The Diet Composition of Beaked Whales and Melon-Headed Whales from the North Pacific

Kristi West
College of Natural and Computational Science
Hawaii Pacific University
45-045 Kamehameha Hwy.
Kaneohe, HI 96744
phone: (808) 236-5841 email: kwest@hpu.edu

William A. Walker
National Marine Mammal Laboratory
Alaska Fisheries Science Center
National Marine Fisheries Service, NOAA
7600 Sand Point Way N.E.
Seattle, Washington 98115
phone: (206) 463-3860 email: mindwalk@msn.com

Robin W. Baird
Cascadia Research Collective
218 ½ W. 4th Avenue
Olympia, Washington 98501
phone: (425) 879-0360 email: rwbaird@cascadiaresearch.org

Award Number: N00014-14-1-0412

LONG-TERM GOALS

Knowledge of the diet of a species is crucial for understanding it's behavior and ecology, and also has relevance to assessing the impact of potential changes in behavior or spatial use that may be associated with anthropogenic activities. Assessing diet for many species of cetaceans is difficult, given that most foraging occurs far below the surface and that stomach contents of stranded animals are rarely available. Very little information on food habits of most species of beaked whales or of melon-headed whales (*Peponocephala electra*) is available from any region of the world.

This project proposes to describe the diet composition of several species of beaked whales and melon-headed whales in the North Pacific by conducting stomach content analysis of available specimens collected from stranded animals. Prey remains are available from 24 beaked whales that represent six species. Additionally, stomach contents have been obtained from six stranded melon-headed whales in Hawaii. The identification of each prey item to the species level and size and mass estimates of prey will allow for a detailed description and comparison of diet composition as well as provide insight into the foraging behavior and ecology of these whales in the North Pacific.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
30 SEP 2014		**00-00-2014 to 00-00-2014**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
The Diet Composition of Beaked Whales and Melon-Headed Whales from the North Pacific	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Hawaii Pacific University,College of Natural and Computational Science,45-045 Kamehameha Hwy,Kaneohe,HI,96744**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**6**	

OBJECTIVES

The first component of this overall project involves describing the diet composition of melon-headed whales from the Hawaiian Islands. This report summarizes progress towards this objective.

Although melon-headed whales are a poorly-known species, there is more known about melon-headed whales in Hawaiian waters than anywhere else in the world (Aschettino et al. 2012; Woodworth et al. 2012). This species is thought to be sensitive to underwater sounds. In 2004, 150 melon-headed whales demonstrated pre-stranding behavior in Hanalei Bay, Kauai, which coincided temporally and spatially with a RIMPAC (Rim of the Pacific) training exercise (Southall et al. 2006). In 2008 approximately 100 melon-headed whales moved into a shallow water lagoon system in Madagascar, with many subsequently stranding, coincident with the use of a high-power mid-frequency multi-beam echosounder used in mapping offshore of the stranding site. The multi-beam echosounder was thought to be the most likely behavioral trigger for the animals entering the lagoon system (Southall et al. 2013).

Despite their distribution throughout the tropics and sub-tropics world-wide, there is no study dedicated to the food habits of this species in the published literature. All that is known of melon-headed whale diet comes from the stomach contents of individual specimens in Hawaii and South Africa and unpublished data from a mass stranding in Brazil (Barros, unpublished, Best and Shaughnessy, 1981; Clarke and Young, 1998; Sekiguchi et al. 1992). An examination of the food habitats of melon-headed whales from any region of the world would be a valuable contribution to furthering our understanding of the foraging behavior of this species. Such an examination of food habits from Hawaiian melon-headed whales would be especially relevant in light of the 2004 mass stranding behavior and the continued importance of Hawaiian waters to naval training exercises.

APPROACH

Stomach contents were collected from five melon-headed whales that stranded between 2009 and 2013 in the main Hawaiian Islands and from one individual that stranded in 1985. Individuals stranded on the islands of Oahu, Maui and Molokai. In all but one case, melon-headed whales were identified to species based on body length, black coloration, head shape and pointed pectoral fins. For the Kaupoa, Molokai individual, genetic analyses performed by the Southwest Fisheries Science Center was necessary to confirm the species identification but it was not possible to obtain sex due to tissue degradation. Based on stranding locations these individuals were likely members of the Hawaiian Islands population, that moves among islands and offshore, rather than the Kohala resident population (Aschettino et al. 2012; Carretta et al. 2014). The Waiehu, Maui individual dorsal fin profile was matched to the Cascadia Research Collective photo-identification catalog. This individual (HIPe0603) had previously been sighted three times since first being identified in 2004 near the Big Island but was part of the Main Hawaiian Islands population, and not the Kohala resident population.

Stomach contents were initially frozen for five of the melon-headed whales and fixed in formalin for one of the whales. Frozen contents were later thawed and each sample was then rinsed through a progression of sieves with decreasing mesh sizes of 1.4 mm, 0.94 mm and 0.50 mm. After sorting, cephalopod beaks, fish bones and crustacean remains were preserved in 70% ethanol. Fish otoliths were stored dry in gelatin capsules. All remains were identified to the lowest possible taxon using the private reference collection of W.A. Walker and the fish bone, otolith and cephalopod beak reference collections housed at the National Marine Mammal Laboratory (NMML), Seattle, Washington. A

voucher series of select beaks and otoliths representing each prey taxon were removed from the individual stomach samples and incorporated into the NMML reference collections. The remainder of the individual stomach samples were stored in alcohol at NMML.

The total number of each species of cephalopod was estimated as the number of lower beaks present. The total number of each fish species was estimated based on the greater number of left and right otoliths. In a few instances the number of fish prey was estimated based on the greater number of left or right paired cranial bones. Dorsal mantle length and total weights were estimated by measuring lower beak rostral length for the cephalopod decapods and lower beak hood length for the cephalopod octopods and then applying the appropriate regression equations. Cephalopod beaks were measured to the nearest 0.1 mm with either an optical micrometer or, in the case of large beaks, Vernier calipers. In most cases, regression equations from Clarke (1986) were used to estimate prey size and mass for the cephalopod species present in the melon-headed whale stomachs. If no regression equations available were available from Clarke (1986), prey sizes for these species were estimated using data from individuals of near equivalent beak size housed in the NMML reference collection. If available in Clarke (1986), pigmentation (darkening) of the wing portions of the lower beak were recorded for the beaks. Beaks were considered to be from adult squid when the wing pigmentation was complete.

Fish otoliths and diagnostic bones were measured to the nearest 0.1 mm using an optical micrometer. In most cases, fish prey standard lengths and weights were estimated using regression equations from the literature (Smale et al. 1995, Ohizumi et al. 2001, Spear et al. 2007), or from regressions developed for similar, closely related species at NMML. In instances where appropriate weight regressions were unavailable, weight was estimated by comparison with other closely related species of similar size.

WORK COMPLETED

Stomach content remains from the six melon-headed whales have been thawed, rinsed, sorted and processed for identification. All remains from the six whales have been identified to the lowest possible taxon using the private reference collection of W.A. Walker and the NMML fish bone, otolith and cephalopod beak reference collections. Cephalopod beaks were measured to the nearest 0.1 mm with either an optical micrometer or Vernier calipers. Fish otoliths and diagnostic bones have also been measured to the nearest 0.1 mm using an optical micrometer. Prey remains have been tabulated for each of the individual whales as well as for all six whales together. Data tabulation allows for an examination of the contribution (by abundance) of each prey species to melon-headed whale diet composition in Hawaii. In order to complete data collection for this objective, it will be necessary to determine if wing pigmentation data is available to distinguish juvenile from adult squid for each of the cephalopod species represented in the stomach content remains. It will also be necessary to apply species specific regression equations for both the cephalopod and fish species present in order to estimate prey size. Future work will include the preparation of figures to illustrate the contribution of juvenile versus adult cephalopods for the most abundant species present in the Hawaiian melon-headed whale diet. Prey size estimates will also be used to calculate the dietary contribution by mass of the prey items identified in the stomachs. Dietary contribution by abundance and mass of prey items will be compared.

RESULTS

Together the six stomachs of melon-headed whales examined contained a total of 320 food items ranging from 2 to 143 prey items/stomach and two to 30 species/stomach. Prey remains were equally represented by cephalopod beaks and fish remains, with 49.7% of the diet comprised of cephalopods and 50.3% by fish when calculating by prey abundance.

A total of 159 lower beaks were identified representing 15 families and 26 species of cephalopods. The three most numerically abundant cephalopod families were Enoploteuthidae (28.3%) which was found in five of the six stomachs examined, Cycloteuthidae (15.1%) which was found in only two of the six stomachs and Histioteuthidae (9.4%) found in two of the six stomachs. These families collectively represented an estimated 52.8% of the total cephalopod prey items identified.

A total of 161 fishes contributed to the stomach content remains of the six melon-headed whales. Four of the six stomachs contained the remains of fish, representing 11 families and 26 species. The Myctophidae family of fishes was the most abundant, comprising 70% of the total fishes by number with at least 14 different species within this family represented in the stomachs. The most abundant myctophid species present were *Lampadena urophaos*, *Lampanyctus nobilis* and *Diaphus fragilis*. The family Stomidae represented 7.7% contribution of the total number of fishes by number.

IMPACT/APPLICATIONS

Melon-headed whales in Hawaiian waters demonstrate a diverse diet comprised of an equal contribution of cephalopods and fish when examined for prey abundance. Fifty-two species of fish and cephalopods that represented 26 families were present among the six stomachs examined in this study. Prey identification from the six Hawaiian melon-headed whales was compared to the only prior study that examined the diet of an individual melon-headed whale in Hawaii. A comparison of our findings to this prior study where only six lower beaks were present suggests that the diet of Hawaiian melon-headed whales is even more diverse than our report of 52 species of fish and cephalopods among the six stomachs. The family Bathyteuthidae and the genus *Teuthowenia* were not among the prey remains identified in the current study but were previously reported in a stranded melon-headed whale from Hawaii (Clarke and Young, 1998).

Although not present in high abundance, the presence of cephalopod species that do not undergo diel migrations provide information about depths of foraging activity by melon-headed whales in Hawaii. The presence of *Mastigoteuthis famelica* which have been taken off O'ahu between 675 to 800 m during both day and night (Young 1978) suggests that melon-headed whales dive to at least 675 m depths in Hawaiian waters. Our findings indicate that both deep water fishes and squid are important prey to Hawaiian melon-headed whales and that foraging activity spans both the mesopelagic and bathypelagic zones.

Next steps will include an assessment of what is known about habitat use and diel migration of the 52 species of prey identified and how this may relate to the behavior and movements of melon-headed whales, including interpretation in relation to what is known about diel patterns of whale behavior. For melon-headed whales in Hawaii, Cascadia Research has movement data from 19 satellite-tagged individuals ranging from 3.7 to 25.4 days (mean = 12.3 days; Schorr and Baird unpublished), two of which were tagged with depth-transmitting satellite tags, with 17 days of dive data available.

The 2004 mass stranding behavior in Kauai and the 2008 Madagascar event strongly suggest that melon-headed whales are vulnerable to anthropogenic noise. Similar to the concern with beaked whales, the displacement of individuals out of their normal habitat for extended periods can lead to secondary factors such as emaciation and dehydration that result in a lethal stranding event (Southall et al. 2013). Our work provides fundamental knowledge on the prey items fed upon by melon-headed whales and provides insight into their activity at depth. This is the first study of the food habits of melon-headed whales from any region of the world and will aid in our understanding of both the basic biology of the species as well as in assessing the impact of activities that have the potential to result in habitat displacement of whales.

RELATED PROJECTS

There are no related projects.

REFERENCES

Aschettino, J.M., R.W. Baird, D.J. McSweeney, D.L. Webster, G.S. Schorr, J.L. Huggins, K.K. Martien, S.D. Mahaffy, and K.L. West. 2012. Population structure of melon-headed whales (*Peponocephala electra*) in the Hawaiian Archipelago: evidence of multiple populations based on photo-identification. Marine Mammal Science 28:666-689.

Best, P.B. and P.D. Shaughnessy. 1981. First record of the melon-headed whale, *Peponocephala electra*, from South Africa. Annals of the South African Museum 83: 33-47.

Carretta, J.V., Oleson, E., Weller, D.W., Lang, A.R., Forney, K.A., Baker J., Hanson, B., Martien, K., Muto, M.M., Orr A.J., Huber, H., Lowry, M.S., Barlow, J., Lynch, D., Carswell, L., Brownell Jr., R.L. and D.K. Mattila. 2014. *U.S. Pacific marine mammal stock assessments: 2013.* (NOAA Technical Memorandum NMFS-SWFSC-532). Washington, DC: National Oceanic and Atmospheric Administration.

Clarke, M. 1986. Cephalopods in the diet of odontocetes. Pages 281-321 in M.M. Bryden and R. Harrison, eds. Research on dolphins. Clarendon Press, Oxford, UK.

Clarke, M. and R. Young. 1998. Description and analysis of cephalopod beaks from stomachs of six species of odontocete cetaceans stranded on Hawaiian shores. Journal of the Marine Biological Association of the United Kingdom 78:623-641.

Ohizumi, H., H. Watanabe, M. Moku, and S. Kawahara. 2001. Species identification for otoliths of myctophid fishes in the western North Pacific. Aquabiology 137:626-637.

Sekiguchi, K., N. T.W. Klages, and P.B. Best. 1992. Comparative analysis of the diets of smaller odontocetes along the coast of southern Africa. South African Journal of Marine Science 12: 843-861.

Smale, M.J., G. Watson, and T. Hecht. 1995. Otolith atlas of southern African marine fishes. Icthyological Monographs of the J.L.B. Smith Institute of Ichthyology 1, Grahamstown, South Africa.

Spear, L.B., D.G. Ainley, and W.A. Walker. 2007. Foraging dynamics of seabirds in the eastern tropical Pacific Ocean. Studies in Avian Biology No. 35:99 pp.

Southall, B.L., R. Braun, F.M.D. Gulland, A.D. Heard, R.W. Baird, S.M. Wilkin, and T.K. Rowles. 2006. Hawaiian melon-headed whale (*Peponocephala electra*) mass stranding event of July 3-4, 2004. NOAA Technical Memorandum NMFS-OPR-31.

Southall, B.L., T. Rowles, F. Gulland, R.W. Baird, and P.D. Jepson. 2013. Final report of the Independent Scientific Review Panel investigating potential contributing factors to a 2008 mass stranding of melon-headed whales (*Peponocephala electra*) in Antsohihy, Madagascar.

Woodworth, P.A., G.S. Schorr, R.W. Baird, D.L. Webster, D.J. McSweeney, M.B. Hanson, R.D. Andrews, and J.J. Polovina. 2012. Eddies as offshore foraging grounds for melon-headed whales **(***Peponocephala electra***).** Marine Mammal Science 28:638-647.

Young, R.E. 1987. Vertical distribution and photosensitive vesicles of pelagic cephalopods from Hawaiian waters. Fishery Bulletin 76:583-615.