AMONG FRIENDS

Friends of the Elephant Seal Member Newsletter

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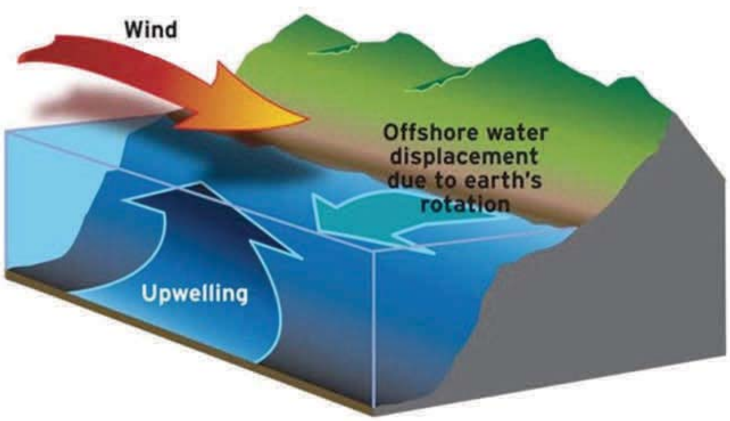
Spring 2015

Coastal Upwelling

Reports about starving sea lion pups have been much in the news, recently. Research suggests that the main cause for this lack of food may be a major reduction in the usual coastal upwelling. Perhaps some information on the causes and effects of coastal upwelling is in order. Coastal upwelling is caused by a particular combination of shoreline direction, wind direction, and the spin of the earth. It is the spin of the earth that causes the wind driven water to be pushed off shore – the *Coriolis* effect.



Matching the diagram to our area, the wind is the California Central Coast's prevailing wind out of the northwest. The *Coriolis* effect is a force that shoves this moving water to the west. Replacement water comes from below and is referred to as the upwelling.

Coming from the bottom, this cooler water is rich in nutrients that support phytoplankton and seaweed growth. Phytoplankton uses sunlight and the nutrients to multiply rapidly and form the energy base of a food web that supports not just sea lions, but fish, sea birds and other marine mammals.

The inconstant factor in the upwelling equation is the wind. If it is weaker, comes from a different direction, or blows for fewer days, upwelling will be reduced. Last winter and spring, the northwest wind was less prevalent and the food supply was affected. If this year follows a similar pattern, many species will again be affected.

How important is coastal upwelling globally? While only about one per cent of the ocean is involved in coastal upwelling, that area accounts for about 50% of the take of the world's fisheries.

Northern elephant seals, feed in many areas not involved in coastal upwelling, and do not seem to be suffering.

Foraging

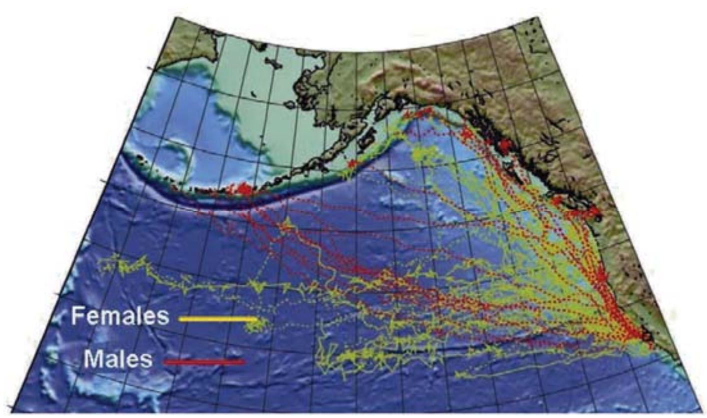
What, When, and Where E-Seals Eat

We are fortunate to be close to the elephant seals during their time ashore. We know that, unique for mammals, they migrate twice a year. For juveniles each migration is roughly 5 months and for adult males about four months. Adult females undergo a short migration of about 2 ½ months after weaning their pup and a long migration of 7 to 8 months after their spring molt.

The behavior of elephant seals on shore is relatively easy to document. However, until fairly recently, their life at sea, 90% of which is underwater, was little observed. As electronic trackers evolved, more information about their marine existence became available. Current trackers use global positioning to locate the e-seal when it surfaces. Besides time and depth data, newer equipment may also record water temperature and salinity. Elephant seals are becoming oceanographers. The most modern of these trackers may record this data as often as once a second. One large study tracked 184 adult females on their long or short migration and collected data from:

- 25,000 seal days at sea
- 788,000 horizontal miles of travel
- 896,000 vertical miles of dives
- 1,404,000 dives
- 1,200,000 temperature profiles

This data allows us to make important conclusions about e-seals life at sea, particularly their feeding habits. The map shows that males and females tend to forage in different areas of the northeast Pacific.



Males travel north along the coast as far as Alaska and the Aleutian Islands, or in open water directly to the Aleutians. Females tend to go northwest and far out to sea. Individuals often forage in the same areas year after year. Their travel to and from the foraging areas is at a rate of 2 to 3 miles an hour. However, they

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do not swim along the surface, but travel in long V-shaped dives that last about 20 minutes. This means that most of the time they are below the usual hunting depths of their main predators, white sharks and orcas. Within a few hundred miles of the rookeries, whether traveling to or from, the seals feed if they come across prey, but mainly are interested in covering the distance to their destination.

Once in the foraging areas, diving behavior changes to match the location of their prey. The dives of males, foraging in shallower water on or near the continental shelf, tend to be flat bottomed. This is interpreted as the males hunting along the bottom. In the open ocean, females forage well above the bottom, at depths of 1,000 to 3,000 feet. In this area, there are billions of small fish, the majority of which are species of bioluminescent lanternfish. The lanternfish are preyed upon by large numbers of squid, which in turn are preyed upon by elephant seals.

A recent study that followed female elephant seals equipped with jaw motion sensors observed large jaw motions that indicated large prey (like squid), but also very small jaw motions that researchers concluded meant the e-seals were also ingesting lanternfish, perhaps enough for them to be considered a normal part of the females' diet. Compared to the bottom following foraging dives of the males, female dives in the open sea often include several up and down excursions at the bottom of the dive, which are assumed to be seeking or chasing behavior. Another dive form observed by tracking both males and females is a dive to several hundred feet, then simply drifting to the surface and finally a return with no apparent hunting. These are assumed to be resting or digesting dives. The energy saved in locomotion is used to digest previous meals. Males may achieve the same end by simply resting on the bottom.

Most of the information about what the seals eat comes from stomach lavage – pumping their stomachs as soon as possible after they come ashore from a migration. Identifiable parts of squid; fish as diverse as hake and hagfish; cartilaginous fish like small sharks, rays and skates; crustaceans and other invertebrates; are among the most commonly found. It must be noted that most of these animals were probably ingested near the rookery, although squid beaks, and some crab and fish parts last longer in the digestive tract. Using stomach lavage ashore you would not expect to find remains of lanternfish that were consumed at sea weeks before arrival at the rookery.

One frequent question that this does not answer is "how many pounds do elephant seals eat a day"? The Marine Mammal Center in Sausalito, Ca., reports that they feed their young, rehabilitating elephant seals about 10% of their body weight each day. The female foraging study found that females average a 2.6-pound daily weight gain while foraging on their long migration and 2.2 pounds on the short migration. A calculation of the amount of prey they have to ingest to accomplish this has not been published.

Not having the echolocating abilities of many whales and dolphins, how do the seals find food at depths that are always dim and often pitch black? Elephant seal eyes are large, shaped for underwater vision, and are especially sensitive to the blue green colors produced by most bioluminescent sea creatures including squid and lanternfish. The whiskers of elephant seals are equipped with many nerve endings, indicating that they are quite sensitive, and are probably used to detect the motion of prey animals. One-way to describe elephant seal feeding is "grab and swallow". The teeth behind their canines are rounded and barely poke through the gums.

Scientists are still waiting for a small battery, light, and camera that would at least work for a few days of seal feeding. Until then we have to be satisfied with this clip of an elephant seal consuming a hagfish. https://www.youtube.com/watch?v=nzMB8jqioV0

Friends' Focus

Financed by your donations, *FES* led a coalition of the *California Department of Parks and Recreation*, the *California Department of Transportation* and the *California Conservation Corp* to replace the deteriorating fencing that keeps elephant seals and people safely apart in the Piedras Blancas Elephant Seal Rookery. The original fence was installed 12 years ago when the elephant seal colony numbered about 10,000 individuals. Human visitors in 2003 were a fraction of the more than 750,000 who will travel to Piedras Blancas this year to visit the colony of 23,000 elephant seals. . .and the new fence.

The 2015 birthing season produced the largest number of live pups at the end of the breeding season, 4,900. This is 9% over 2014 and 2% over 2013, our previous record year.

In the past three months, twenty-three schools brought students to the Piedras Blancas Rookery to learn about the elephant seals from specially trained docents. Our "Schools program" strives to incorporate California life-science standards into the docents' interpretations. Busing cost for six of these schools (476 students) was provided by your donations to *FES*.

The growing list of organizations advocating for the Piedras Blancas State & National Monument Initiative has spread beyond California to Nevada, Utah, Arizona, New Mexico and Colorado. The initiative campaign is led by the *Piedras Blancas Light Station Association* and *Friends of the Elephant Seal.*

How Do They Do It?

The elephant seal is a truly champion diver, going to depths as great as 5788 feet, staying under for periods up to two hours and diving repeatedly over periods of months with only brief breathing periods on the surface. This article will look at many elements that make that possible.

The first, common to all mammals is the **dive response**. When the seal's head is immersed four things happen: breathing stops (apnea), pulse rate drops, arteries and veins in extremities are reduced in diameter. In elephant seals the drop in pulse rate can be dramatic – by as much as factors of eight to ten. The blood pressure remains fairly constant, maintaining the rate of flow to the brain and heart. The pulse rate appears to be subject to some control as it drops less in advance of short dives and more for longer dives.

The oxygen supply in elephant seals at the beginning of a dive is considerable. On diving, the seal exhales so that little air is left in the lungs, accounting for less than 5% of the oxygen supply. While that oxygen is used in the early moments of the dive, as the depth and pressure increase, the lungs completely collapse forcing the remaining air into the trachea. Elephant seals are 22% blood by weight, compared to 7% for humans. Their blood is richer with over 60% of blood volume occupied by red blood cells compared to 40% - 45% for humans. In addition to the blood oxygen, held by hemoglobin molecules in the red blood cells, there is oxygen in the muscle held by myoglobin molecules. Per pound of body weight the elephant seal has more than 15 times as much myoglobin as a human.

While the structure and size of an elephant seal heart is similar to that of a land mammal, there are important differences in the circulatory system. The arterial system is, for the most part, similar to that for humans. Differences include an elastic enlargement of the aorta which may help to keep the blood flowing throughout the heart cycle. In addition there are elaborate networks of arteries and veins that contribute to blood capacity. These networks can also provide for heat exchange, for example between the warm arterial blood heading for the rear flippers and the cold venous blood returning from those flippers.

The system of veins, Figure 1, has some features that are common to most seals but is not found in land mammals.

Some of the networks (plexi) are shown. The large and elastic posterior vena cava and hepatic sinus absorb the blood from the extremities during the dive response. The rate of blood return to the heart is regulated by a sphincter muscle, the caval sphincter.

A fourth factor is size. The larger the animal the less oxygen per unit mass is necessary for its activities.

Finally, the secret to the elephant seals ability to dive continuously for extended periods is its extraordinary tolerance of low oxygen and management of blood stores. A recent study[1] of blood oxygen levels in elephant seals at sea has shown that for dives longer than ten minutes, the great majority of dives, the blood oxygen concentration drops to a far lower percentage than is found in or (even) survivable by other mammals. The profile of oxygen saturation during a diving bout is shown in Figure 2. The study did not include an analysis of myoglobin stores through the dives. While lactic acid producing anaerobic (oxygen-less) processes are possible, they cannot be significant for constant diving with brief breathing periods since clearing the blood of lactic acid is too time consuming. Figure 2 shows the saturation level of the blood through a dive sequence, the depth is shown in red, the degree of saturation in black. The period when the seal is at the surface is white. Note that the oxygen saturation begins to rise in the artery shortly after surfacing, while that in the vein takes about a minute longer.

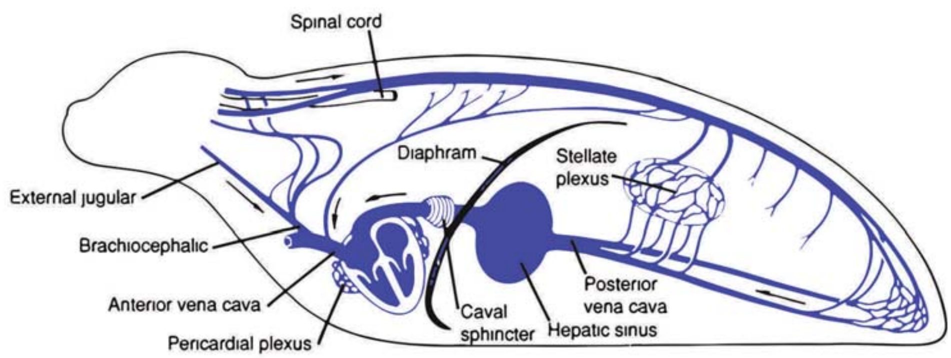

Figure 1. Diagram of the venous circulation in a phocid with the major vessels labeled. (From *Seals of the World*, J. E. King, 1983)

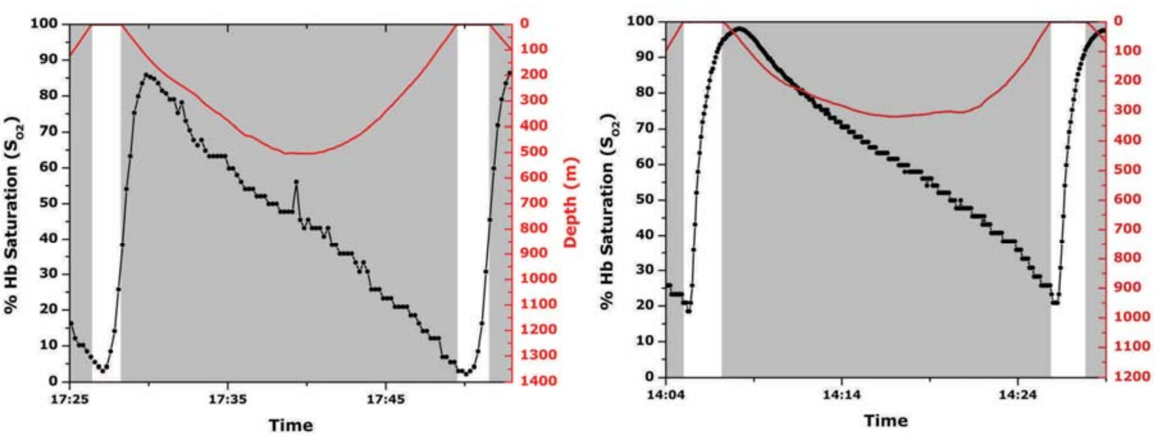

Figure 2: % of blood oxygen saturation through a dive as measured in a major vein (left) and a major artery (right)

[1]Meir, J. U., *et al.*, Extreme hypoxemic tolerance and blood oxygen depletion in diving elephant seals, *American Journal of Physiology - Regulatory, Integrative and Comparative Physiology* 297: R927-R939, 2009**)**