How important is bone density in NES?

On the bluff we cite an unpublished study done at Año Nuevo based on 1 juvenile northern elephant seal (NES) in the late 1980's. Its bone density was measured using a CT-scan shortly after its arrival for fall haul-out, and again shortly before its return to the sea. The results showed an increase in bone density during the haul-out.[1]

This bone density change is based on one seal, which is hardly a study size with which we can be confident in extrapolating to the NES population. In addition, we discuss no apparent physiological reason with visitors for the change in bone density.

This summary will explore the research on bone density, the role of haul-out in juvenile skeletal development, physiology of bone remodeling, and potential relationship to buoyancy and diving. The conclusion will list the talking points for docents to consider using on the bluff based on the summary findings.

Little research has been done on seal bones and bone density in particular. When asked about bone density in NES Burney Leboeuf stated "I'm not sure that bone density increases when ESs haul-out. I know of no data on this. Moreover, I would think that the changes in bone density may not occur fast enough to serve the demands on land. I suspect that bone composition would have to be a compromise between serving needs at sea and on land".

Even though we may not have a lot of data on bone density in adult seals we do have a study that included skeletal development in juveniles. This study by Bryden[2] on skeletal development in southern elephant seals (SES), showed the greatest bone growth, based on an increase in bone weight, occurred in the ribs and sternum. This study makes the case that haul-outs on land during the winter rest periods (our fall haul-outs) for juveniles are necessary for chest cavity development which provides adequate support to the weight of body tissues when the seal next hauls out on land. Otherwise seals could perish, when hauled out on beaches, as whales do, due to collapse of the rib cage.

In general, we know that if mechanical loading on a particular bone increases, the bone will remodel itself over time to become stronger to resist that sort of loading (Wolff's law).[3] How would this method apply to NES to combat weaker bones, which may occur as a result of a more weightless marine environment? Burney Leboeuf speculated that "NES might be expected to have stronger bones that aid swimming (rear flippers) as they are diving 24-7". Thus they are exercising those bones (rear flippers).. During haul-out the front flipper bones that support the seal against gravity should strengthen.

Furthermore, the opinion of LeBoeuf is supported at least in skeletal development of juveniles in Bryden's study[2] in that SES when first at sea began to strengthen bones of the rear flippers in response to their increased use during aquatic life. The bones of the front flippers exhibited considerable development during the suckling period and first haul-out associated with their terrestrial activity when used to "gallump" on land.

Another function that might be influenced in the NES by changes in bone density could be buoyancy, which would influence diving behavior. An article by Wall[4] and Stein[5,6] indicated the bone density in aquatic animals is greater than that of similar terrestrial animals in order to reduce buoyancy and aid diving. According to the article, the bone density of NES is within the range of terrestrial animals, presumably because NES decrease buoyancy by expelling air from their lungs before they dive, and that their lungs collapse during deep dives contributing to the decrease in buoyancy[5]. There has been no research to confirm this hypothesis.

In a more recent paper Webb, et.al.[7] have demonstrated that changes in lean/fat mass ratio might better help explain the variability of NES deeper diving habits. The aim of this study was to determine experimentally the relationship between buoyancy and diving behavior in NES by modifying the buoyancy of seals moved from Año Nuevo to various sites in Monterey bay and examining the resultant changes in diving behavior. Mean descent rates were faster for reduced buoyancy seals (the more negative the buoyancy the greater the rate of descent) which was significantly different when compared to the control and increased buoyancy seals. There was no correlation between ascent rate and buoyancy, in fact all seals ascended at about the same rate, which may mean that seals don't take advantage of buoyancy by rising faster, but that they swim only as hard as necessary to achieve their preferred rate of ascent.

In conclusion, for all of our docents to provide a common message on the subject of bone density in NES to visitors, the following talking points are provided:

1. There is limited research on bone density in NES which means we do not know if bone density is any different than it needs to be to provide skeletal support on land and sea.

2. A major reason for the lack of research on bone density is that it is difficult to measure. The old methods to measure bone density by Stein [5,6] and Wall [4] use bones from museum fossils and from non-living subaquatic and aquatic marine mammals. The current preferred method of Dual Energy Xray Absorptiometry (DEXA or DXA) measures bone density on living animals and is quite expensive.

3. However we do know that the juvenile haul-outs during the fall and molting are important times of physiological change, and are necessary for juvenile skeletal development of the chest cavity and front flippers.

4. Mechanical stimulation of bone tissue accelerates bone formation in regions of high stress (front and rear flippers) and effectively strengthens bones. The NES have potentially weaker bones because of spending a substantial portion of their life in a somewhat weightless marine environment. However, the rear flippers become stronger at sea because of their continued use in diving 24-7 and the front flippers become stronger on land because they are used to support movement.

5. For NES, deep diving habits depend on buoyancy which is determined primarily by body composition, particularly the ratio of adipose tissue to body mass which is measured by the lean/fat ratio. For example, post-parturient females have been fasting and nursing and have lost up to 40% of their body weight, mostly fat, which is less dense than lean tissue. Thus they have reduced buoyancy when they return to sea to feed. This allows them to descend faster when they dive, but as they regain fat tissue the lean\fat ratio decreases which reduces their diving rate of descent. However, because body composition cannot be adjusted in the short term, NES probably adjust their behavior to suit their buoyancy rather than adjusting their buoyancy to suit their dive.

1.Pat Morris, Research biologist UC Santa Cruz;Assistant mgr Ano Nuevo island reserve; personal communication.

2.Bryden,M.,M.;1969. Relative Growth of the Major Body Components of the Southern elephant seal Mirounga Leonina. Aust.J.Zool, 17, 153-177.

3.Robling,A.,G.;Castillo,A.,B.;and Turner,C.,H;2006. Bio mechanical and Molecular Regulation Bone Modeling. Annu.Rev.Biomed.Eng.8:455-498.

4.Wall,W.,P.;1983. The Correlation between High-Density and Aquatic Habits in Recent Mammals. Journal of Paleontology, Vol.57,#2, pp197-207.

5.Stein, B.,R.;1991. Functional correlates of differences in bone density among terrestrial and aquatic genera in the family Mustelidae(Mammalia).

6.Stein,B.,R.;1989. Bone Density and Adaption in Semi-aquatic Mammals. Journal of Mammology, Vol.70,#3, pp.467-476.

7. Webb,P.M.;Crocker,D.,E.;Blackwell,S.,B,;Costa, D.,P.;and Le Boeuf,B.,J.1998. Effects of Buoyancy on the Diving Behavior of Northern Elephant seals. Journal of Experimental Biology 201,2349-2358.