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Materials and methods

Nine free-ranging Galapagos sea lions were immobilised for marking, using a combination of ketamine (3 to 5 mg per kg) and xylazine (0.5 to 10 mg per kg). The degree of effect depended largely on the animals' behaviour and physiological state before immobilisation (after parturition, high arousal, subject to aggression, etc.). All nine animals survived. Overheating in the immobilised state may quickly result in heart and circulatory failures.

Immobilisation of pinnipeds by means of drugs administered intramuscularly presents difficulties (Geraci 1973, Geraci and Sweeney 1978, Wiesner 1975). The drugs were injected intramuscularly into the thigh, where the blubber layer is comparatively thin, and penetration into the muscle easiest. Records were kept of the animals' behaviour from injection to recovery. Some were observed occasionally for several days subsequently. Only animals well inland were injected, to avoid the risk that they might re-enter the sea and drown. As the animals easily overheat, they were immobilised only during the cool early morning or late evening, and kept wet.

Results and discussion

Every syringe penetrated the tough hide, but the extreme tips of some of the needles were bent slightly. Only one syringe tried to keep its head up, scanning the surroundings. Immobilised animals sat still or lay down after five to 10 minutes.

The drugs were injected intramuscularly into the thigh, where the blubber layer is comparatively thin, and penetration into the muscle easiest. Records were kept of the animals' behaviour from injection to recovery. Some were observed occasionally for several days subsequently. Only animals well inland were injected, to avoid the risk that they might re-enter the sea and drown. As the animals easily overheat, they were immobilised only during the cool early morning or late evening, and kept wet.

Weight estimates were not very accurate. Average-sized adult females were assumed to weigh about 80 kg; the measured weights of a few immatures were about 25 kg. According to their size and physical state, other animals were estimated between these extremes. The degrees of immobilisation obtained were categorised into six classes (Table 1), similar to those defined by Briggs and others (1975).

Results and discussion

Every syringe penetrated the tough hide, but the extreme tips of some of the needles were bent slightly. Only one syringe, shot obliquely, did not penetrate deeply enough to inject the drugs.

Table I shows the results of nine immobilisations of Galapagos sea lions with a combination of ketamine and xylazine. Some animals hardly reacted to the syringe’s impact, bit at it, stood up, walked a few steps, looked round, and sat or lay down again. Because of their general inactivity, it was difficult to determine when the drugs took effect, and this time is given in the table only to the nearest five minutes. Often the first sign of an effect was somewhat laboured breathing, while the animal still tried to keep its head up, scanning the surroundings. Immobilised animals sat still or lay down after five to 10 minutes.

---

**TABLE 1:** Results of immobilisation experiments with Galapagos sea lions

<table>
<thead>
<tr>
<th>Number</th>
<th>Age</th>
<th>Sex</th>
<th>Estimated weight (kg)</th>
<th>Ketamine dosage (mg/kg)</th>
<th>Xylazine dosage (mg/kg)</th>
<th>Kineticin (150 IU)</th>
<th>Time (min) before first effects</th>
<th>Recovery after (min)</th>
<th>Degree of effect*</th>
<th>State before injection</th>
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<tbody>
<tr>
<td>1 1y</td>
<td>d</td>
<td>30</td>
<td>4.3 0.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>75</td>
<td>1</td>
<td>1</td>
<td>Sleeping</td>
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<tr>
<td>2 1y</td>
<td>g</td>
<td>25</td>
<td>3.2 0.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>60</td>
<td>3</td>
<td>3</td>
<td>Sucking</td>
</tr>
<tr>
<td>3 8y</td>
<td>g</td>
<td>30</td>
<td>4.0 0.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>50</td>
<td>3</td>
<td>3</td>
<td>Resting</td>
</tr>
<tr>
<td>4 2-3y</td>
<td>d</td>
<td>40</td>
<td>5.0 1.0</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>40</td>
<td>2</td>
<td>2</td>
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</tr>
<tr>
<td>5 3-4y</td>
<td>d</td>
<td>40</td>
<td>4.2 0.75</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>60</td>
<td>2</td>
<td>2</td>
<td>After</td>
</tr>
<tr>
<td>6 adult</td>
<td>g</td>
<td>80</td>
<td>2.0 0.3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>100</td>
<td>2</td>
<td>2</td>
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<tr>
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<td>g</td>
<td>80</td>
<td>2.5 0.65</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>1-2</td>
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<td>d</td>
<td>70</td>
<td>1.8 0.3</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>70</td>
<td>2</td>
<td>2</td>
<td>Resting</td>
</tr>
<tr>
<td>9 adult</td>
<td>d</td>
<td>70</td>
<td>2.8 0.35</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>70</td>
<td>2</td>
<td>2</td>
<td>Resting</td>
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* 0=no visible effect; 1=incapable of locomotion but able to resist handling; 2=capable of movements of head and hindquarters; 3=incapable of any movement; 4=flaccid; 5=sleeping totally relaxed

† Second dosage given 40 min after first injection
The maximum degree of immobilisation reached in each animal did not appear to be strictly dose-related. One reason may be that the weight estimates were only rough ones. In addition, the spots hit by the syringes were of course not exactly uniform, and in some cases some of the drugs may have been lost in the blubber.

Another factor strongly affecting the success of the immobilisation was the activity and/or excitation of the animals before the injection. The one-year-old male (1) was sound asleep when injected. He actually slept for about 20 minutes while immobilised and was unable to move for about an hour, with a dosage of 4.3 mg per kg ketamine and 0.5 mg per kg xylazine. Males 4 and 5 had been moving slowly and occasionally interacting with one another when injected, with about the same dosage as male 1, but these showed a lesser degree of immobilisation (Table 1). Male 8 was injected with only 1.8 mg per kg ketamine and 0.3 mg per kg xylazine; a dosage obviously too low to immobilise a sea lion; it showed no signs of immobilisation. Generally, a dosage of 3 to 4 mg per kg ketamine and 0.5 to 1.0 mg per kg xylazine permitted safe handling. However female 7 was injected twice, receiving a total dosage of 4.0 mg per kg ketamine and 1.1 mg per kg xylazine, and it could still resist handling, at least by a single person. It had given birth about eight hours before the injection, and the physiological stress of birth may have made it more drug-resistant.

A similar finding was made in the Münchner Tierpark Hellabrunn when one of us (H.W.) tried to immobilise a very excited South American sea lion (Otaria byronia) directly after parturition. The animal was estimated to weigh 50 kg. It showed no effect after the injection of 3.6 mg per kg ketamine and 0.18 mg per kg xylazine. This dosage was repeated after 20 minutes, again with no results.

As mentioned by Geraci (1973) and Briggs and others (1975), animals immobilised with ketamine alone showed moderate to strong tremors. For that reason ketamine should not be used in pinnipeds suffering from any form of respiratory disease, or on animals with a history of hypersensitivity to cyclic amides. Salivation was apparently somewhat increased. This should be prevented by the use of atropine in the next trials. But even animal 1, which was sleeping deeply, kept breathing quite regularly, although occasionally gurgling a little.

Later on, animals 1, 2, 3, 6 and 7 were seen several times, and showed no after-effects of the immobilisation.

Thermoregulatory risks accompanying immobilisation

In the California sea lion it has been demonstrated that at an air temperature of 30°C physiological means of thermoregulation are insufficient to maintain body temperature at a normal level (Whittow and others 1971, 1972). Temperatures at which this applies may even be much lower, as the 19° to 29°C range was not tested. Observations on free-living California sea lions (Peterson and Bartholomew 1967, Odell 1974), Steller sea lions (Gentry 1973), and other pinnipeds (e.g. White and Odell 1971, Gentry 1973, Bartholomew and Wilke 1956) and these observations on the Galápagos sea lion (Fig 1) show that even resting animals tend to sluice themselves increasingly as radiation and substrate temperatures rise. Dry pups of the Galápagos sea lion overheat considerably within only 15 minutes when active at substrate temperature 29°C and air temperature 23-8°C (Trillmich, unpublished data).

In the helpless, immobilised state there is grave danger of death from overheating, as the pinnipeds are incapable of the thermoregulatory behaviour normally resorted to. Also when recovering from immobilisation there was high sustained activity, especially when trying to escape from an observer. The animals would rear up and move with highly exaggerated movements, falling down frequently. All this could soon have caused overheating, if the animals had not been kept wet by sluicing with cold sea water until their movements became almost normal. Sluicing also wets the sand on which they rest, increasing heat loss by conduction (Ohata and Whittow 1974).

Although the few immobilisations of Galápagos sea lions with ketamine plus xylazine do not yet provide conclusive evidence that the method is safe, the described results show it to be superior to the use of ketamine alone (Eulenberger and Puschmann 1976, Geraci 1973). Perhaps the xylazine dosage should be slightly increased to obtain a higher degree of immobilisation. In further experiments the behavioural state of the animals (activity, general arousal, parturition, etc) should be taken into consideration, as well as the danger of heat prostration, which may be the main cause of heart and circulatory failure in pinnipeds after immobilisation.

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