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# A Comparison of the Rate of Oxygen Store Development in Phocid Seals



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## Abstract

Phocids have large oxygen stores that result in prolonged diving capabilities. Pups do not have fully developed stores at birth for diving and foraging and require a terrestrial post-weaning fast to develop adequate oxygen. A review of previously published data of various oxygen components in three high latitude phocid species, gray, harbor, and northern elephant seals, was conducted. Analyses of variances (ANOVA) indicates weight had a significant ( $p < 0.05$ ) effect on blood oxygen stores in gray seals while age class did not. Age had a significant ( $p < 0.01$ ) effect on blood oxygen stores in harbor seals, while age and weight had a significant ( $p < 0.05$ ) effect on muscle oxygen stores in northern elephant seals. Multiple comparison Steel post-hoc test indicates juveniles and adults had significantly higher blood oxygen stores than nursing, and weaned/fasting pups ( $p < 0.05$ ). Age and weight significantly affects the rate of  $O_2$  store development in the blood and muscle and may correlate to nursing and weaning duration necessary for pups to develop adequate oxygen stores for aerobic diving.

## Introduction

Phocids have substantial blood and muscle oxygen stores which lead to great diving capabilities. Most pups do not have fully developed oxygen stores ( $O_2$ ) at birth, and cannot dive immediately. Instead, their ability to store oxygen increases during the period from nursing to post-weaning. A terrestrial post-weaning fast (PWF) is crucial for pups to rapidly develop mature  $O_2$  stores. As pups age and diving becomes a regular component of daily life, muscle oxygen tends to increase while blood oxygen concentrations maintain a steady level. The rate of oxygen development may be affected by age, body weight, or differences in nursing and weaned periods among species, which may affect the diving ontogeny of pups.

Gray (*Halichoerus grypus*), harbor (*Phoca vitulina*), and northern elephant seals (*Mirounga angustirostris*) from discrete locations were analyzed for oxygen stores (Figures 1 & 2). Northern elephant seals have significantly greater diving capacity than gray and harbor seals, which would indicate that there are differences in oxygen stores (Figure 3). Age and weight (kg) were compared within each species to determine the effects on hemoglobin (Hb), hematocrit (Hct), and myoglobin (Mb).

### Gray Seal

- Born w/o blubber
- Nurse ~ 18 days
- PWF 10-28 days

### Harbor Seal

- Born w/ blubber
- Nurse 21-28 days
- PWF 15-17 days

### Northern Elephant Seal

- Born w/o blubber
- Nurse ~ 28 days
- PWF ~ 2.5 months

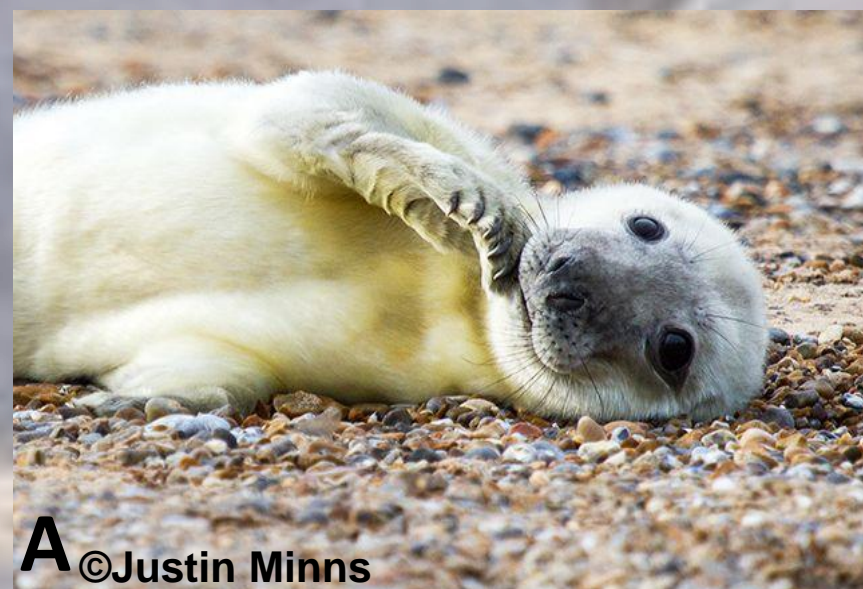


Figure 1. Study species of young A) gray, B) harbor, and C) northern elephant seals.



Figure 2. Location of gray, harbor, and northern elephant seals sampled for hematology. Data were provided by Hall 1998, Sea Mammal Research Unit; Thomas and Ono 2015, Marine Animal Rehabilitation and Conservation Program; and Somo et al. 2015, Año Nuevo State Reserve.

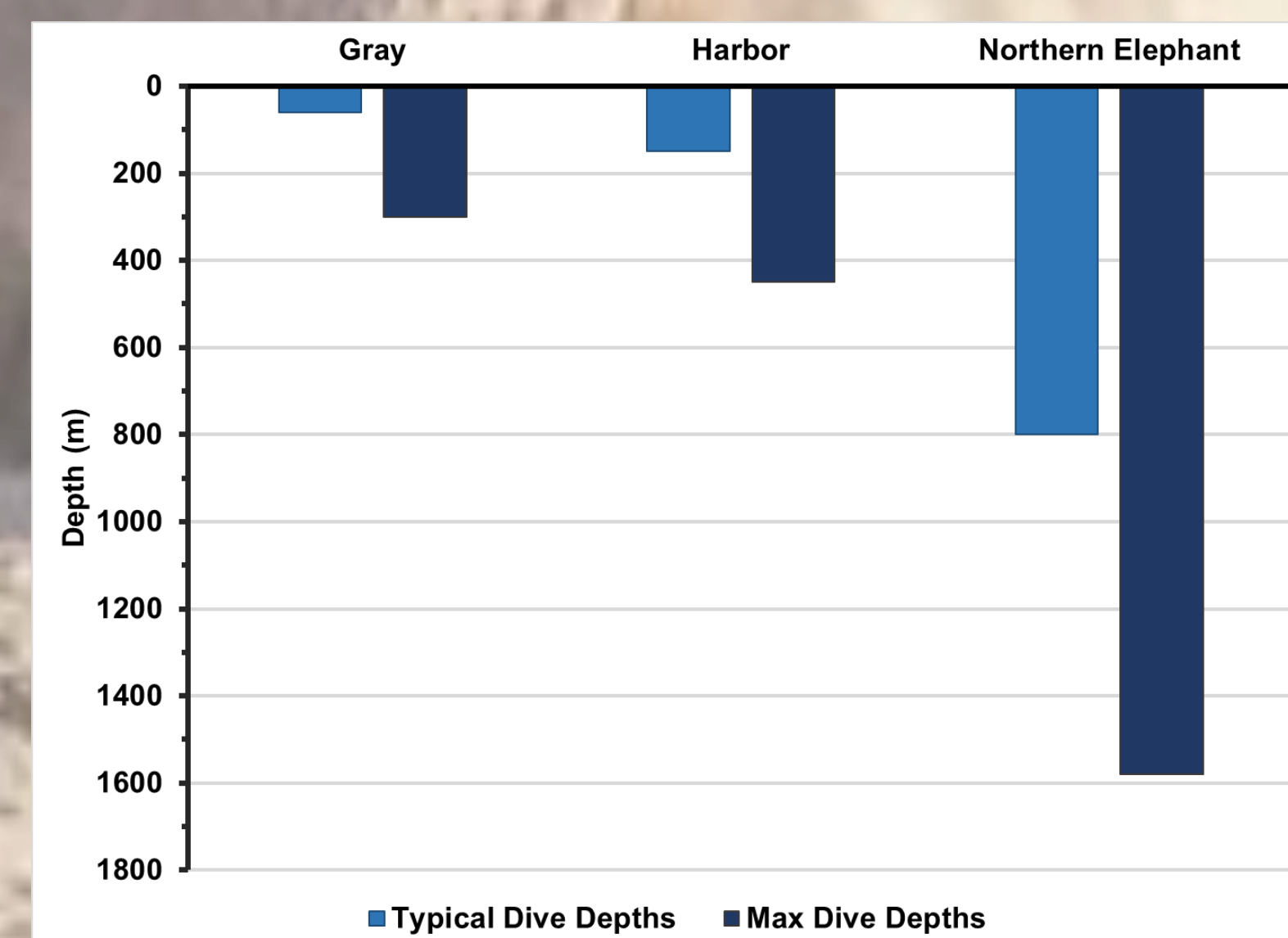


Figure 3. Typical and maximum dive depths of the study species (Reeves et al. 2002; Shirihai 2006; Jefferson 2008).

## Results

### Overall

- There were species specific hematologic differences
- Hb was highly correlated to Hct ( $p < 0.05$ ,  $r = 0.89$ )
- Combined, age and weight had no significant effect on Hb in gray and harbor seals, but there were individual effects (Figure 4)
- Only post-weaning data for northern elephant seals

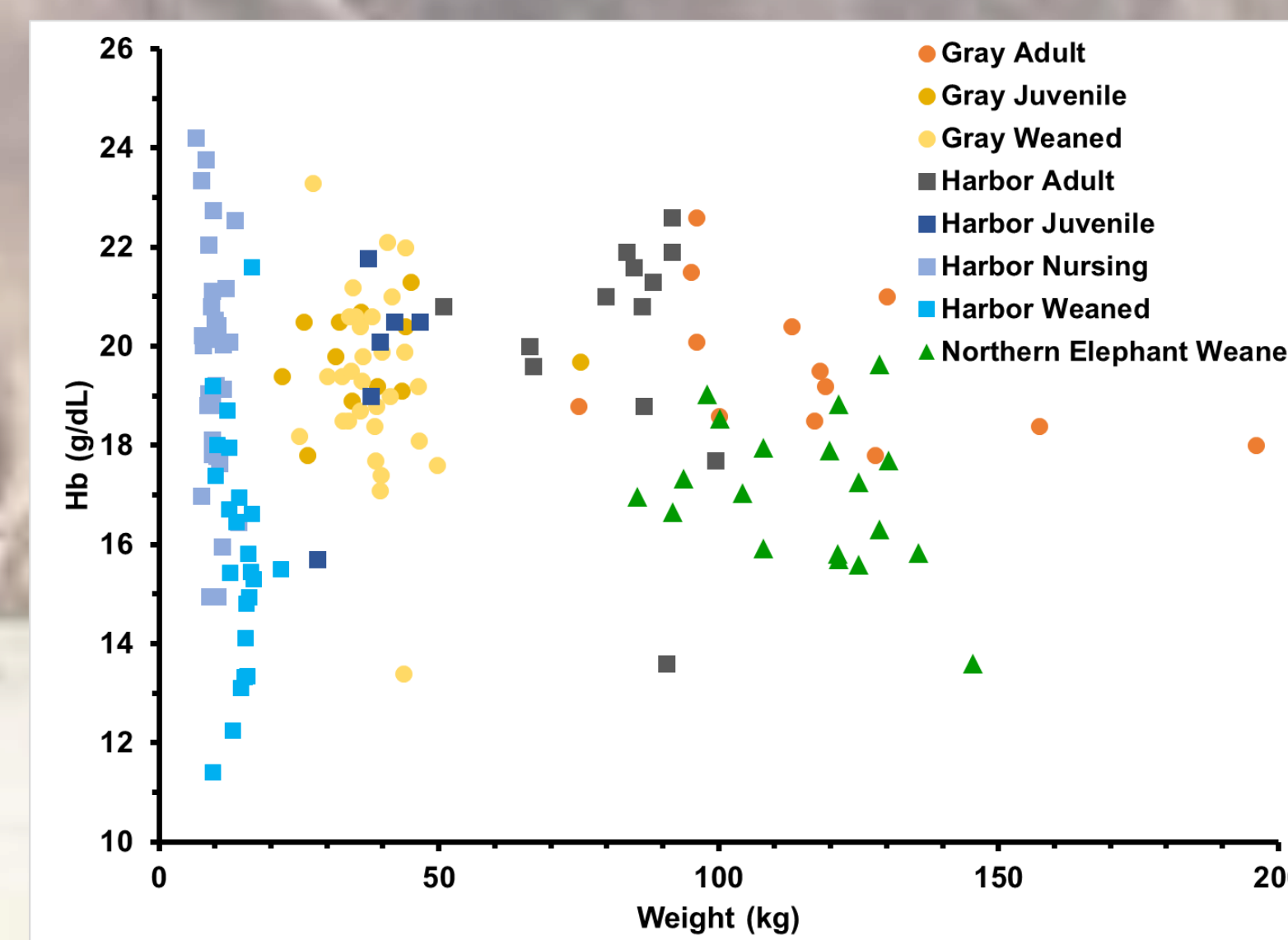


Figure 4. Hb differences within species' age class.

### Gray Seal

- Age had a significant ( $p < 0.01$ ) effect on weight but had no effect on either Hb or Hct
- Weight had a significant effect on both Hb and Hct ( $p < 0.01$  and  $p < 0.05$ , respectively) (Figure 5)

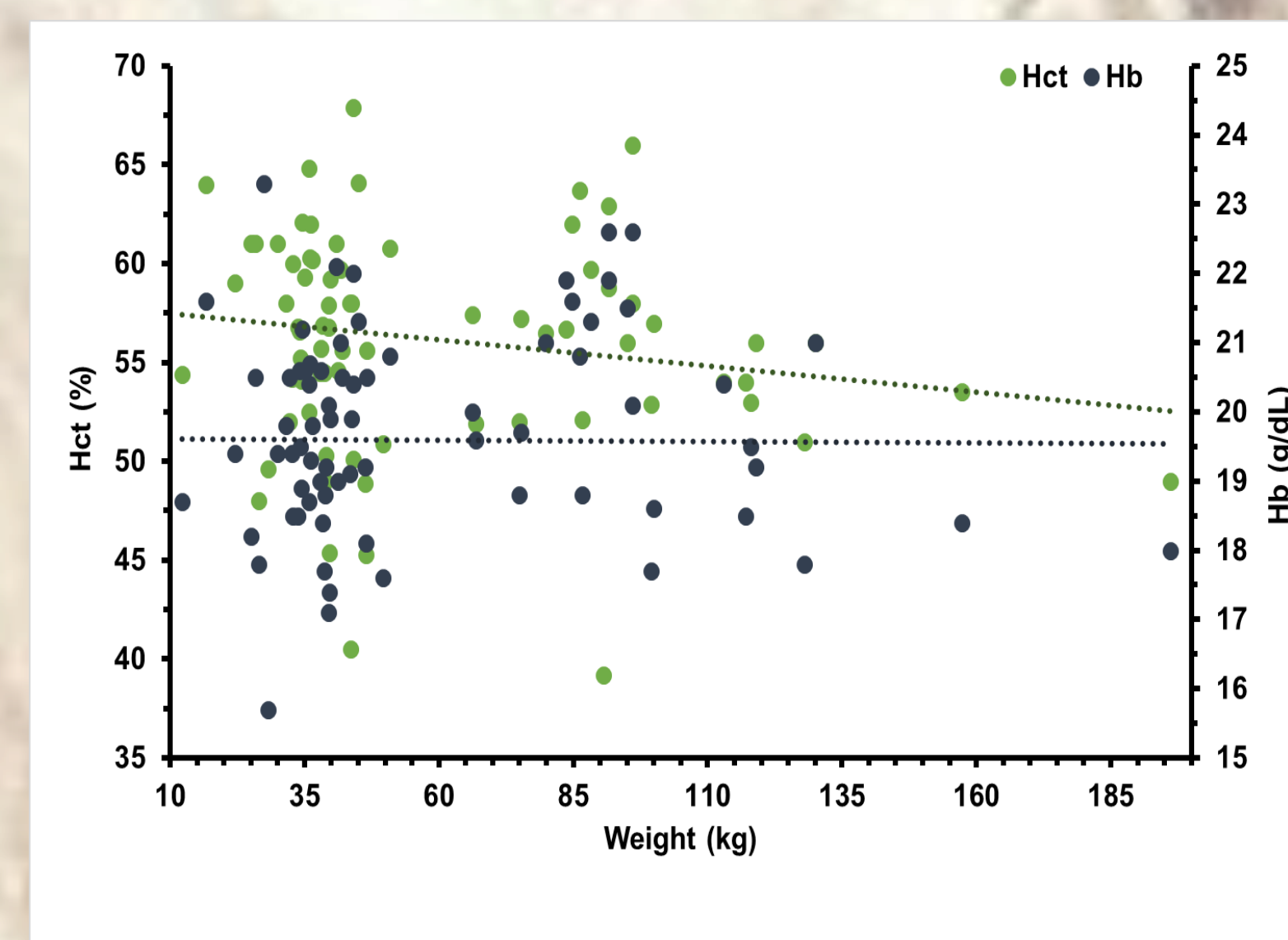


Figure 5. Effect of weight on Hb and Hct in gray seals.

### Harbor Seal

- Age had a significant ( $p < 0.05$ ) effect on weight and on Hb between weaned and juvenile, and weaned and adult seals ( $p < 0.05$  and  $p < 0.01$ , respectively) (Figure 6)
- Weight had no effect on hematology parameters

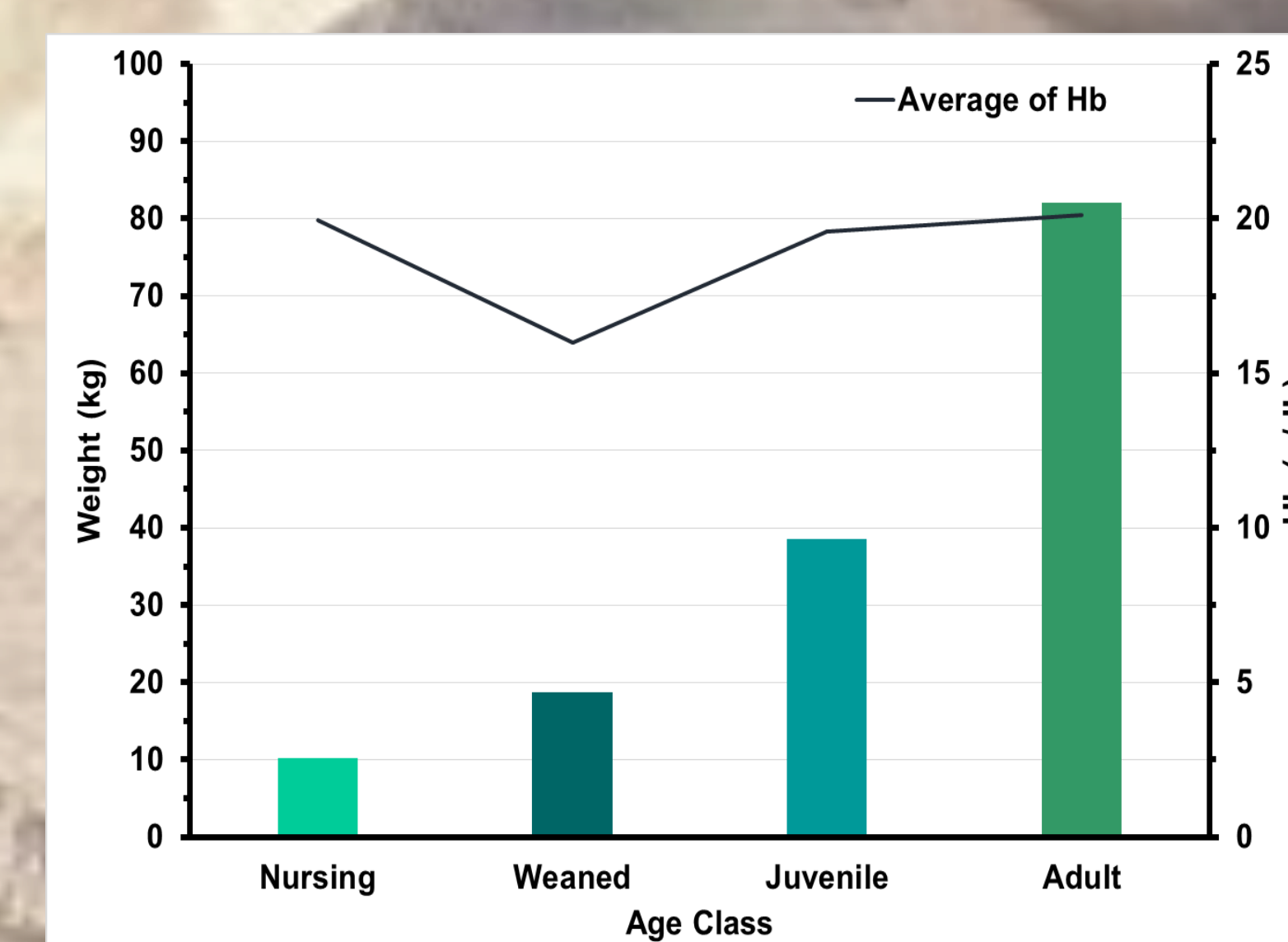


Figure 6. Hb compared with age and weight in harbor seals.

## Results- cont.

### Northern Elephant Seal

- Age had a significant ( $p < 0.01$ ) effect on weight but not on Hb or Hct in weaned pups (Figure 7)
- Age and weight had a significant ( $p < 0.05$ ) effect on Mb throughout the weaning period (Figure 7)

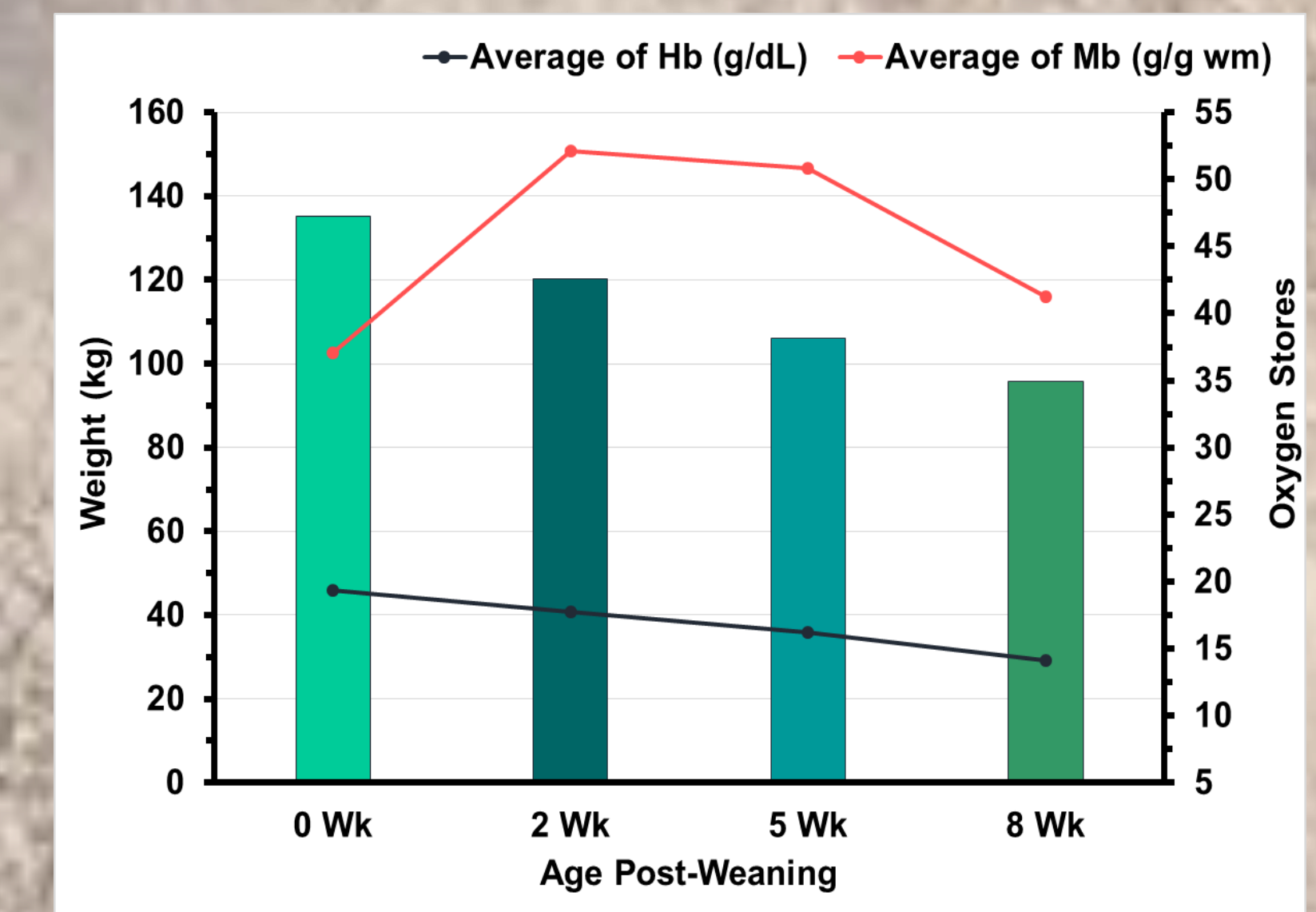


Figure 7. Hb and Mb changes post-weaning in northern elephant seals. Oxygen stores is the relationship between Hb and Mb.

## Key Findings

- Weight significantly affected Hb and Hct in gray seals
- Age class significantly affected Hb and Hct in harbor seals
- Age and weight had a significant effect on Mb in weaned northern elephant seals
- Nursing and weaned pups had similar Hb and Hct values adults, although there were significant increases among age classes (Figures 5 & 6)
- Based on this preliminary study, pups appear to store proportionately more oxygen in their blood than their muscles
- Research on individual species indicates seals do not develop greater muscle oxygen stores until they begin diving and foraging
- In northern elephant seals, there was a substantial difference in the amount of oxygen stored in Hb compared to Mb during the terrestrial fasting period, which lends support to the hypothesis that Hb is more developed than Mb (Figure 7)

## Future Work

- Raw myoglobin data has only been acquired thus far for one species. In order to conduct more rigorous analysis of Mb contribution to oxygen stores, data from other phocid species are needed
- Expand analysis to include harp, hooded, Weddell, and southern elephant seals
- The addition of these species will allow for comparison among subpopulations and between hemispheres
- Add otariid data to compare diving ontogeny differences between families

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