

## **Apnea: Ashore and at Sea**

### **Definitions:**

Apnea: transient cessation of respiration.

Eupnea: normal respiration.

Sleep Apnea: (for our purposes) sleeping without breathing.

Note: In humans, sleep apnea is considered a medical disorder, while in elephant seals it seems to be an evolved, energy and water saving response.

In this paper, seals always refer to elephant seals (ES).

We know that when seals are resting on the beach they often undergo apnea for several minutes at a time. How soon does this ability to sleep without breathing develop? Is it the same for all ages? How long are these apneas? Do the seals also experience reduced heart rate during apneas ashore? Do they breathe while asleep? This paper will discuss the development of apnea, beginning with neonates, and attempt to answer all these questions.

### **Apnea at sea**

#### **The dive response**

1. Apnea (not breathing)
2. Bradycardia (reduced heart rate)
3. Vasoconstriction (reduction of blood flow to the extremities)

This complex of physiological changes during a dive is called the dive response. Apnea is just one of three major responses to an ES dive. The heart rate markedly slows and peripheral blood circulation is greatly reduced. The core organs receive blood as needed, with the heart and brain being continuously supplied. Restricting peripheral blood flow reduces heat loss as well as making less work for the heart. In both cases this reduction in energy usage means a saving in oxygen consumption. Little research has been done regarding vasoconstriction; it will not be discussed in this paper.

### **Apnea ashore**

Mammals generally are born able to undergo periods of apnea. This is a mechanism that enables them to survive many of the complications of birth that might cut off their supply of oxygen. So it is no surprise that ES pups can undergo apnea. The unusual part is that they experience apnea while simply resting or sleeping. Neonates, on average, undergo longer apneas than nursing pups and also spend a larger percentage of their time in apnea than nursing pups. For other mammals the ability of newborns to undergo apnea begins to diminish as the trials of birth are past. With ES however, the ability to undergo apnea decreases during the nursing period, then begins to increase around the time of weaning, and generally weaners experience longer apneas than neonates. This trend continues as the weaners prepare for their first migration. Figure 1 shows the average lengths of apneas ashore for eight age and sex groups. There were about 20 animals in each of the age and sex groups studied.<sup>1</sup> The development of apnea was determined by selecting seals in different age groups, not by following the same seals over several years.

Because of these sample sizes the most we can say about the mean lengths of apneas for the groups old weaners through adults is that they are all in the range 7.5 to 10 minutes.

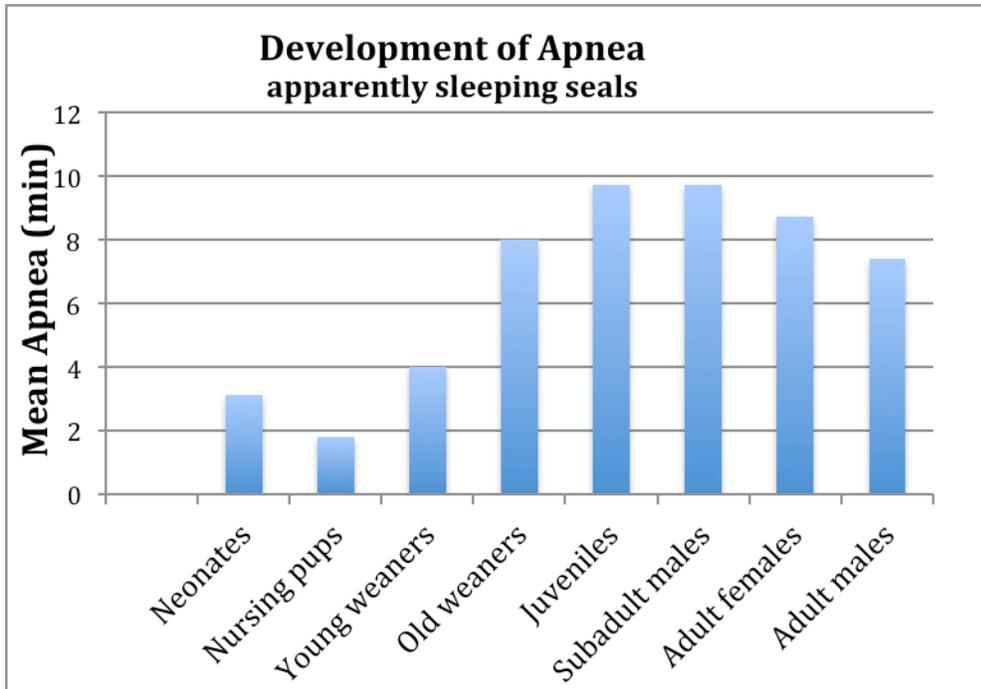


Figure 1. Based on visual observation of apparently sleeping seals. The length of apneas for the age groups old weaners through adult are not statistically different.

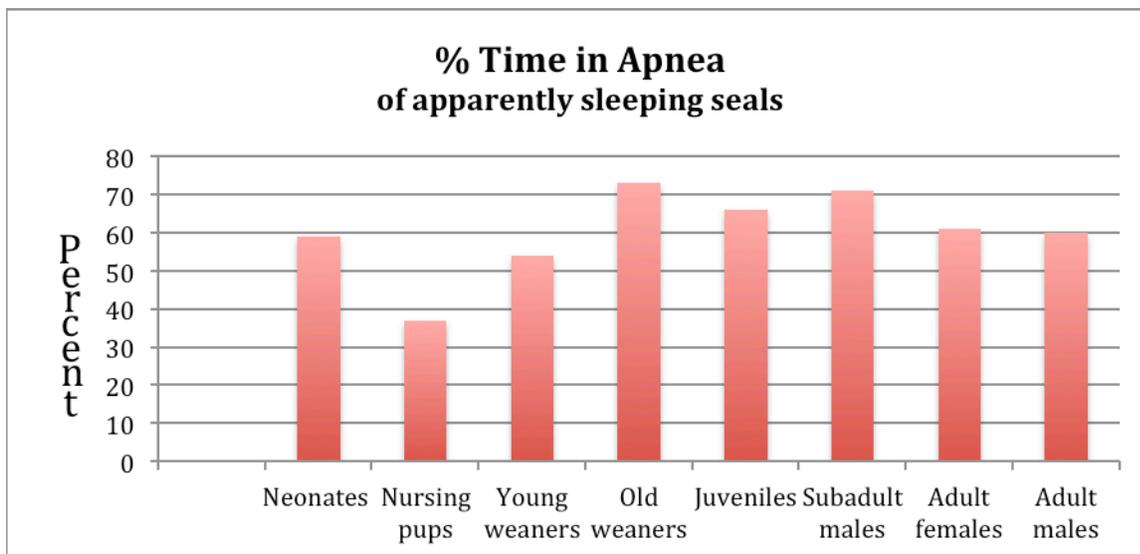


Figure 2. The percent of resting time spent in apnea based on visual observation of apparently sleeping seals.

How does apnea on shore compare to apnea at sea? Figure 3 uses data Blackwell compiled from several sources to make this comparison for different age and sex groups. Each juvenile and adult group represents data from multiple apneas ashore as well as many dives. Most of these groups comprised about 20 seals. Data from animals at sea is obtained from time/depth recorders that show when the seal is at the surface.

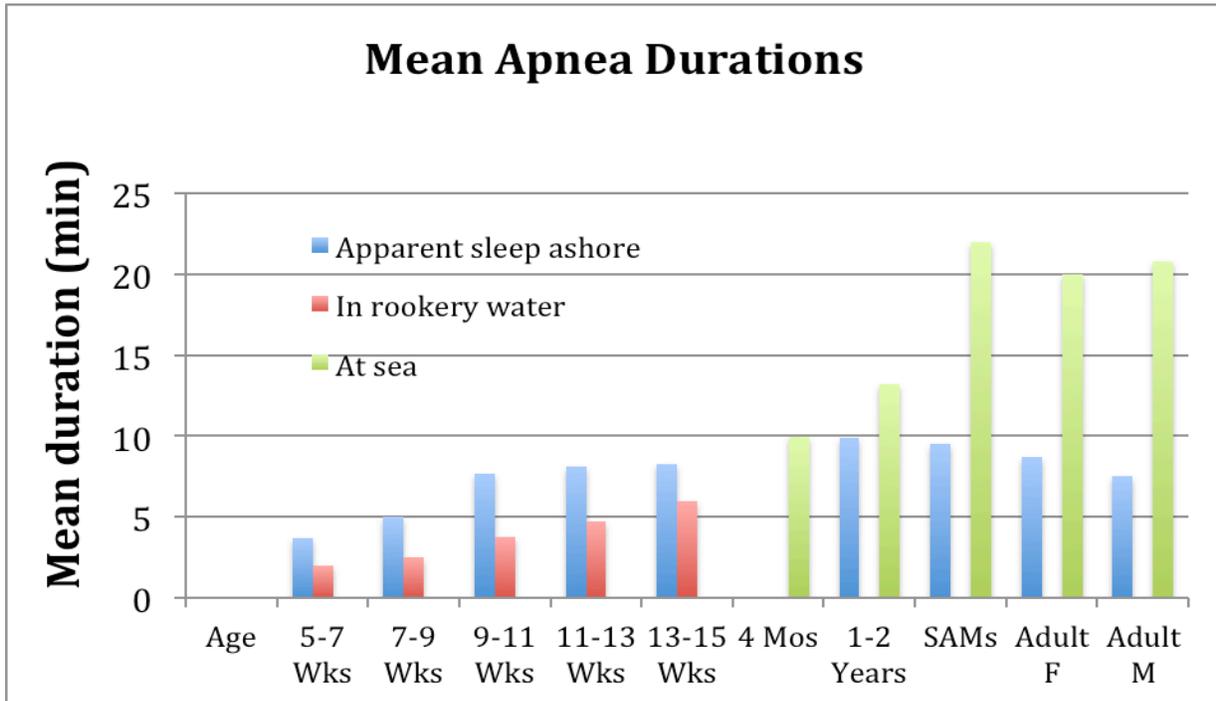


Figure 3. The left side of the graph shows weaners in the rookery, the right side shows weaners on their first migration and older animals at sea.

### Heart rate

Another major aspect of the dive response is heart rate (HR). A seal diving at sea experiences a high HR at the surface (around 100 beats per minute (bpm)), but immediately as it dives the HR drops (often to between 15 and 40 bpm). It remains at that rate until the seal nears the surface. Does this pattern carry over to apneas ashore? To answer this question, four juveniles were instrumented with HR and respiration monitors.<sup>2</sup> They were moved about 100 miles off shore of the rookery. Data was recorded during their return to the rookery and for 12 to 18 hours thereafter. On shore, the data was tabulated only for periods of sleep or quiet rest. At sea their HR's averaged 33 bpm during dives (apnea), and 105 during surface intervals (eupnea). Ashore their HR's averaged 45 bpm during apnea, and 65 bpm during eupnea. We see a reduction of HR during both instances of non-breathing, but it is much less extreme ashore. This does not seem surprising since a seal on land can breathe at will while a seal at sea has to wait to return to the surface no matter how stressed it might feel. (Note: the most extreme low HR's are found in laboratory studies involving forced diving, and at sea if a seal reverses its ascent and goes down again.)

The data also allows a comparison between respiration rates between dives and while resting ashore. At sea the seals had a high respiration rate (averaging 23 breaths per minute); while resting ashore the rate was 9.2 breaths per minute. But when the breaths were counted over a cycle of dive and recovery, or of not breathing then breathing ashore, the average overall respiration rates were about the same (2.3 breaths per minute at sea vs. 2.6 breaths per minute resting ashore).

	Apnea (min)	Apnic HR	Eupnic HR	Eupnic Breath rate	Episode Breath rate	% of Time in Apnea
At Sea	17	33	108	23	2.3	89
Ashore	9	45	65	9.2	2.6	67

Table 1. Averages based on four seals undergoing 47 dives, and 127 periods of apnea ashore.

### Apnea and sleep

Do seals breathe while they are asleep? To determine this the seals had to be instrumented with EEG (electroencephalogram) monitors. This allowed the researchers to distinguish between wakefulness, slow wave sleep (SWS), and rapid eye movement (REM) sleep.<sup>3</sup> This study involved pups about 4 months old. Because of the monitors, this study was done in a lab with a dry area and a tank for swimming. Data was taken while they were dry, and when they were in water. A typical pattern is shown in the strip chart (Fig. 4). We see there are periods of SWS when the pups breathed. The researchers report that this same pattern was observed with the pups sleeping in water: they would raise their heads above water to breathe without awakening. REM sleep only occurred during apnea, whether the seals were in water or dry

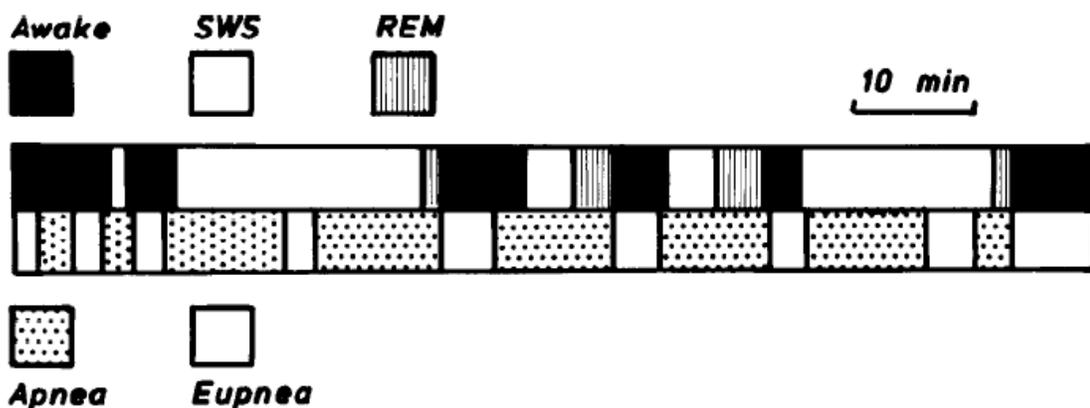


Figure 4. Awake-sleep state and apnea-eupnea patterns recorded during an hour from a dry weaner in the lab.

## Conclusions

- It is normal for ES neonates to sleep without breathing. Although this ability decreases during nursing, by weaning it begins to increase. Average apneas ashore for old weaners through adults are all in the range of 7 to 10 minutes.
- Apneas ashore involve a lowered HR, though not nearly as low as diving seals.
- ES may interrupt apnic periods to breathe without waking, or undergo periods of apnea while quietly awake.

Summary by Tim Postiff

Papers cited are listed by lead author and title.

<sup>1</sup>Blackwell, Susanna B., Developmental aspects of Sleep apnoea in northern elephant seals, *Mirounga angustirostris*.

<sup>2</sup>Andrews, R. D., Heart rates of northern elephant seals diving at sea and resting on the beach.

<sup>3</sup>Castellini, Michael A., Patterns of respiration and heart rate during wakefulness and sleep in elephant seal pups.