

- (1) Southwest Fisheries Science Center, 3333 North Torrey Pines Court, La Jolla, CA, 92037, USA  
 (2) Scripps Institution of Oceanography, 9500 Gilman Drive, La Jolla, CA, 92093, USA  
 (3) Southwest Fisheries Science Center, 110 Shaffer Road, Santa Cruz, CA, 95060, USA  
 Corresponding author: Jessica.Redfern@noaa.gov

Most readily available measures of oceanic habitat are from physical and biological oceanographic variables. However, we expect cetacean distributions to be determined more by the abundance of their prey, typically mid-trophic species such as krill, small fish, and squid. We built cetacean-habitat models to determine whether predictor variables comprised of oceanographic measurements, mid-trophic prey indices, or a combination of both yield the best model fit and predictive power. Mid-trophic indices were derived from manta and bongo net tow samples and from acoustic backscatter data. We used four years of data collected from August - November in two large marine ecosystems: the California Current ecosystem (CCE) in 2001 and 2005, and the eastern tropical Pacific Ocean (ETP) in 2003 and 2006. Models of encounter rate were built for striped dolphin (*Stenella coeruleoalba*, 133 sightings) and short-beaked common dolphin (*Delphinus delphis*, 167 sightings) in the CCE and ETP, Dall's porpoise (*Phocoenoides dalli*, 94 sightings) and blue whales (*Balaenoptera musculus*, 22 sightings) in the CCE, and eastern spinner dolphin (*S. longirostris orientalis*, 83 sightings) and Bryde's whales (*B. edeni*, 26 sightings) in the ETP. Variables were selected using an automated forward/backward stepwise approach based on Akaike's Information Criterion (AIC). Comparison of the models was based on AIC values, explained deviance, and temporal ratios of observed to predicted encounter rates. The effect of including mid-trophic prey indices on cetacean-habitat models was species specific. Mid-trophic indices did improve model fit and predictive power for striped dolphin, eastern spinner dolphin, and Dall's porpoise, but did not improve models for short-beaked common dolphins, Bryde's whales, or blue whales. These analyses confirm the potential power of mid-trophic indices to predict cetacean distributions, but highlight the importance of obtaining species-specific prey indices.

### Longitudinal change in diving and physiology of Steller sea lion pups

Rehberg, Michael J.<sup>1</sup>; Rea, Lorrie D.<sup>2</sup>

- (1) Alaska Dept of Fish and Game, Statewide Marine Mammal Program, 525 West 67th Avenue, Anchorage, AK, 99518, USA  
 (2) Alaska Dept of Fish and Game, Steller Sea Lion Research Program, 245 O'Neill Building, University of Alaska Fairbanks, Fairbanks, AK, 99775, USA  
 Corresponding author: michael.rehberg@alaska.gov

To assist recovery efforts for the Steller sea lion in Alaska, we are examining the combined roles that physiological development, nutritional source and the demand for independent foraging play in the ontogeny of behavior by sea lion pups during their first winter. To accomplish this, we captured 30 and 39 sea lions in Prince William Sound, Alaska at 5 months of age during November 2005 and 2007, respectively. We successfully recaptured 30 of these pups in April at 10 months of age for longitudinal physiological and morphological sampling. Over the winter, pups gained  $30 \pm 13$  kg by individual, grew  $16 \pm 6$  cm in length and increased  $21 \pm 7$  cm in chest girth. The proportion of total body lipid calculated by deuterium dilution increased  $9 \pm 8\%$  and blubber depth measured by ultrasound increased  $0.81 \pm 0.31$  cm. We also recovered archival time-depth recorders that reported continuous dive and activity behavior from 20 of these pups. Between November and April, the proportion of bouts of contiguous similar diving that occurred during daylight or the full moon increased from  $52 \pm 5\%$  to  $62 \pm 5\%$ , and by April  $85 \pm 6\%$  of dives remained below the calculated aerobic dive limit. For most sea lions, bout duration, dive depth and dive duration peaked in February, indicating possible response to seasonal herring abundance. Whether pups targeted these prey as suggested by their behavior is complicated by visual observations and longitudinal trends in vibrissae stable isotopes indicating most pups were not fully weaned by April. However, previous cross-sectional study of pups in this region demonstrated seasonal differences in blubber fatty acids, suggesting either change in prey selection or a shift from exclusive suckling to suckling supplemented with prey capture by the end of their first winter.

### Underwater acoustic displays of a Pacific walrus (*Odobenus rosmarus divergens*): Source level estimates and temporal patterning

Reichmuth, Colleen<sup>1</sup>; Mulsow, Jason<sup>2</sup>; Schusterman, Ronald J.<sup>1</sup>

- (1) UC Santa Cruz, Institute of Marine Sciences, 100 Shaffer Road, Santa Cruz, CA, 95060, USA  
 (2) UC Santa Cruz, Department of Ocean Sciences, Earth and Marine Sciences Building, Santa Cruz, CA, 95064, USA  
 Corresponding author: coll@ucsc.edu

Walrus breed in winter in the high Arctic in areas typically associated with pack ice. As a result, their sub-surface breeding displays have only rarely been directly observed. The acoustic portion of these displays has been described as complex, temporally patterned songs comprised mainly of sharp pulses and metallic bells. The source levels of these unusual underwater signals have not previously been measured; however, the songs of free-ranging males are detectable over distances of  $>10$  km. In the present study, we examined the underwater acoustic displays emitted by a 14-year-old male walrus in a captive environment. Acoustic displays were emitted by this male nearly continuously from March through May. Several distinctive sounds were recorded at close range during displays, including moans, bells, pulsatile knocks, and high-intensity claps produced by smacking the fore-flippers together. Moans had maximum energy at frequencies near 0.375 kHz and maximum source levels  $\leq 166$  dB peak re  $1\mu\text{Pa}$ . They were emitted alone or simultaneously with pulsed sounds. Bell sounds were broadband and were typically emitted alone and close to the surface in a head up posture. They had maximum energy near 5 kHz and maximum levels  $\leq 147$  dB peak re  $1\mu\text{Pa}$ . Knocks and claps were the predominant sound types emitted and were highly rhythmic. Knocks were produced as single pulses or as doublets that were typically repeated at rates of 0.8/s to 2/s with source levels  $\leq 179$  dB peak re  $1\mu\text{Pa}$ . Claps produced highly stereotyped, broadband pulses that were typically emitted at rates of 0.8/s to 1/s with source levels  $\leq 205$  dB peak re  $1\mu\text{Pa}$ . Claps and knocks were often produced simultaneously, and sometimes synchronously, for extended intervals lasting several minutes. The energy produced by clapping the fore-flippers under water is remarkable and has never been reported as a component of walrus underwater acoustic displays.

### Odontocete air-heads: Empty spaces full of function

Reidenberg, Joy S.<sup>1</sup>; Laitman, Jeffrey T.<sup>1</sup>

- (1) Mount Sinai School of Medicine, Center for Anatomy & Functional Morphology, New York, NY, 10029-6574, USA  
 Corresponding author: joy.reidenberg@mssm.edu

The odontocete respiratory tract, particularly the nasal region, has been modified evolutionarily to accommodate aquatic life. Fossil evidence indicates cranial sinuses occurred in archaeocetes, but such sinuses are absent in modern odontocetes. Although soft-walled gas spaces are present in modern species, it is unclear if they derive from cranial sinuses. Respiratory anatomy is explored in 68 specimens of eleven odontocete genera (*Phocoena*, *Lagenorhynchus*, *Stenella*, *Delphinus*, *Tursiops*, *Grampus*, *Globicephala*, *Mesoplodon*, *Ziphius*, *Physeter*, and *Kogia*) collected post mortem. Evolution, anatomy, and function of odontocete air sacs are compared with cranial sinuses in terrestrial mammals and published observations on fossil cetaceans. Odontocetes exhibit several pairs of paranasal air sacs, located rostral-superiorly between the skull and the blowhole. Pigmentation of the paranasal sacs indicates that they likely derived from integumental invaginations. Odontocetes also have paired pterygoid sacs that are located along the ventro-lateral surface of the skull, connecting the pharynx and middle ear cavities. As these air sacs are also found in mesocetes, they are probably derived from a terrestrial character found in a common ancestor. Lateral pharyngeal pouches or the middle ear cavities and mastoid sinuses are good candidates, as they also occur in the closely related artiodactyls. The loss of cranial sinuses in modern odontocetes appears to be a diving adaptation. Bone-enclosed air chambers have rigid walls that would fracture during descent/ascent due to changing gas volumes. As odontocete air sacs are not circumferentially enclosed in bone, their flexible walls can accommodate such diving induced gas volume changes. Odontocete air sacs may have analogous respiratory, structural, and vocal functions to the cranial sinuses of terrestrial mammals, including gas exchange, thermoregulation, skeletal pneumatization, and resonance. In addition, they may subserve unique aquatic functions, such as increasing inspiratory volume, mitigating volume changes, regulating buoyancy,