina*), Mazzaro and Dunn (2009) noted no tag-associated changes in health or behavior until one tag started to loosen a few days before detachment, at which time a small area became irritated when the epoxy cracked and began rubbing against the seal. However, there have been no studies of potential injuries that might lead to pain as a result of instrument attachment on wild seals. This is primarily because of the difficulty in monitoring instrumented marine mammals following their release.

Here we (1) present information on the performance of three different, widely used, epoxies to determine whether any of them might cause burns *via* exothermic chemical reactions when the glue cures under common fieldwork conditions in subantarctic and polar deployments; and (2) review injury rates for 454 southern elephant seals and 54 Weddell seals (*Leptonychotes weddellii*) that have been resighted after instruments have been deployed.

We designed a laboratory experiment to assess whether commonly used two-part epoxies reach curing temperatures sufficient to burn a seal during instrument attachment (under simulated field conditions). The peak temperature reached within and around the epoxy as it cures depends on the volume of epoxy used over a given surface area and how much the instrument insulates the epoxy under it. Other factors like the speed of curing, the initial epoxy temperature when applied, the temperature of the tag, or other attached materials can also have important effects. For each epoxy we tested (Araldite 268–1, Huntsman Advanced Materials, Deer Park, Victoria, Australia; Devcon 5 minute epoxy, ITW Devcon, Danvers, MA; and RS quick set epoxy, RS Components, Corby, Northamptonshire, U.K.), we attached three dummy instruments to nylon-lined 7-mm neoprene. The dummy instruments were made from 35-mm-thick acrylic blocks similar in dimensions to a Sea Mammal Research Unit satellite-linked data logger (Boehme *et al*. 2009) with a footprint area of approximately 100 mm × 70 mm. The neoprene was used to insulate the glue and simulate the thermal properties of a seal's skin and blubber layer. The experiment

Table 1. Typical epoxy thickness used during curing temperature tests along with the temperature maxima and effective curing times.

Epoxy	Epoxy thickness (mm)	Maximum curing temperature (°C)	Time to effective curing (min)
Araldite 268—1	4	33.2	17
Devcon 5 min	2	33.7	19
RS quick set	2	25.4	27

was undertaken in a temperature-controlled room, with the room's temperature varying from 2.7°C to 6.8°C. The epoxies were kept at a constant temperature in a water bath of 6.5°C until mixed and used to cement the acrylic blocks to the neoprene. The dummy instruments were also kept in the temperature-controlled room prior to attachment. The thickness of the glue layer was similar to the amount that would normally be used when attaching instruments to seals (Table 1). The curing temperature of the glue was measured by placing a thermocouple between the neoprene and the acrylic block in the center of the area being glued. Temperature (±0.01°C) was recorded every 40 s using an ACR Smartreader Plus 6 data logger (ACR systems Inc., Surrey, British Colombia, Canada). The effective curing time was defined as the time when the two-component epoxy was mixed until its surface was slightly malleable (*i.e.*, leaving a shallow indent when pressed forcefully by a fingernail), but the dummy instrument did not move from the attachment site.

The temperature at which cell damage occurs causing a burn in mammals is ~50°C (Leach *et al.* 1943) when exposure lasts >10 min. In our experiment, the maximum temperatures recorded for all three epoxies were less than 34°C (Table 1, Fig. 1). Two of the epoxies had peak temperatures of around 34°C (Araldite and Devcon), while RS epoxy had a cooler peak at around 24°C. The higher curing temperatures for Araldite and Devcon epoxies were coincident with shorter curing times of 17 and 19 min, respectively, compared to 28 min for RS epoxy. These results suggest that under similar temperature environments, including temperate, subarctic and subantarctic, or polar field conditions, none of these epoxies are likely to cause a burn.

Over the past 11 yr, we have collected data on injuries related to instrument attachment for 508 seals that were either resighted or captured after being instrumented. These included 454 southern elephant seals (n = 232 at Macquarie Island and n = 222 at Marion Island) and 54 Weddell seals at Turtle Rock in Antarctica. Resightings of animals were collected when researchers made daily, weekly, or monthly observations at the seals' haul-out areas (Harcourt *et al.* 2000, Hindell *et al.* 2003, Field *et al.* 2007, de Bruyn *et al.* 2008). The animals had been instrumented in a number of different ways, with varying instrument footprint sizes, and for different periods of time. These resighting data provide the first opportunity to record presence or absence of injuries and relate these to the use of different epoxies or attachment techniques (Table 2). Resighting data included whether a seal had a burn mark, abrasions, or lesions (>50 mm^2). The occurrence and nature of the wounds (Fig. 2) were evaluated with respect to the location of the attachment (on the seal's back, shoulders, or head), the size of the attachment footprint (Fig. 3), the epoxy used, and the attachment technique (directly to the hair or using mesh/neoprene and

Table 2. The number and percentage (in brackets) of seals observed to have burns, abrasions or lesions greater than 10 mm *vs*. the types of epoxies used, whether the instrument was attached directly to the hair or using mesh and cable ties, and where the instrument was attached to the seal (on the head, shoulders or back) for instrumented southern elephant seals and Weddell seals at several subantarctic and antarctic field sites.

Species	Location	*n*	Epoxy	Attachment technique	Placement of device	Seals with burns	Seals with abrasions or lesions
Southern elephant seals	Macquarie Island	18	Araldite 268–1	Direct	Head	0 (0)	1 (5.6)
		214	Araldite 268–1	Direct	Shoulders	2 (0.9)	3 (1.4)
	Marion Island	222	Araldite AW 2101	Mesh	Head	0 (0)	32 (14.4)
	All	454				2 (0.4)	36 (7.9)
Weddell seals	Turtle Rock	37	RS 2107	Direct	Back	2 (11.8)	0 (0)
		17	Araldite 268–1	Direct	Back	0 (0)	0 (0)
	All	54				2 (3.7)	0 (0)
Overall		508				4 (0.8)	36 (7.1)

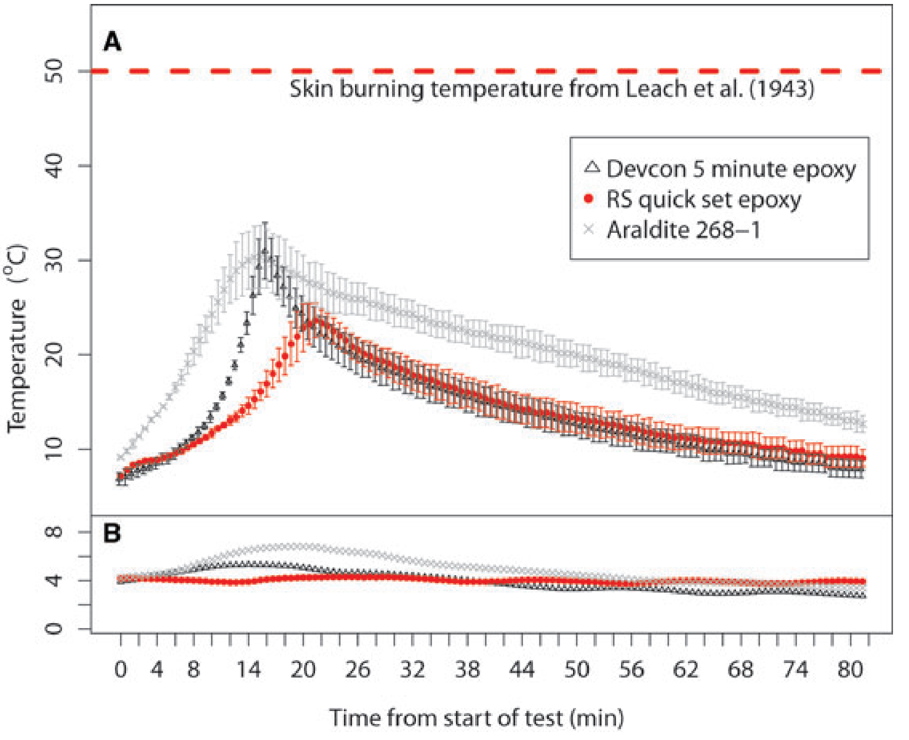

Figure 1. (A) Mean temperatures (±2 SE) recorded as each of the epoxies cured under realistic environmental conditions, and (B) the concomitant temperatures of the controlled environment room.

cable ties) (Table 2). Abrasions and lesions <50 mm^2 that were superficial or healed within 2–3 wk) were not considered further.

Four of the 508 seals had lesions under the footprint of the instrument that we suspect were caused by the epoxy getting too hot. All of these deployments occurred in 1999, and all involved the epoxy being heated (in a water bath between 20°C and 30°C) prior to mixing. The practice of preheating the epoxy has been abandoned for these projects. All four animals, the two elephant seals at Macquarie Island and the Weddell seals at Turtle Rock have been sighted in subsequent years, fully healed following the postinstrument-deployment molt.

Small superficial abrasions or lesions at or toward the edge of the footprint have been observed on 36 seals (∼7%; Fig. 2). These injuries were likely caused by abrasion between the skin and the edge of the glue patch or other material used for the attachments. Although we cannot separate the effects of epoxy type and use of direct instrument gluing *vs*. the use of various mesh/cable tie arrangements, it seems reasonable to suggest that the mesh and other materials were the source of increased abrasions, given that the various brands of epoxy are created for similar purposes and are likely to have similar properties, and mesh and cable ties have been suggested to be an issue regarding abrasions or lesions in other studies (Mazzaro and Dunn 2009).

Figure 2. Attachment sites on the seal's head (A) and on the shoulders (B). Two attachment sites, immediately post unit removal, are shown—one where the unit had rounded edges and has left no marks (C) and one where a sharp edge has left two small lesions (D) approximately 20 and 15 mm in length along the edge on the lower side of the image. Finally images E and F show an uninjured seal with hair discoloration and a seal with some healed scar tissue from an abrasion, respectively. Photo credits: images A, B, C, and D were taken by ICF, image E by LB, and image F by NdB.

All the abrasions observed in this study were healed following the first molt after instrument deployment.

This study highlights a number of key points beyond those suggested by Morton *et al*. (2003) and Casper (2009) for minimizing the impacts of attaching instruments for tracking or bio-logging studies involving seals:

- In cold conditions, although it may be necessary to prevent the epoxy from freezing, do not overheat the epoxy.
- In the field, use a touch test to make sure the epoxy is not too hot before attaching the unit.
- Keep epoxy volume and the attachment footprint to a minimum to reduce size and edge effects.
- Where possible, the edges of the epoxy that are adjacent to the seal's skin should be rounded upwards away from the seal to minimize sharp or abrasive surfaces.
- When possible, glue the devices directly to the hair/fur.
- In the field for each attachment process, note the environmental conditions, preapplication temperature of the glue, volume of epoxy used, footprint size of the epoxy and take photos of the instrument in place so future resights of the seal can be assessed in relation to any injuries that may be observed.
- Before using untried epoxies in the field, test the thermal properties under realistic conditions.

Our study supports the conclusions of McMahon *et al*. (2008) and Mazzaro and Dunn (2009) that, at least for the range and sizes of instruments discussed here, deploying instruments on Weddell and elephant seals has minimal short-term negative impacts and no detectable impact of biological consequence.

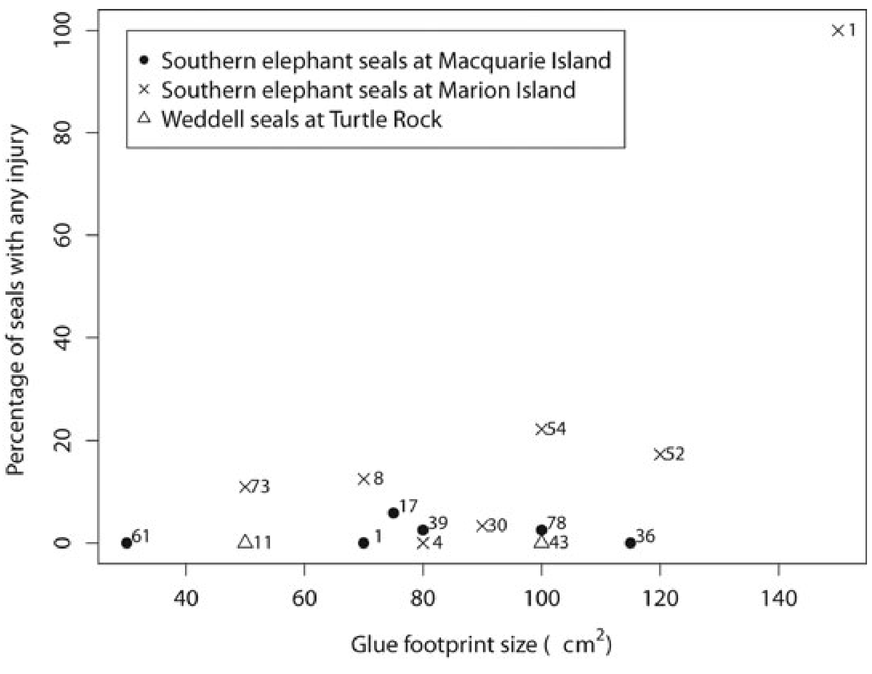

Figure 3. The relationship between the size of the epoxy footprint and the percentage of seals that had any injury, including burns, abrasions, or lesions greater than 10 mm. The total numbers of seals in each footprint size group are shown next to the data point.

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