

OVERVIEW

Diets for several species of adult turtles from two seasons (winter and summer) were analyzed, as well as diets for hatchlings of some species. The nutrient requirements of all of these species are unknown. Dietary and nutrient recommendations are based solely on extrapolations of known requirements for other taxonomically unrelated species.

Estimated nutrient composition of the diets is based on published data for grasshoppers, water snails, land snails, and vegetables; analytic data for earthworms, freshwater fish, fish pellet; and label information for the pig pellet. Compositional (analytic) data for a commercial fish pellet (Trout Chow) were used for the fish pellet. There were insufficient data available to separate the composition of the water and land snails; therefore, an average snail composition was used for both types of snails.

Without analytic data of the actual food items used, the nutrient composition of the calculated diet is at best an estimate of the true composition. Variation and differences among the nutrient composition of the data used and the actual composition of the food items fed are to be expected. For example, there may be differences in the composition of the snails, grasshoppers and earthworms due to the fact that the data used for calculating the nutrient composition of the diets may not be from the same species of snails, grasshoppers and earthworms that are actually fed. Moreover, there are likely seasonal differences in these food items, as well as freshwater fish, which can impact the overall diet composition. There are sufficient compositional data for most of the feed items to evaluate the macronutrient profile and selected minerals of the diets.

The composition of the individual diet items is presented in Table 1. There are minor differences associated with the fruit and mixed diet fed at different times of the year.

The average daily diet nutrient composition was computed for each species based on the amounts and frequency of each food item offered. In general, the diets appear to contain appropriate concentrations of macronutrients and minerals (Tables 2 and 3). Figures 1-4 illustrate seasonal differences of crude protein, crude fat, calcium and phosphorus.

FINDINGS

On average, the dry matter content of the diets is approximately 20%. One notable exception are the diets (summer and winter) for *Siebenrockiella crassicollis*, which are approximately 50%. The higher dry matter content of these diets is a consequence of the relatively high proportion of fish pellet in this diet. Several hatchling diets are also higher in dry matter (*Cuora amboinensis*, *Cyclemys pulchristriata*, *Ocadia sinensis*, *Siebenrockiella crassicollis* and *Sacalia quadriocellata*).

Crude protein concentration of most diets is approximately 20% of dry matter. Some diets contain a considerably higher concentration of crude protein, including the diets (summer and winter) for *Pelodiscus sinensis*, *Siebenrockiella crassicollis*, and *Sacalia quadriocellata* (> 40% crude protein). Some diets contain less than 10% crude protein, including the diets (summer and

winter) for *Cuora galbinifrons* and *Pyxidea mouhotii*. These lower-protein diets contain a higher proportion of fruit than other diets.

Crude fat concentration of most adult diets is approximately 4% of dry matter. Several diets have a crude fat concentration greater than 10%, including the diets (summer and winter) for *Pelodiscus sinensis*, *Sacalia quadriocellata* and *Siebenrockiella crassicollis*. These higher fat diets are also the same diets with a higher concentration of crude protein. These diets contain a relatively high proportion of fish. Crude protein and fat content will be dependent on the protein and fat content of the prey items (especially fish), which may vary seasonally, and this variation is not accounted for in these analyses.

Many diets contain a sufficient concentration of calcium and phosphorus, and all diets appear to contain an appropriate ratio of calcium and phosphorus (between 1:1 and 2:1). A few diets (including the summer diets for *Cuora galbinifrons* and *Pyxidea mouhotii*) appear to contain a relatively low concentration of calcium (<0.3% of dry matter). The amount of phosphorus in these lower-calcium diets is also low; however, the ratio of calcium-to-phosphorus appears adequate. These lower-calcium diets tend to have a higher proportion of fruit and invertebrate prey items.

The iron concentration of most of these diets is relatively low (<40 ppm) compared to a desired concentration of >50 ppm. The few diets that include earthworms have higher iron concentrations as a consequence of the relatively high iron concentration typically found in earthworms.

Zinc concentration of many diets is approximately 15 to 20 ppm of the dry matter, and this concentration is relatively low compared to the desired concentration of >80 ppm. The diets with sufficient zinc tend to be those diets that include earthworms.

Seasonal Differences in Diet Composition

In general, the composition of the diets between seasons is similar. The amount of dry matter offered in the summer is generally greater than the amount offered in the winter. However, the protein and fat content is slightly lower in the summer diets than the winter diets. There are some large seasonal differences in the iron and zinc content of the diets which reflects when earthworms are added to the diet. For some species earthworms are added in winter (e.g., *Cuora galbinifrons* and *Pyxidea mouhotii*) whereas for other species, earthworms are added in summer (e.g., *Hieremys annadali* and *Heosemys grandis*).

Hatchling Diets

There is a greater range in macronutrient concentration in the hatchling diets compared to the adult diets.

The calcium and phosphorus content of the hatchling diets of several species is very low, including the diets of *Ocadia sinensis*, *Pyxidea mouhotii*, and *Siebenrockiella crassicollis*. The diet for hatchling *Pyxidea mouhotii* contains only the fruit mixture. The diet for hatchling

Ocadia sinensis and *Siebenrockiella crassicollis* contains only grasshoppers. The iron and zinc concentration of these three diets also is low. These monotypic diets are not as well balanced nutritionally as diets containing multiple foods.

RECOMMENDATIONS

Nutritional inadequacies should be minimized. For diets that are borderline nutritionally (for example, the diets for *Cuora galbinifrons* and *Pyroidea mouhotii*), providing a variety of foods will help to minimize the impact of any single food that may be nutritionally inadequate. Combinations of invertebrate prey items and the Mixed Diet or fruit will help to balance nutrients better than feeding just one food item. With the exception of earthworms, invertebrates are generally a poor source of calcium.

Manipulate protein, as needed. To increase protein intakes (for example, in the diets for *Cuora galbinifrons*), decrease the amount of the fruit mixture and increase the amount of other food items.

Manipulate fat, as needed. To modulate the fat content of those diets where the fat content is high or low, adjust the amount of fish being offered; however, the fat content of the fish may change seasonally.

Use caution when changing the source of the commercial diets. One reason for the relatively high (and appropriate) concentration of calcium and phosphorus in many diets is the inclusion of a commercial pig diet that contains a very high concentration of these minerals (atypically high for a complete pig diet). If for some reason a different commercial pig diet is used in place of the current diet, the calcium and phosphorus concentration of the turtle diets will possibly change, if the replacement pig diet is not similar in composition to the current pig diet.

Improve nutrient content of diets for hatchlings. Provide a variety of foods such as prey, fruit, and the mixed diet to hatchlings to compensate for nutritional deficiencies (or excesses) associated with monotypic diets.

Minimize the ability of turtles to select specific foods from the Mixed Diet. If a turtle can select individual food items from the Mixed Diet, then the nutrients provided from the Mixed Diet may be dramatically different than the overall Mixed Diet. To minimize selection of individual ingredients, the ingredients should be cut as small as possible and well-mixed with the pig pellet.

Develop a plan to analyze food items. Analytical data will help to improve the estimated nutrient content of these diets.

Specific recommendations

Specific recommendations for adult *Cuora galbinifrons*. Reduce the amount of fruit from 30 g/animal to 20 g/animal, increase the amount of Mixed Diet from 10 g/animal to 25 g/animal and increase the amount of worms from 25 g/animal to 30 g/animal.

Specific recommendations for hatchling *Cuora galbinifrons*. Reduce the amount of fruit from 15 g/animal to 5 g/animal, increase the amount of Mixed Diet from 5 g/animal to 15 g/animal and increase the amount of worms from 4 g/animal to 6 g/animal.

Specific recommendations for adult *Pyridea mouhotii*. Reduce the amount of fruit from 30 g/animal to 25 g/animal, increase the amount of Mixed Diet from 10 g/animal to 20 g/animal and increase the number of snails from 1/animal to 2/animal.

Specific recommendations for hatchling *Pyridea mouhotii*. Add worms 2 times per week (2 g/animal) and add fish 3 times per week (1 g/animal).

Specific recommendations for hatchling *Ocadia sinesis*. Add worms 2 times per week (2 g/animal) and add fish 3 times per week (1 g/animal).

Specific recommendations for hatchling *Siebenrockiella crassocollis*. Add worms 2 times per week (2 g/animal) and add fish 3 times per week (1 g/animal).

Table 1. Nutrient composition of individual foods and food mixtures used in the analysis (dry matter basis).

		Crude protein (%)	Crude fat (%)	Carbohydrate (%)	Ash (%)	Calcium (%)	Phosphorus (%)	Ca:P ratio	Iron (ppm)	Magnesium (%)	Potassium (%)	Sodium (%)	Zinc (ppm)
Fruit	winter	6.2	1.1	88.5	4.1	0.07	0.16	0.46	19	0.12	1.69	0.09	11
Fruit	summer	6.3	1.2	88.4	4.2	0.07	0.16	0.44	19	0.12	1.72	0.09	11
Mixed Diet	winter	24.2	5.6	63.3	7.0	1.09	0.58	1.86	47	0.20	1.79	0.17	17
Mixed Diet	summer	21.4	5.1	66.7	6.8	0.84	0.48	1.74	48	0.21	1.94	0.17	17
Grasshopper		31.8	4.6	52.7	10.9	0.14	0.12	1.18	14	0.16	0.12	0.35	11
Worm		49.7	7.7	36.5	6.2	1.03	0.75	1.36	1765	0.12	0.55	0.27	504
Fish		56.7	28.1	5.1	10.2	2.32	1.80	1.29	106	0.12	1.12	0.73	97
Snail		25.5	1.7	71.1	1.8	0.26	0.17	1.54	120	0.06	0.26	0.07	21

Table 2. Nutrient composition of diets fed to adults during two seasons.

Species	Season	Amount of food offered (g/individual)	Amount of dry matter offered (g/individual)	Dry matter (%)	Dry matter basis											
					Crude protein (%)	Crude fat (%)	Carbohydrate (%)	Ash (%)	Calcium (%)	Phosphorus (%)	Ca:P ratio	Iron (ppm)	Magnesium (%)	Potassium (%)	Sodium (%)	Zinc (ppm)
<i>Cuora amboinensis</i>	winter	23.4	4.5	19.4	21.1	5.9	68.0	6.5	0.78	0.51	1.53	40	0.16	1.60	0.20	21
<i>Cuora amboinensis</i>	summer	37.7	6.8	18.0	18.0	4.9	71.9	6.1	0.60	0.42	1.44	39	0.17	1.74	0.18	19
<i>Cuora galbinifrons</i>	winter	37.1	7.1	19.2	6.8	1.4	67.0	3.5	0.39	0.33	1.16	400	0.13	1.45	0.14	118
<i>Cuora galbinifrons</i>	summer	58.6	10.8	18.4	7.4	1.5	73.1	3.9	0.31	0.29	1.08	273	0.13	1.58	0.12	82
<i>Cyclemys pulchristriata</i>	winter	19.1	3.7	19.5	24.2	6.9	63.6	7.0	0.93	0.59	1.59	45	0.17	1.58	0.22	24
<i>Cyclemys pulchristriata</i>	summer	30.6	5.5	18.0	20.8	5.8	67.9	6.6	0.73	0.48	1.52	44	0.18	1.75	0.20	21
<i>Cyclemys tcheponensis</i>	winter	19.1	3.7	19.5	24.2	6.9	63.6	7.0	0.93	0.59	1.59	45	0.17	1.58	0.22	24
<i>Cyclemys tcheponensis</i>	summer	30.6	5.5	18.0	20.8	5.8	67.9	6.6	0.73	0.48	1.52	44	0.18	1.75	0.20	21
<i>Geoemyda spengleri</i>	winter	19.8	4.6	23.3	18.2	3.3	62.7	4.5	0.67	0.40	1.67	169	0.14	1.26	0.13	48
<i>Geoemyda spengleri</i>	summer	31.2	6.4	20.4	16.9	3.3	66.6	4.9	0.57	0.36	1.57	134	0.15	1.49	0.14	39
<i>Hieremys annadalii</i>	winter	17.1	3.1	18.0	19.5	4.4	72.0	6.2	0.82	0.47	1.74	40	0.18	1.76	0.15	15
<i>Hieremys annadalii</i>	summer	24.3	4.1	17.0	16.6	3.9	74.8	6.0	0.60	0.38	1.57	39	0.18	1.87	0.14	15
<i>Heosemys grandis</i>	winter	27.1	4.9	17.9	20.2	4.6	71.1	6.3	0.86	0.49	1.76	41	0.18	1.76	0.15	15
<i>Heosemys grandis</i>	summer	34.3	5.8	16.9	17.3	4.1	73.8	6.1	0.63	0.39	1.60	40	0.18	1.88	0.15	16
<i>Indotestudo elongata</i>	winter	21.4	3.9	18.1	16.7	3.7	75.4	5.8	0.67	0.41	1.64	35	0.16	1.75	0.14	14
<i>Indotestudo elongata</i>	summer	35.7	6.1	17.2	15.0	3.5	76.9	5.7	0.51	0.34	1.49	36	0.17	1.85	0.14	14
<i>Mauremys annamensis</i>	winter	23.4	4.5	19.4	21.1	5.9	68.0	6.5	0.78	0.51	1.53	40	0.16	1.60	0.20	21
<i>Mauremys annamensis</i>	summer	37.7	6.8	18.0	18.0	4.9	71.9	6.1	0.60	0.42	1.44	39	0.17	1.74	0.18	19
<i>Manouria impressa</i>	winter	21.4	3.9	18.1	16.7	3.7	75.4	5.8	0.67	0.41	1.64	35	0.16	1.75	0.14	14
<i>Manouria impressa</i>	summer	35.7	6.1	17.2	15.0	3.5	76.9	5.7	0.51	0.34	1.49	36	0.17	1.85	0.14	14
<i>Ocadia sinensis</i>	winter	14.9	2.9	19.7	29.2	8.5	56.8	7.7	1.17	0.70	1.66	52	0.18	1.55	0.26	27
<i>Ocadia sinensis</i>	summer	23.4	4.2	17.9	25.3	7.2	61.6	7.4	0.93	0.58	1.61	52	0.20	1.75	0.23	24
<i>Pyxidea mouhotii</i>	winter	38.4	8.4	21.8	8.7	1.3	65.2	3.2	0.36	0.30	1.19	354	0.11	1.27	0.13	103
<i>Pyxidea mouhotii</i>	summer	59.8	12.0	20.0	8.6	1.5	71.2	3.7	0.30	0.27	1.10	254	0.12	1.44	0.12	75
<i>Pelodiscus sinensis</i>	winter	2.0	0.6	32.5	46.8	18.7	24.1	10.5	1.45	1.13	1.29	70	0.14	0.72	0.58	63
<i>Pelodiscus sinensis</i>	summer	2.0	0.6	32.5	46.8	18.7	24.1	10.5	1.45	1.13	1.29	70	0.14	0.72	0.58	63
<i>Siebenrockiella crassicollis</i>	winter	2.9	1.5	50.9	43.5	13.2	36.7	10.3	1.85	1.29	1.43	256	0.18	0.89	0.59	124
<i>Siebenrockiella crassicollis</i>	summer	2.9	1.5	52.8	41.9	12.7	35.4	10.0	0.63	0.49	1.29	30	0.06	0.31	0.25	27
<i>Sacalia quadriocellata</i>	winter	2.0	0.6	32.5	46.8	18.7	24.1	10.5	1.45	1.13	1.29	70	0.14	0.72	0.58	63
<i>Sacalia quadriocellata</i>	summer	2.0	0.6	32.5	46.8	18.7	24.1	10.5	1.45	1.13	1.29	70	0.14	0.72	0.58	63

Table 3. Nutrient composition of diets fed to hatchlings.

	Season	Amount of food offered (g/individual)	Amount of dry matter offered (g/individual)	Dry matter (%)	Crude protein (%)	Crude fat (%)	Carbohydrate (%)	Ash (%)	Calcium (%)	Phosphorus (%)	Ca:P ratio	Iron (ppm)	Magnesium (%)	Potassium (%)	Sodium (%)	Zinc (ppm)
<i>Cuora amboinensis</i>	winter	2.3	1.5	67.0	42.0	10.9	42.1	10.3	2.02	1.37	1.48	335	0.20	0.96	0.59	150
<i>Cuora amboinensis</i>	summer	2.3	1.6	70.5	39.9	10.3	40.0	9.8	0.29	0.23	1.29	14	0.03	0.15	0.12	63
<i>Cuora galbinifrons</i>	winter	16.7	3.2	18.9	7.7	1.5	75.5	4.0	0.31	0.28	1.10	227	0.13	1.57	0.12	69
<i>Cuora galbinifrons</i>	summer	31.7	5.8	18.2	7.7	1.6	80.2	4.2	0.23	0.24	0.96	135	0.13	1.68	0.11	43
<i>Cyclemys pulchristriata</i>	winter	1.4	1.3	93.5	39.9	8.3	47.5	10.3	1.98	1.30	1.52	368	0.21	0.94	0.57	157
<i>Cyclemys pulchristriata</i>	summer	1.4	1.4	99.2	37.6	7.9	44.8	1.0	0.01	0.01	1.18	1	0.01	0.01	0.03	58
<i>Heosemys grandis</i>	winter	15.6	3.8	24.4	24.4	5.3	66.4	7.2	1.15	0.73	1.57	153	0.18	1.52	0.28	65
<i>Heosemys grandis</i>	summer	25.6	5.5	21.5	19.6	4.4	70.3	6.5	0.35	0.25	1.43	26	0.13	1.40	0.10	25
<i>Indotestudo elongata</i>	winter	14.6	2.7	18.6	12.9	2.8	67.1	4.8	0.63	0.42	1.50	269	0.15	1.57	0.15	80
<i>Mauremys annamensis</i>	winter	2.3	1.5	67.0	42.0	10.9	42.1	10.3	2.02	1.37	1.48	335	0.20	0.96	0.59	150
<i>Mauremys annamensis</i>	summer	2.3	1.6	70.5	39.9	10.3	40.0	9.8	0.29	0.23	1.29	14	0.03	0.15	0.12	63
<i>Ocadia sinensis</i>	winter	0.1	0.1	91.7	31.8	4.6	52.7	10.9	0.14	0.12	1.18	14	0.16	0.12	0.35	11
<i>Ocadia sinensis</i>	summer	0.1	0.1	91.7	31.8	4.6	52.7	10.9	0.14	0.12	1.18	14	0.16	0.12	0.35	11
<i>Pyxidea mouhotii</i>	winter	6.4	1.2	18.8	6.2	1.1	88.5	4.1	0.07	0.16	0.46	19	0.12	1.69	0.09	11
<i>Pyxidea mouhotii</i>	summer	12.9	2.3	18.2	6.3	1.2	88.3	4.2	0.07	0.16	0.44	19	0.12	1.72	0.09	11
<i>Siebenrockiella crassicollis</i>	winter	0.1	0.1	91.7	31.8	4.6	52.7	10.9	0.14	0.12	1.18	14	0.16	0.12	0.35	11
<i>Siebenrockiella crassicollis</i>	summer	0.1	0.1	91.7	31.8	4.6	52.7	10.9	0.14	0.12	1.18	14	0.16	0.12	0.35	11
<i>Sacalia quadriocellata</i>	winter	2.3	1.5	67.0	42.0	10.9	42.1	10.3	2.02	1.37	1.48	335	0.20	0.96	0.59	150
<i>Sacalia quadriocellata</i>	summer	2.3	1.6	70.5	39.9	10.3	40.0	9.8	0.29	0.23	1.29	14	0.03	0.15	0.12	63