NUTRITIONAL MANAGEMENT IN PRACTICE OF SAND TIGER SHARK (*CHARCARIAS TAURUS*) IN AQUARIUM

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Abstract
Large sharks, such as the sand tiger shark (*Carcharias taurus*), usually attract public attention in visiting aquariums. It is considered one of the most popular great sharks in captivity. The lack of information on shark and ray nutrition means that there is no consensus on the diet to be offered and on the rate of feeding or frequency of meals. The frequency can vary from 1 to 7 times a week and the rate varies from 1.0-18.1% of the live weight per week or more until apparent satiety. One of the main pathologies found in this species is the deviation of the spine, with obesity and an unbalanced diet being predisposing factors. The present work reports a practical way of calculating the diet of these sharks taking into account their weight, the nutritional characteristics of the food, supplementation, and the energy demand for their maintenance. The 9.6 kcal/BW^0.8 equation was used as a basis for the prediction of the maintenance energy requirement. Supplementation must be balanced according to the food and the amount offered to the animal in order to meet the stipulated nutritional requirements. Food management is done by calculating the energy supply of the food item offered to the animal, thus estimating the number of days it will have its energy demand met. Thus, we managed to avoid excessive weight gain, improving the health, well-being, and longevity of this species. Specific studies must be carried out to ensure more safety in food and nutritional management with the species.

Introduction
The sand tiger shark (*Carcharias taurus*) is a large coastal shark, found in all warm seas except perhaps the eastern Pacific (Compagno & Niem, 1998). Annual population growth rates are very low, reducing their ability to withstand fishing pressure, thus being classified as vulnerable by the IUCN (Pollard & Smith, 2009). Among the species of large and non-sedentary sharks, *C. taurus* is the most popular, presenting 36 individuals distributed in 16 European institutions (Janse *et al.*, 2017).

Nutritional management of sharks varies between institutions, with a lack of consensus on shark nutrition in general. The weekly frequency at which food is offered may vary according to the individual's age. In SeaWorld Ohio, USA, newborn sand tiger sharks were fed daily, juveniles of a total length (TL) of 1.0-1.5 m were fed three times a week, and adult sharks were fed twice a week. (Janse *et al.*, 2004). The recommendation of the weekly feeding rate for the species varies from 1-2% BW for adult individuals (Mohan, 1996) to 18.1% BW for young animals (Janse, 2003), with the possibility to disregard the rate, with the offer until apparent satiety one day of the week or all (Janse *et al.*, 2004).

This method is frequently adopted in the nutrition of aquarium sharks (Janse *et al.*, 2004); however, it has some flaws as it does not consider the energetic need to maintain the different species of sharks, as well as disregarding the energy supply of the food offered. Since different species of fish are used as a food item and have different nutritional levels, there is a different energy value between the type of fish used, even if they are offered in the same quantity by weight.

Obesity is a condition frequently found among sand tiger sharks kept in under human care, as they usually receive food above their maintenance demand and as an attempt to reduce the teleost predation rate (Janse *et al.*, 2004). The overeating scenario contributes to overweight animals and other nutritional problems, which are factors that predispose them to spinal deformity (Journal *et al.*, 2012), a pathology well described for the species (Preziosi *et al.*, 2006; Janse *et al.*, 2004) with prevalence in 1/3 of the captive sand tiger shark population (Walsh & Richards, 2002). Considering that the spine is located dorsally to the stomach, with increased organ volume, it is possible that there is a predisposition to the occurrence of spinal subluxations, which are more common in this region (Berzins & Jesselson, 1999). Another factor that contributes to the occurrence of problems in the spinal column is the long-term imbalance of micronutrients (Anderson, 2012; Berzins & Jesselson, 1999). There are significant differences in the composition of the fish offered, in addition to the freezing of food for storage, which favors excessive cellular dehydration and protein denaturation, making it even more difficult to standardize food among institutions (Janse *et al.*, 2004).

The present work presents a model that establishes an adequate nutritional management for individuals of adult sand tiger shark taking into account their energy demand and nutritional composition of the fish. These will be determinants for the optimal food frequency, which varies according to the weight and type of food. The goal of this study is to contribute to the health, well-being, and longevity of animals kept in aquariums.

Materials & Methods

Values for nutritional requirements were acquired from the tables of the National Research Council (NRC, 2011). The document, Nutritional Requirements of Fish and Shrimp, presents a compilation of information regarding nutrients and nutritional requirements for fish and shrimp. The maintenance energy requirement for fish at an optimal temperature can be estimated using the equation 9.6 to 19.1 kcal x $(BW)^{0.8}$, where BW is the animal's live weight in kilograms. As the species *C. taurus* has a slow swimming habit, and the individuals in question will be considered adults, the constant 9.6 was used for the calculations.

Two models will be used: the first where the independent variable is the live weight of the sand tiger shark, with the dependent variable being the energy requirement for maintenance per day. The types of food are defined according to the local availability, which vary between regions and time of year. The second model has the independent variable of the weight of the food offered and the dependent variable of the days supplied by the caloric demand offered, so it is possible to establish the next day of food supply. Respecting periods of fasting, reported by Taylor & Smale (2010), who found about 47% of empty stomachs for the species, suggesting a spacing between the meals of free-living individuals.

We recommend offering different species of fish, in order to provide a variety of food items. These animals have a wide range of prey and a relatively low incidence of most of them, suggesting a high degree of opportunistic feeding in the wild. When analyzing stomach contents, coastal, pelagic, demersal, benthic sand bottom, and coral reef fish and prey associated with the medium and external continental shelf can be found. The size of the shark also affects the type of food consumed, sharks smaller than 2m consumed a total of 31 taxa, 12 being shared with larger individuals, while adults consumed a total of 47 taxa of prey, 28 of which are exclusive to this group (Smale, 2005).

Results and Discussion

Energy demand

Our model uses the NCR (2011) 9.6 kcal x (BW)^0.8 formula as the basis. For the following example, a 50 kg (110.23 lbs) shark was considered. We found an energy demand of 220 kcal per day. Multiplying by 7, we will have a weekly energy demand of 1540 kcal that must be supplied by the food offered throughout the week. The offer calculated according to the percentage of live weight for the same individual would be 0.5 kg (1.10 lbs) considering the feed rate of 1% BW or 1 kg (2.20 lbs) for 2% BW. Since the weight of the food does not vary according to the species of prey (Table 2), we can find in Table 1 three different species of teleost with energy values offered ranging from 516 -1324 kcal. An energy supply below demand can lead to negative energy balance and long-term weight loss or an increase in the rate of predation in the aquarium.

Food frequency

The number of times that food is offered throughout the week is also not a consensus among institutions that maintain sand tiger shark in aquariums and can vary according to the age and size of the individual. In SeaWorld Ohio, USA, newborns were fed daily, 1.0-1.5 m TL juveniles were fed three times a week, and adult sharks were fed twice a week (Janse *et al*., 2004). Considered an adult individual, he would be fed twice a week regardless of the amount of energy that the fish offered presents. The model we propose automatically calculates the next feeding day, according to the fish offered in the previous feeding (Table 3). For example, if a 0.7 kg (1.54 lbs) *Katsuwonus pelamis* is offered, which corresponds to an offer of 722.3 kcal, the shark will have its daily energy demand (220 kcal) supplied 3.2 times, that is, the fast may be 3 days, without prejudice to the individual's energy balance. Thus, the fasting period varies according to the species and the weight of the food offered.

Vitamin and mineral supplementation

In an *ex situ* environment, elasmobranchs are fed mainly with pre-frozen fish in order to ensure that there is no risk of parasitic infection through fish (Jansen, 2004). Due to freezing, loss of essential vitamins and minerals can occur, making supplementation necessary. The loss of nutrients during the handling and storage of fish (Tarr, 1962, Ikeda & Taguchi, 1996, Stoskopf, 1983, Dierenfeld, 1990) can contribute to the incidence of pathologies due to nutritional deficiency in carnivorous piscivores (Wilson, 1972; Geraci & St. Aubin, 1979; Geraci, 1981; Wallach & Boever, 1983; Citino *et al.,* 1985; Alexander & Johnson, 1989; Dierenfeld, 1990). In a study by Fennema (1978), in order to examine the loss of vitamins from animal tissues during storage, it was found that after six months of storage at -18 ° C, oysters lost 22% of pre-existing thiamin (vitamin B_1), 0% riboflavin (vitamin B_2), 35% of niacin (vitamin B_3), and 46% pyridoxine (vitamin B_6). For elasmobranchs, supplements are commonly adopted as prevention, since nutritional requirements are not established (Jansen, 2004). Ideally, supplementation of vitamins and minerals should be used as a food supplement based on the nutritional needs of the species, as well as the food item used, thus avoiding episodes of deficiencies (Jansen, 2004) or intoxications (NRC, 2011).

Currently, it is possible to find specific vitamin and mineral supplements for elasmobranchs on the market, but we have a very diverse range of species and eating habits within this group, in addition to different food items offered. Thus, commercial supplements do not consider the individual needs of the animal as a physiological state or the nutritional levels of the food item offered. That said, the ideal would be an individual formulation based on the range of requirements for fish available in the NCR (2011), taking into account the composition of the food used, thus contributing to better nutrition.

Although Vitamin C deficiency has already been associated with spinal deviation in sand tiger shark (Anderson *et al.*, 2012; Huber *et al.*, 2013), there are indications that elasmobranchs have the ability to synthesize it. The enzyme gulonolactone oxidase participates in the final stage of the synthesis of Vitamin C and has already been found, together with the gene responsible for vitamin synthesis, in *Squalus acanthias* (Mæland & Waagbø, 1998)*, Dasyatis akakei*, and *Mustelus manazo* (Touhata *et al.*, 1995). Some research has shown that the increase in the concentration of ascorbic acid in the diet does not exert negative feedback on the endogenous synthesis in white and lake sturgeon (Moreau *et al*., 1999; Dabrowski, 1994; Mureau *et al*., 1999).

Fat-soluble vitamins such as Vitamin A, D and E can accumulate in animal tissue when in excess causing a toxic hypervitaminosis condition (NCR, 2011). For proper nutrition they must be balanced with each other, avoiding antagonistic absorption effects. The excess of Vitamin A reduces the concentration of Vitamin E in tissues (Olivares *et al.*, 2008).

The lack of minerals can be caused by the drainage of mineral stocks in the water, for example by the skimmer. To date, the only pathological condition related to a mineral deficiency is goiter or hyperplasia of the thyroid, resulting from iodine deficiency (Gruber & Keyes, 1981; Uchida & Abe, 1987; Pike *et al.,* 1993; Lloyd, 1995; Sondervan, 1997; Van der Veek *et al.,* 2001; Janse, 2003). Symptoms of the goiter include a ball-like swelling under the lower jaw, which can prevent the shark from eating and ultimately lead to death.

Goiter is considered a common condition in all installations that hold elasmobranchs captive, especially in closed rearing systems, with filtering and water circulation through pumps without the need for water exchange with the natural environment. It is the result of the reduction in the amount of thyroid hormone in animals, caused by the low concentration of iodine in the water. Clinical signs include a progressive swelling of the thyroid gland, which can expand up to 300 times its normal size. This condition, if left untreated, can result in difficulty in swallowing, causing decreased food intake, cachexia, and even death. As prophylaxis for the development of goiter, it is necessary to supplement the iodine in the feeding of sharks.

The concentration of micronutrients can vary according to the food and its quantity offered to the animal. If the supplement is not formulated with certain criteria, the concentration of some nutrients in the diet as a whole may not be achieved or exceed the recommendations (Hoopes, 2017; Table 4).

Conclusion

The available equations make it possible to formulate a diet with greater security for individuals of sand tiger shark kept under human care. However, specific studies with the species should be done to have better information about the nutrition of elasmobranchs.

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Literature Cited

Alexander JW and Johnson B (1989) Nutritional myopathy (white muscle disease) in a California sea lion (*Zulophus californiunus*). In: Schroeder JP and Leamaster JL, Eds. *Proceedings of the International Association of Aquatic Animal Medicine*, IAAAM. Gulfport, MS. pp 66-69.

Anderson PA, Huber DR, and Berzins IK (2012) Correlations of capture, transport, and nutrition with spinal deformities in sandtiger sharks, *Carcharias taurus*, in public aquaria. *J Zoo Wildl Med* 43(4): 750–758.

Castro-González MI, Montaño BS, Ledesma CE, and Péres-Gil RF (2007) Evaluación de los ácidos grasos n-3 de 18 especies de pescados marinos mexicanos como alimentos funcionales. *Arch Latinoam Nutr* 57(1): 85-93.

Christiansen SM (2018) Nutritional composition and heavy metal content in *Sardinella maderensis, Decapterus rhoncus, Sardinella aurita, Trachurus trecae* and *Sphyraena guachancho* off the coast of Angola. Master Thesis, University of Bergan. 1-64.

Citino SB, Montali RJ, Bush M, and Phillips LG (1985) Nutritional myopathy in captive California sea lion. *J Am Vet Med Assoc* 187(11): 1232- 1233.

Compagno LJV and Niem VH (1998) Part Sharks: Hexanchidae, Echinorhinidae, Squalidae, Squatinidae, Heterodontidae, Parascyllidae, Bracheluridae, Orectolobidae, Hemiscyllidae, Odontaspididae, Scyliorhinidae, Proscyllidae, Triakidae. In: K.E. Carpenter and V.H. Niem, Eds. FAO Identification Guide for Fishery Purposes. The Living Marine Resources of the Western Central Pacific. Food and Agriculture Organization. pp 1195–1232, 1235–1259, 1264–1267, 1279–1295, 1297–1304, 1312–1360.

Dabrowski K (1994) Primitive Actimoterigian fishes can synthesize ascorbic acid. *Experientia,* 50(8): 745-748.

Dierenfeld ES, Katz N, Pearson J, Murru F, and Asper ED (1991) Retinol and alpha-tocophero1 concentrations in whole fish commonly fed in zoos and aquariums. *Zoo Biol* 10(2): 119-125.

Fennema, O (1982) Effect of processing on nutritive value of food: freezing. In: Rechcigl M, Ed. Handbook of Nutritive Value of Processed Food Volume 1 Food for Human Use, 1st Edition. pp 31-44.

Gencbay G and Turhan S (2016) Proximate composition and nutritional profile of the Black Sea Anchovy (*Engraulis encrasicholus*) whole fish, fillets, and by-products. *J Aquat Food Prod Technol* 25(6): 864–874.

Geraci JR (1981) Dietary disorders in marine mammals: Synthesis and new findings. *J Am Vet Med Assoc* 179(11): 1183-1191.

Geraci JR and St. Aubin DJ (1979) Nutritional disorders of captive fish-eating animals. In: R.J. Montali RJ and Migaki G, Eds. The Comparative Pathology of Zoo Animals. pp 41-49.

Gruber SH and Keyes RS (1981) Keeping sharks for research. In: Hawkins AD, Ed. Aquarium Systems. pp 373-402.

Hoopes AL (2017) Elasmobranch Mineral and Vitamin Requirements. In: Smith M, Warmolts D, Thoney D, Hueter R, Murray M, and Ezcurra J, Eds. The Elasmobranch Manual II: Recent Advances in the Care of Sharks, Rays and their Relatives. pp 135-146.

Huber DR, Neveu DE, Stinson CM, Anderson PA, and Berzins IK (2013) Mechanical properties of sand tiger shark (*Carcharias taurus*) vertebrae in relation to spinal deformity. *J Exp Biol* 216(22): 4256–4263.

lkeda S and Taguchi T (1996) Improved assay method and levels of vitamin E in fish tissues. *Bull Jap Soc Sci Fish* 32: 346-351.

Janse M (2003) Considerations on the diet composition and feeding rate of dermersal sharks in 15 European public aquaria. *Zoo Biol* 22(3): 203-226.

Janse M, Firchau B, and Mohan PJ (2004) Chapter 14. Elasmobranch Nutrition, Food Handling, and Feeding Techniques. In: Smith M, Warmolts D, Thoney D, and Hueter R, Eds. The Elasmobranch Husbandry Manual: Captive Care of Sharks, Rays and their Relatives. pp 183-200.

Janse M, Zimmerman B, Geerlings L, and Brown C (2017) Sustainable species management of the elasmobranch populations within European aquariums: a conservation challenge. *J Zoo Aquar Res* 5(4): 172–181.

Lloyd N (1995) Treatment of goiter in Atlantic Nurse sharks *Ginglymostoma cirratum* at the Blackpool Sea Life Centre. *Int Zoo Yearb* 34(1): 95-98.

[NRC] National Research Council. (2011) Nutrient requirements of fish and shrimp. Washington, D.C.: National Academies Press.

Mahaliyana AS, Jinadasa BKKK, Liyanage NPP, Jayasinghe GDTM, and Jayamanne SC (2015) Nutritional composition of skipjack tuna (*Katsuwonus pelamis*) caught from the oceanic waters around Sri Lankae. *Am J Food Nutr* 3(4): 106–111.

Mæland A and Waagbø R (1998) Examination of the qualitative ability of some cold water marine teleosts to synthesise ascorbic acid. *Comp Biochem Physiol A Mol Integr Physiol* 121(3): 249-255.

Moura, ES (2012) Influência da adição da fibra de maracujá em reestruturado empanado a partir de resíduo de pescada amarela (*Cynoscion acoupa*). Master Thesis, Federal University of Pará. 1-79.

Mohan, PJ (1996) Using fisheries data to manage the diets of captive elasmobranchs. In *Proceedings of the AZA Annual Conference*. American Zoo and Aquarium Association, Waikiki, Honolulu, Hawaii. pp 265-273.

Moreau R, Dabrowski K, Czesny S, and Chila F (1999) Vitamin C - vitamin E interaction in juvenile lake sturgeon (*Acipenser fulvescens* R.), a fish able to synthesize ascorbic acid. *J Appl Ichthyol* 15(4-5): 250-257.

Moreau R, Dabrowski K, and Sato PH (1999) Renal L-gulono-1,4-lactone oxidase as affected by dietary ascorbic acid in lake sturgeon (*Acipenser fulvescens*). *Aquac* 180(3-4): 359-372.

Olivares A, Rey AI, Daza A, and Lopez-Bote CJ (2009) High dietary vitamin A interferes with tissue a-tocopherol concentrations in fattening pigs: a study that examines administration and withdrawal times. *Anim* 3(9): 1264–1270.

Pike CS, Manire CA, and Gruber SH (1993) Nutrition and nutritional diseases in sharks. In: Stosskopf MK, Ed. Fish Medicine. pp 764

Preziosi R, Gridelli S, Borghetti P, Diana A, Parmeggiani A, Fioravanti ML, Marcer F, Bianchi I, Walsh M, and Berzins I (2006) Spinal deformity in a sandtiger shark, *Carcharias taurus* Rafinesque: A clinical-pathological study. *J Fish Dis* 29(1): 49–60.

Pollard D and Smith A (2009) *Carcharias taurus*. In: The IUCN Red List of Threatened Species. https://www.iucnredlist.org/. Accessed May 20, 2021.

Sondervan P (1996) Iodine in seawater: Measurements and policy in aquarium systems. In: *Proceedings of the European Union of Aquarium Curators*. EUAC. pp 15-19.

Stoskopf MK (1983) Providing proper nutrition for captive alcids and penguins. In: Meehan TP and Allen ME, Eds. *Proceedings of the Third Annual Dr Scholl Conference on the Nutrition of Captive Wild Animals*. Chicago, Illinois. pp 46-69.

Tabela brasileira de composição de alimentos (2020) Universidade de São Paulo (USP) Food Research Center (FoRC). Release 7.1 São Paulo. http://www.fcf.usp.br/tbca. Accessed May 20, 2021.

Tarr, HLA (1962) Chapter 6. Changes in nutritive value through handling and processing procedures. In: G. Borgstrom, Ed. Fish and Food, Vol. 11. pp 235- 266.

Taylor, Smale MJ (2005) The diet of the ragged-tooth shark, *Carcharias taurus* Rafinesque 1810 in the Eastern Cape, South Africa. *Afr J Mar Sci* 27(1): 331-335.

Touhata K, Toyohara H, Mitani T, Kinoshita M, Satou M, and Sakaguchi M (1995) Distribution of L-gulono-1,4-lactone oxidase among fishes. *Fish Sci* 61(4) 729-730.

Uchida H and Abe Y (1987) The prevention of goitre in captive sharks. *Int Zoo Yearb* 26(1): 59-61.

Van der Veek YJM, Dorrestein JA, and Mol PM (2001). The effect of administration of potassium iodine on goiter and serum T4 levels in lesser spotted dogfish (*Scyliorhinus canicula*). In: *Verhandlungsberichte der Internationalen Symposien über die Erkrankungen der Zootiere* pp 35-40.

Wallach JD and Boever WJ (1983) Diseases of Exotic Animals: Medical and Surgical Management. Philadelphia: W.B. Saunders Co.

Wilson TM (1972) Diffuse muscular degeneration in captive harbor seals. *J Am Vet Med Assoc* 161(6): 608-610.

[TACO] Tabela brasileira de Composição de Alimentos (2014) -Tabela brasileira de Composição de Alimentos-TACO/ NEPA. UNICAMP. 4ª edição. Campinas – SP.: BookEditora.

[USDA] U.S. Department of Agriculture Agricultural Research Service (2019) FoodData Central. https://fdc.nal.usda.gov/. Accessed May 20, 2021

Table 1. Fish used as a food item in the Oceanic Aquarium and their nutritional levels in natural matter.

Fish	Moisture %	CP[1] %	EE[2] %	Energy kcal/100g	References
Sardinella brasilienses	76.60	21.1	2.70	114.00	(TACO, 2014)
Scomberomorus brasilienses	75.58	22.48	1.77	105.80	(USDA, 2019)
Engraulis encrasicholus	68.22	16.06	12.79	179.35[3]	(Gencbay & Turhan, 2016)
Xiphias gladius	73.80	16.72	6.65	144.00	(USDA, 2019)
Cynoscion acoupa	74.87	16.72	6.71	130.63[3]	(Em *et al.*, 2012)
Katsuwonus pelamis	73.28	24.13	0.41	100.21[3]	(Mahaliyana *et al.,* 2015)
Sphyraena guachancho	76.15	20.8	2.10	102.1[3]	(Christiansen, 2018)
Mugil curema	75.55	17.06	7.13	132.41[3]	(Castro-Gonzalez *et al.,* 2007)
Cynoscion leiarchus	78.60	16.00	4.49	104.00	(TACO, 2014)

[1]Crude Protein
[2]Ether Extract (fat)
[3]Energy calculated by: (CP x 4) + (EE x 9)

Table 2. Comparison between four different ways of offering a diet for a sand tiger shark *C. taurus*, weighing 50 kg with three different fish species.

Fish	7.8% BW[1]/week[2]		18.1% BW/week[2]		1% BW/week[3]		2% BW/week[3]		9.6 x (PV)^0.8[4]	
	kcal	kcal	kcal	kcal	kcal	kcal	kcal	kcal	kcal	kcal
Katsuwonus pelamis	3.90	4025	9.05	9340	0.50	516	1.00	1032	1.49	1540
Mugil curema	3.90	5164	9.05	11983	0.50	662	1.00	1324	1.16	1540
Cynoscion leiarchus	3.90	4078	9.05	9463	0.50	523	1.00	1046	1.47	1540

[1]Body Weight
[2]Janse (2003)
[3]Mohan (1996)
[4]NRC (2011)

Table 3. Example of nutrition factsheet for controlled feeding of sand tiger shark.

Day	Food	Amount, g	kcal	Fasting Days	Next Date Power Input
03/11/2021	*Katsuwonus pelamis*	700	722.3	3	03/14/2021
03/14/2021	*Mugil curema*	280	370.8	2	03/16/2021
03/16/2021	*Scomberomorus brasilienses*	744	787.6	4	03/19/2021
03/19/2021	*Katsuwonus pelamis*	1194	1232.1	6	03/24/2021
03/24/2021	*Mugil curema*	332	439.6	2	03/26/2021
03/26/2021	*Mugil curema*	306	405.2	2	03/28/2021
03/28/2021	*Katsuwonus pelamis*	970	1001	5	04/01/2021
04/01/2021	*Mugil curema*	324	429	2	04/03/2021
03/04/2021	*Sardinella brasilienses*	208	209.4	1	04/04/2021
04/04/2021	*Katsuwonus pelamis*	900	928.7	4	04/08/2021
04/08/2021	*Sardinella brasilienses*	140	141	1	04/09/2021
04/09/2021	*Mugil curema*	324	429	2	11/04/2021
04/11/2021	*Katsuwonus pelamis*	800	825.5	4	04/14/2021
04/14/2021	*Cynoscion leiarchus*	1114	1164.8	5	04/18/2021

Table 4. Concentration of nutrients in the supplement, nutritional levels per kilogram of dry matter of different supplemented food items and the recommendations according to the NRC (2011).

	Supplement	*Katsuwonus pelamis*[1]	*Mugil curema*[2]	*Cynoscion leiarchus*[3]	Recommendation
Nutrient	Unit/kg DM	Unit/kg DM	Unit/kg DM	Unit/kg DM	Unit/kg DM
Vitamin A, UI	2000	9310	26878	10327	6600 – 13000
Vitamin D, UI	342.5	1594	4603	1769	400 – 2400
Vitamin E, UI	50	233	672	258	25 – 200
Vitamin C, mg	245	1140	3293	1265	100 – 500
B12, µg	1.85	9	25	46	10 – 50
B1, mg	41.5	193	558	214	1 – 10
Riboflavin, mg	0.75	3	10	6	3 – 20
Niacin, mg	1.25	6	17	6	12 – 150
Pyridoxine, mg	0.75	3	10	4	1 – 20
Biotin, µg	29.5	137	400	200	50 – 250
Folic Acid, mg	0.37	1.7	4.9	2.4	1 – 10
Pantothenic Acid, mg	2	9	27	10	10 – 50
Zn, mg	4.2	45	56	33	20 – 150
Mn, mg	1.55	7	21	8	7 – 13
Mg, mg	0.15	1	2	893	500 – 700
Fe, mg	0.13	92	2	8	30 – 200
I, mg	26.6	124	357	137	0.6 – 1.1
Ca, mg	19	88	255	828	2000 – 15000

[1]Average fish weight = 800 g
[2]Average fish weight = 300 g
[3]Average fish weight = 900 g