Journal of Zoo and Wildlife Medicine 42(1): 124–127, 2011

SERUM VITAMIN A CONCENTRATIONS IN CAPTIVE SEA OTTERS (*ENHYDRA LUTRIS*)

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Abstract: Individual dietary preferences and difficulty with animal training create challenges and nutritional concerns when evaluating a captive sea otter (*Enhydra lutris*) diet. The importance of vitamin A within the body reflects the necessity that it be ingested in adequate amounts to ensure optimal health. To compare levels of serum vitamin A concentrations from captive sea otters on daily oral vitamin A supplementation, serum samples from eight adult sea otters from three institutions were evaluated for serum vitamin A concentrations. The eight animals were fed a total of four different diets and received oral supplementation via three different methods. Multiple diet items were analyzed for vitamin A content and were found to have low to nondetectable levels of vitamin A. Oral vitamin A supplementation, as a slurry with dietary items, was shown to be effective and a mean serum concentration of approximately 170 ± 51 µg/L was obtained for serum vitamin A concentrations in captive sea otters. Captive diets can be modified to increase vitamin A concentration and supplementation and, if accepted, can be used as a means to ensure adequate vitamin A intake.

Key words: *Enhydra lutris*, sea otter, serum concentration, supplementation, vitamin A.

BRIEF COMMUNICATION

Multiple facilities in the United States house captive sea otters (*Enhydra lutris*). Since the time they were classified as a threatened species under the Endangered Species Act,[3] Southern sea otters (*Enhydra lutris nereis*) have become sentinels of environmental conservation efforts as well as popular exhibit animals that represent a treasured North American marine species. There are many challenges in keeping these animals healthy in captivity. Unknown nutritional requirements make it challenging to ensure that they are receiving all the nutrients they need in their diet. Individual dietary preferences, the availability of certain prey species, and difficulty with animal training all compound the problem and augment the uncertainty regarding their nutritional status. Diets and supplementation differ from institution to institution and, currently, there does not appear to be a consensus on the best feeding method.

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Vitamin A plays a role in a number of metabolic and structural functions within the body. The role of vitamin A in immune system regulation, epithelial differentiation, bone and tooth formation, reproduction, and vision reflects the importance that it be ingested in adequate amounts in order to ensure optimal health.[4] In conditions of hypervitaminosis A, multiple periarticular exostoses has been reported in captive, nondomestic animals.[5] Vitamin A deficiency has been reported to cause retinal dysplasia in European river otters (*Lutra lutra*) as well as skull malformation and spinal cord degeneration in young captive lions (*Panthera leo*).[2,6]

Prior to this study, vitamin A deficiency was diagnosed incidentally in two captive sea otters, housed in a captive institution, when they were found to have no measurable hepatic retinol concentration. Subsequently, two clinically normal sea otters from the same enclosure that did not voluntarily accept daily oral vitamin A supplementation were treated with i.m. vitamin A injections. Serum levels of vitamin A were determined in these animals; however, there were no published serum vitamin A concentrations in captive sea otters for comparison. To obtain comparative levels of serum vitamin A concentrations from captive sea otters receiving daily oral vitamin A supplementation, serum samples from eight adult sea otters from three institutions were evaluated for vitamin A concentrations. The eight sea otters consisted of seven females and one male ranging in age from 2 yr to over 12 yr old. The sea otters were all deemed to be in good

Table 1. Serum vitamin A concentrations, daily vitamin A supplementation, and diet of captive sea otters.

Animal	Age (yr)	Sex	Weight (kg)	Supplementation (IU vitamin A/day)	Diet, as-fed	Serum vitamin A (μg/L)
A	12	F	18.3	6,250	1[a]	214
B	12	M	31.0	6,250	2[b]	231
C	2	F	19.1	10,000	3[c]	96
D	10	F	20.8	3,125	4[d]	140
E	12+	F	21.3	3,125	4[d]	170
F	8	F	21.2	3,125	4[d]	230
G	11	F	19.0	3,125	4[d]	120
H	8	F	19.9	3,125	4[d]	180

[a] 21% Hoki fillets, 34% surf clam foot, 31% decapitated shrimp, and 14% squid.
[b] 43% surf clam foot, 43% decapitated shrimp, and 14% squid.
[c] 50% surf clam foot and 50% decapitated shrimp.
[d] 18% whole surf clam, 8% peeled shrimp, 18% surf clam foot, 8% squid, 25% whole Manila clams, 5% crab, and 8% mussels.

health based on clinical history, complete blood counts, blood chemistry, and physical examination by the veterinarians at their institutions. None of these animals demonstrated clinical signs suggestive of vitamin A deficiency or toxicity such as night blindness, xerophthalmia, urolithiasis, immunosupression, incoordination, ataxia, retinal dysplasia, hyperostosis, cervical spondylosis, and tooth loss.[4,5,6,8] Serum samples were evaluated at two American Association of Veterinary Laboratory Diagnosticians-accredited veterinary diagnostic labs with analogous instrumentation and methodology. Samples from animals A, B, and C were sent to Michigan State University's Diagnostic Center for Population and Animal Health (4125 Beaumont Road, Lansing, Michigan 48910, USA) for serum vitamin A analysis by high-performance liquid chromatography (Model 2690 HPLC System, Waters Corporation, Milford, Connecticut 01757, USA). Serum samples from animals D, E, F, G, and H were sent to the California Animal Health and Food Safety Laboratory (CAHFS, University of California, Davis, West Health Sciences Drive, Davis, California 95616, USA) for serum vitamin A analysis by high-performance liquid chromatography (Model Alliance 2695 HPLC System, Waters Corporation; and Model 1100 HPLC System, Agilent Technologies, Santa Clara, California 95051, USA). The results from these analyses are listed in Table 1.

There were a total of four different diets fed among the eight animals (Table 1). Additionally, each sea otter received daily oral vitamin A supplementation using products by two manufacturers at three different doses (Table 1). Diet 1 consisted of 21% Hoki (*Macruronus novazelandiae*) fish filets, 34% surf clam (*Spisula solida*) foot, 31% decapitated shrimp (*Penaeus* sp.), and 14% squid (*Loligo* sp.) with the pen removed. Diet 2 consisted of 43% surf clam foot, 43% decapitated shrimp, and 14% squid with the pen removed. Diet 3 consisted of 50% surf clam foot and 50% decapitated shrimp. Occasionally, squid with the pen removed and octopus were given as treats. Diet 4 consisted of 18% hand-shucked whole surf clam, 8% peeled shrimp, 18% surf clam foot, 8% squid, 25% live, whole Manila clams (*Venerupis philippinarum*), 5% crab (*Cancer* sp.), and 18% mussels (*Mytilus* sp.). Many of the food items were analyzed for vitamin A (retinol) content (Table 2). The food items, as fed, were found to have low to nondetectable vitamin A content with the whole clam having the highest amount of vitamin A. Decapitated shrimp, clam foot, and squid samples were sent to the CAHFS and were analyzed for vitamin A (retinol) content by HPLC (Model 1100 HPLC System, Agilent Technologies). Whole clam and mussel samples were sent to Dr. Kevin McGraw at the Arizona State University School of Life Sciences (Tempe, Arizona 85287, USA) and were analyzed by HPLC (HPLC, Waters Alliance Instrument, Waters Corporation) for vitamin A (retinol) content.

Animals D, E, F, G, and H were fed the most diverse diet, diet 4, and were the only ones that

Table 2. Vitamin A (retinol) concentrations of food items as fed to captive sea otters.

Food item	Total vitamin A (μg/g)
Mussels	1.86
Shrimp	ND[a]
Squid	0.25
Surf clam foot	ND[a]
Whole clam	6.62

[a] None detected (minimum detection 0.2 μg/g).

received whole clam or mussel meats. These animals additionally received 3125 IU of vitamin A (retinyl acetate) oral supplementation daily. One quarter of a Sea Tab® (Original Sea Tabs®, Pacific Research Laboratories, La Jolla, California 92037, USA) was ground and blended with food items into a slurry and then immediately orally administered to the animals with a syringe. These otters were supplemented with the lowest amount of vitamin A. Their serum vitamin A concentrations ranged from 120–230 μg/L. The whole clam and mussel meats in these four animal's diet had the highest concentration of vitamin A of the food items analyzed (Table 2). The higher concentration of vitamin A in their diet likely adjusted for the lower vitamin A supplementation these animals received.

Animals A and B were fed moderately diverse diets, diets 1 and 2; however, no whole clam or mussel meat was offered. Similar to animals D through H, animals A and B were given daily oral vitamin A supplementation in a food slurry via an oral syringe; however, they were also given 6250 IU of vitamin A (retinyl acetate) or half of a Sea Tab. This is twice as much supplementation as animals D through H received. This higher supplementation dose resulted in higher serum vitamin A concentration in animals consuming a less diverse diet containing a lower vitamin A content.

Animal C, with the lowest serum vitamin A concentration, received the least-diverse diet, diet 3, consisting of just two main food components with an occasional cephalopod. Like sea otters A and B, animal C was not fed any whole clam or mussel meat, and the food items fed contained no detectable levels of vitamin A. This sea otter's diet was supplemented with a multivitamin that does not contain vitamin A. Vitamin A (retinyl acetate) was provided by placing one whole softgel (Product 6480, Major Pharmaceuticals, Livonia, Michigan 48150, USA) containing 10,000 IU of vitamin A into each slot of an ice cube tray containing a food and multivitamin slurry. The cubes were then frozen and the sea otter was administered one cube per day. This sea otter was given the highest daily vitamin A supplementation, yet had the lowest serum vitamin A concentration. Because the supplement was provided as a whole pill rather than as part of a slurry, questions arose regarding the amount of vitamin A the animal was actually consuming. It is possible that the animal was discarding the intact vitamin; however, no softgels were ever recovered. The low serum vitamin A concentration in this animal was likely due to the low vitamin A concentration in the food items fed as well as unreliable supplementation ingestion.

The Marine Sanctuary Conservation Series reported a mean serum vitamin A concentration of 170 ± 42 μg/L, with a range of 110–270 μg/L, for 30 live, healthy, free-ranging Northern sea otters (*Enhydra lutris kenyoni*).[1] In comparison, the mean vitamin A concentration found in the eight captive sea otters in this study was 173 ± 51 μg/L, with a range of 96–231 μg/L. While the means were similar, it is the similar ranges that will be important when evaluating clinical cases in the future.

The test animals were all wild-born, captively held, stranded animals. The periods of captivity were at least 1 yr for all animals. The authors cannot rule out a role for polychlorinated biphenyls (PCB) exposure impacting these animals—either from direct ingestion or secondary ingestion while nursing from wild dams with high concentrations of toxins. Because PCBs are a known complication associated with low vitamin A concentrations,[7] wild-born sea otters and their offspring should be considered as vulnerable for this concern.

These data provide a range of serum vitamin A concentrations to serve as a guide for serum levels in captive sea otters. In order to achieve concentrations similar to ranges listed above, administration of oral vitamin A supplements as slurry has been shown to be effective. Administration of a softgel supplement in a frozen slurry may be a second option for daily vitamin A supplementation. It is recommended that the softgel be opened up and mixed in with the slurry to ensure ingestion of the supplement. The safety and efficacy of vitamin A injections as a manner of supplementation should be evaluated by determination of serum concentrations. Data from free-ranging sea otters with no supplementation suggests that the captive diets containing whole prey items can provide adequate vitamin A concentrations. Due to the low vitamin A concentrations of the food items fed to these captive otters, it is likely that the food processing, and the limited spectrum of items fed to the captive otters, provided less vitamin A than was consumed by their free-ranging counterparts. Captive diets should be analyzed and serum levels checked to determine if vitamin A supplementation is necessary or adequate to achieve target serum levels. If supplements are accepted, commercially available vitamin A supplementation can correct dietary deficiencies of vitamin A content.

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Received for publication 14 January 2010