"In Joyance of Things to Eat" Beginning the Study of Turtle Nutrition

Harriet Forrester
Turtle Rescue of New Jersey
Hardwick, New Jersey

Come from the hole where the dark days drew thee,
Wake, Methuselah! Wag thy tail!
Sniff the snare of the winds that woo thee,
Sun–kissed cabbage and sea–blown kale.

Flap thy flippers, O thou most fleet
As once in joyance of things to eat...

Introduction

This paper's title is from a turn of the century poem called "Wake, Methuselah!" by an unknown author contemplating a hibernating tortoise at the London Zoo. The line about the enjoyment of eating is captivating. How much thought is given to the possibility that turtles and tortoises get pleasure from eating? Do they derive sensory enjoyment from the amazing array of their natural food items? Can stress be lessened in captivity by feeding natural diets and using food as an enrichment strategy? How do the food preferences and energy requirements of turtle and tortoise species differ?

Why is a great deal of time spent formulating hundreds of species–specific diets for mammals and birds, yet the same boring, lifeless pellets are tossed to turtles and tortoises?

Nutrition for chelonians (turtles and tortoises) is as complex as nutrition for birds or mammals, but only in recent years has the study of reptile nutrition finally started to catch up with that of other animals. The exact nutritional requirements for chelonians are still largely unknown; however, the study is ongoing and fascinating.

Harriet Forrester is a New Jersey state licensed wildlife rehabilitator and the founder of Turtle Rescue of New Jersey.

The Elements of Nutrition

Nutrition is defined as the process by which a living organism assimilates food and uses it for growth and maintenance. There are seven categories of nutrients that the body needs: protein, carbohydrates, fats, vitamins, minerals, fiber, and water.

Carbohydrates, Proteins, and Fats. All animal activity requires energy, and energy requirements are met by food containing three main energy sources: carbohydrates, proteins, and fats.

- Carbohydrates are a group of organic compounds that includes sugars, starches, celluloses, and gums. Carbohydrates fuel muscles and the central nervous system. They provide immediate energy for activity.
- Proteins are complex molecules built from chains of amino acids. Proteins come mainly from animal sources such as meat and fish. Plants also contain protein, but the biological value is considered lower than that from animal sources. They are essential to many bodily functions, including the growth and repair of tissue and bone.
- Fats are oily compounds that are widely found in plant and animal tissues. They are essential to the digestion, absorption, and transportation of the fat–soluble vitamins A, D, E, and K. Fats are also the source of essential fatty acids that support the cardiovascular, reproductive, immune, and nervous systems.

Vitamins. Vitamins, like proteins, carbohydrates, and fats, are *organic* nutrients. Vitamins do not provide energy, nor do they construct any part of the body. They are, however, essential for transforming foods into energy and body maintenance. There are 13 vitamins: A, B1, B2, B3, B5, B6, B7, B9, B12, C, D, E, and K.

Minerals. Minerals are *inorganic* nutrients. Minerals play a vital role in keeping bodies healthy, strong, supple, and resistant to disease. Dietary minerals are classified as major minerals and trace minerals. Major minerals are calcium, phosphorus, magnesium, potassium, sulfur, chloride, and sodium. Trace minerals are iron, zinc, copper, iodine, fluoride, chromium, selenium, manganese, molybdenum, bromide, cadmium, vanadium, tin, nickel, aluminum, and silicon.

Fiber. Fiber refers to components of plant–based foods that cannot be digested, and is classified as insoluble fiber and soluble fiber. Insoluble fiber does not dissolve in water, increases fecal bulk, and speeds up the passage of food through the digestive tract. Soluble fiber partially dissolves in water, and ferments in the large intestine. An understanding of fiber is especially important when dealing with species such as herbivorous tortoises, since they have high fiber requirements.

Water. Water is essential for all life. It is necessary for the healthy function of all internal organs, including those involved in nutrient digestion and absorption. It is required for the excretion of metabolic waste through urination and bowel movements. Water also cushions and protects vital organs, joints, the spinal cord, and other sensitive tissues.

Adequate water intake is necessary for chelonians in rehabilitation to prevent dehydration from injury, disease, anorexia, or inadequate humidity in habitats. Water must be available to all chelonians, including tortoises.

Ectotherms, Energy, and Calories

Birds and mammals are endotherms and produce their own body heat by chemical metabolization of the food they eat. Turtles and tortoises are ectotherms, meaning they depend on external sources to regulate body temperature. This difference results in ectotherms using one–seventh to one–tenth less energy than endotherms. Energy also is used for different purposes—ectotherms convert 40 to 80 percent of their food energy into new body tissue, whereas endotherms use about 98 percent for temperature regulation and activity (Pough et al 1998).

The energy from food is measured in calories. How fast an animal converts food into energy is its metabolic rate. Basal Metabolic Rate (BMR) and Metabolic Energy Coefficient (MEC) are terms used for endotherms. Caloric needs for chelonians are measured by the Standard Metabolic Rate (SMR), which is the minimum rate at which an ectotherm uses energy to support basic life functions at rest with no stress, with an empty stomach, and *at a certain temperature*.

The use of different terms reflects the fact that SMR is temperature dependent in ectothermic reptiles, since the body temperature and metabolic rate change with environmental temperature (Willmer et al 2000). To correctly use SMR charts for chelonians, the turtle or tortoise must be brought up to appropriate temperatures for that species.

SMR is measured in kilocalories (kcals) per day. To calculate kcals per day, the formula is

$$BW_{kg}^{0.75} \times 32$$

(bodyweight in kilograms raised to the 0.75 power, multiplied by 32). A scientific calculator is helpful to perform the calculation. To determine the minimum kcals needed for a 400 gram box turtle (*Terrapene carolina carolina*) at 86°F:

$$0.400^{0.75} = 0.50 \times 32 = 16 \text{ kcals/day}$$

If a scientific calculator is not available, this formula can be worked out with a regular calculator in a four–step process:

1. Cube the body weight .400 x .400 x .400 = 0.064
2. Calculate the square root $\sqrt{0.064} = 0.253$
3. Calculate the square root again $\sqrt{0.253} = 0.50$
4. Multiply by 32 0.50 x 32 = 16 kcal/day

The SMR is just a starting point—the absolute minimum number of calories needed to maintain life. Caloric requirements increase with activity (1.5 to 2 x SMR), reproduction or growth (2 to 2.5 x SMR), and wound healing or stress (2.5 to 3 x SMR).

For example, if the 400—gram box turtle noted above is a normal healthy turtle, her caloric intake might be calculated at 1.5 x SMR, or 24 kcals per day. If she were gravid, that would increase to 2 x SMR or 32 kcals per day. If she had a shell fracture, the caloric intake would be increased to 2.5 x SMR, or 40 kcals per day.

How Are Calories Supplied? All food contains some combination of these three calorie sources: carbohydrates, proteins, and fat. Carbohydrates and proteins contain 4 kcals per gram, while fats contain 9 kcals per gram. For example, the calories in an adult mouse are distributed as 5 percent carbohydrates, 48 percent protein, and 47 percent fat. Calories from dandelions, on the other hand, are made up of 72 percent carbohydrates, 15 percent protein, and 13 percent fat.

Table 1. Percent of Total Kcalories.

	Protein	Carbohydrate	Fat	Total
Carnivore	50%	5%	45%	100%
Omnivore	25%	50%	25%	100%
Herbivore	20%	75%	5%	100%

Table 2. Sampling of fruits, vegetables, and weeds and approximate energy value (% of kcal) on "as fed" basis (rounded to nearest value).

Food Item	Kcal/gram	Protein	Carbohydrate	Fat
Carrot	0.4	6	89	5
Apple	0.5	2	95	3
Opuntia cactus	0.4	6	84	10
Blueberry	0.6	4	91	5
Tomato	0.2	12	79	9
Butternut squash	0.5	5	93	2
Dandelion	0.5	15	72	13
Lambsquarter	0.4	24	60	16
Duckweed	2	55	33	12

Table 3. Sampling of vertebrate and invertebrate prey items and approximate energy value (% of kcal) on "as fed" basis (rounded to nearest value).

Food Item	Kcal/gram	Protein	Carbohydrate	Fat
Cricket (juvenile)	0.9	65	4	31
Cricket (adult)	1.4	57	0	43
Earthworm	0.7	60	20	20
Mealworm	2.1	36	6	58
Silkworm	0.7	55	26	19
Superworm	2.4	32	2	66
Waxworm	2.8	20	0	80
Mouse (pinkie)	0.8	57	3	40
Mouse (fuzzy)	1.7	29	2	69
Mouse (adult)	1.7	48	5	47
Smelt	1	63	6	31

To make things even more interesting, carnivores, herbivores, and omnivores each require their calories to be obtained from a different percentage of carbohydrates, proteins, and fat. While there are many different versions of these ratios, one of the most recent (Donoghue 2006) suggests divisions as noted in Table 1.

Gathering Nutritional Information

One of the best Internet sites for nutritional information is Nutrition Data, which can be found online. This site lists the complete nutritional analysis of over 8,000 food items. The website gives the complete carbohydrate, protein, amino acid, caloric, vitamin, and mineral breakdown for each food item.

Nutrition Data shows that 14 g (1/2 oz) of butternut squash contains 6.3 kcals, is a good source of dietary fiber, vitamin E, thiamin, niacin, vitamin B6, folate, calcium, and magnesium, and a very good source of vitamin A, vitamin C, potassium, and manganese.

Another example shows that 14 g (1/2 oz) of dandelion greens has 6.25 kcals, is a good source of folate (a B vitamin and natural source of folic acid), magne-

sium, and copper. Dandelions are also a very good source of dietary fiber, vitamin A, vitamin C, vitamin E, vitamin K, thiamin, riboflavin, vitamin B6, calcium, iron, potassium, and manganese.

This information can be a great help when formulating diets that require increased calcium, more fiber, or certain vitamins.

'As Fed' Versus 'Dry Matter' Basis. When comparing foods, make sure the nutritional charts and information are based on the same formula. Nutritional information can be presented in two different ways: As Fed or Dry Matter. As Fed shows what the animal is actually eating. Dry matter is calculated with the water removed and is useful when comparing two different foods, such as a dry pellet food versus a wet canned food. For a good explanation of dry matter versus as fed and how to convert one to the other, visit Know What You Feed at <http://www.knowwhatyoufeed.com/faq.html#express>.

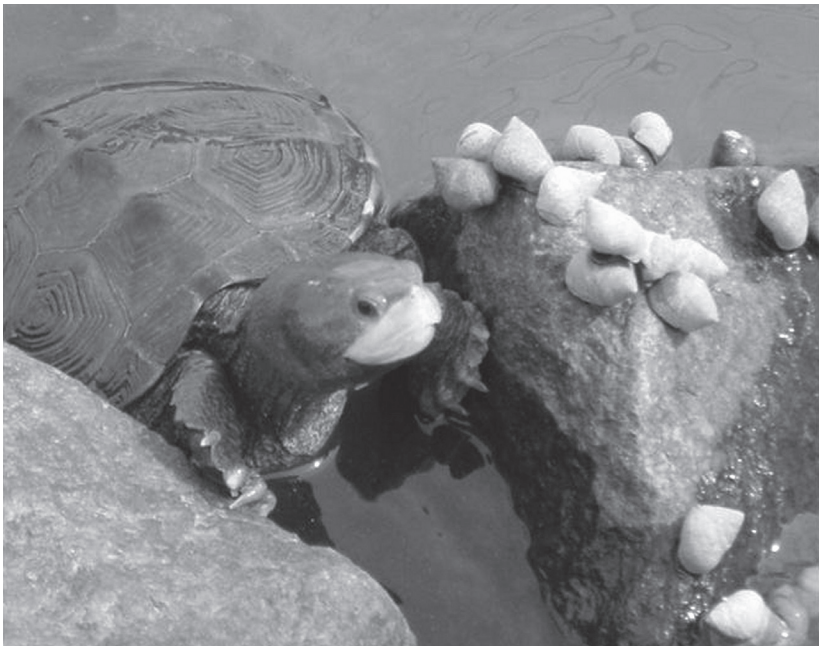

Figure 1. Diamondback terrapin (Malaclemys terrapin) *in the wild with periwinkles* (Littorina *sp.).*

The Energy Value of Various Foods. The charts on the preceeding page (Tables 2 and 3.) show the kcals per gram in a variety of foods. Also shown is the percentage of protein, carbohydrate, and fat in the kcals. Carrots, for example, have 0.4 kcals per gram. Six percent of those 0.4 kcals come from protein, 89 percent from carbohydrate, and 5 percent from fat. The information is shown on an 'As Fed' basis.

Charts like these can help when formulating a meal for chelonians in rehabilitation. For example, a one kg juvenile snapping turtle (*Chelyora serpentina*) recovering from shell injury requires 80 kcals per day (2.5 x SMR). To meet that caloric requirement, one of his meals might consist of eight 6–gram smelt and a 20–gram adult mouse, which would supply 82 calories. Fifty–five percent of those calories come from protein, 5 percent from carbohydrates, and 39 percent from fat. Protein is important for wound healing, so adding high–protein duckweed in the habitat as a free–choice food would ensure that the snapper meets protein requirements.

Many invertebrate prey items are deficient in calcium. Dusting or gut loading techniques can increase the calcium content. There are a number of great papers on improving the calcium content of invertebrates, especially those by Diane Winn and Mark Finke (see Recommended Reading).

Different Species—Different Food

The following are a few suggestions for feeding aquatics, semi–aquatics, box turtles, and tortoises. Please remember that some species are food specialists and the following lists may or may not apply to chelonians in a specific geographical area. Rehabilitators are encouraged to research the *specific* nutritional needs for the species in their care and tailor diets to fit the species dietary requirements.

Keeping in mind the 'one size does not fit all' concept, the following lists can be used in different ratios depending on the needs of the individual species. For example, softshell turtles are highly insectivorous so add insects and larvae (e.g., mayflies, caddisflies, beetles, cicadas, aphids, grasshoppers) to the general aquatic diet. The diet for diamondback terrapins and many map species must emphasize snails and mollusks over the other items on the list. Adult cooters and red–bellied turtles should be fed a diet high in plant items, but still can be offered a variety of the other items.

The following food lists are starting points and diet choices certainly are not limited to these items.

Food for Aquatics. Aquatic turtles are a large group consisting of cooters and red–bellied turtles (*Pseudemys* spp.), sliders (*Trachemys* spp.), maps (*Graptemys* spp.), common snappers (*Chelydra serpentina*), alligator snappers (*Macroclemys temminckii*), muds (*Kinosternon* spp.), musks (*Stenotherus* spp.), painteds

Figure 2. Salad of dandelion, portabello mushrooms, and red peppers supplies calcium, copper, manganese, selenium, and vitamins A, C, E and B6.

(*Chrysemys picta*), western ponds (*Actinemys marmorata*), chicken turtles (*Deirochelys reticularia*), softshells (*Apalone* spp.), and diamondback terrapins (*Malaclemys terrapin*).

Remember that many (but not all) aquatic turtle species become more herbivorous with age. Aquatic turtles will not eat on land, so all food for aquatics must be offered in the water. Food for aquatic turtles can include the following.

- Fresh fish (do not use frozen fish as a regular part of the diet as this can result in thiamine deficiency), thawed mice, crickets, snails, crabs, crayfish, clams, freshwater mussels, shrimp (Figure 1.)
- Earthworms, waxworms, blackworms, bloodworms, tubifex worms. Earthworms are an excellent natural food and a good source of copper, zinc, manganese, and iron (Bernard 1997; Donoghue 2006).
- Aquatic plants (duckweed, water lettuce, water hyacinth, elodea, water shield). Keeping aquatic plants available at all times satisfies the foraging instincts and enrichment needs of many aquatic turtles.
- Greens (kale, romaine, dandelion)
- Fruits (especially berries) and vegetables

Food for Semi–aquatics.
Semi–aquatics include species such as Blanding's (*Emydoidea blandingii*), bog (*Glyptemys muhlenbergii*), spotted (*Clemmys guttata*), and wood (*Glyptemys insculpta*) turtles. Semi–aquatics will eat in or out of the water. Foods for these species can include:

- Fresh fish, worms (earthworms, wax worms, blackworms), crickets, beetles, grubs, sowbugs, pillbugs, slugs, snails, and thawed mice
- Aquatic plants (duckweed, water lettuce, water hyacinth, elodea, water shield)
- Greens (kale, romaine, dandelion)
- Fruits (strawberries, blackberries, blue berries)

In addition to the food items listed above, wood turtles also will eat:

- Additional fruits (apples, peaches, cantaloupe)
- Vegetables (squash, sweet potatoes, mushrooms, carrots)

Food for Box Turtles. As opportunistic omnivores in the wild, box turtles are relatively easy to feed because of the wide variety of foods they will accept (Figure 2.). Hatchling and juvenile box turtles require a higher percentage of animal protein in their diet. Food for box turtles can include the following:

- Earthworms, waxworms, beetles, sowbugs, pillbugs, grubs, crickets, slugs, grasshoppers, snails, and thawed mice
- Fruits (apples, peaches, strawberries, blackberries, blueberries, mulberries, cantaloupe)
- Greens (kale, romaine, dandelion)
- Vegetables (squash, sweet potatoes, tomatoes, peppers, mushrooms, carrots)

Food for Tortoises. There are three species of tortoise native to the United States: the desert tortoise (*Gopherus agassizii*), Texas tortoise (*Gopherus berlandieri*), and the gopher tortoise (*Gopherus polyphemus*). All of these tortoises are strictly herbivorous and need a diet high in calcium and fiber, and low in phosphorus, protein, and fat. Think of these tortoises as cows with shells—the digestive system simply is not designed to process animal protein, sugars, or large amounts of fat. Flowers, leaves, seeds, and grasses supply the protein required for the slow, fermentation–based digestive tract of tortoises. Fruit should be avoided in a native

tortoise diet, since it is high in sugar and can quickly overwhelm their digestive system.

Fiber consists of plant cell wall components that are not digestible and is of major importance in our native tortoises' diets. A nutritional analysis of major foods eaten by desert tortoises in the wild showed a fiber range of 21.2 to 36.9 percent (Hansen et al 1976). If a tortoise is getting enough fiber, the feces will be firm with traces of actual plant material (fecal pellets look like little hand grenades). If the fecal material is loose and watery, the tortoise is not getting sufficient fiber.

Tortoises will thrive on a diet that includes the following:

- Cacti (spineless prickly pear/opuntia pads)
- Grasses and hay (Bermuda grass, wheatgrass, bentgrass, orchard hay, broomsedge, panic grass)
- Leafy greens (kale, romaine, endive, grape leaves, mulberry leaves)
- Assorted flowers (hibiscus, coreopsis)
- Assorted weeds, including dandelion, hawkbits, sowthistles, hawkweeds, hawkbeards, plantains, clovers, honeysuckle, cat's ears, vetches, trefoils, mallows, bindweeds, and sedums.

The Debate about Commercial Foods

Commercial foods are often thought to be an easy answer to supplying a chelonian's nutritional needs. While their use with pet turtles is up to the pet owner, there is real concern over the suitability of commercial foods for wild chelonians in rehabilitation.

In the wild, chelonians avail themselves of the tremendous selection that nature offers, thereby ensuring a varied and complete diet. In the wild, the painted turtle (*Chrysemys picta*) eats at least 13 different types of algae, 14 types of plants, 14 types of invertebrates, 11 kinds of insects, 11 species of fish and frogs, and anything else it can get into its mouth. It has been documented that they consume at least *62 different kinds of food* (Ernst et al 1994)!

A simple rule for turtle nutrition would be if a chelonian does not eat a particular food (or something very similar) in the wild, there is no reason to offer it in captivity (Highfield 2002). With that in mind, a close look at commercial turtle food is in order.

General Concerns.

- Adult wild chelonians usually do not recognize commercial processed products as food, so they may not eat at a time when nutrition is crucial to recovery.
- Hatchlings' feeding behaviors and preferences can be altered by feeding commercial food. Foods experienced early in life are preferred over those experienced later, and this can affect feeding choices. It also has been suggested that there is a food/olfactory 'imprinting' in turtles (Burghardt 1977; Burghardt et al 1966). If hatchling turtles are fed diets that look, smell, and taste differently from wild foods, they may become dependant on food that is not available to them after release. This could lead to a period of not eating until the hatchlings adjust to wild foods, with a resulting lack of nutrition just when it is most needed.
- A monotonous diet of pellets or food sticks denies hatchlings the opportunity to recognize wild foods, satisfy natural food preferences, or develop essential food foraging skills. "...it doesn't take a genius to figure out that life in a bucket or raceway with a kind person dumping in prepared food pellets once a day is not what the real world is all about" (Woody 1990).
- Pelleted foods contain about 10 percent to 12 percent water. Compare that to the 85 percent to 92 percent water content of fresh greens, or the 60 percent to 70 percent water content of invertebrates. A turtle or tortoise fed only pellets or sticks receives much less water from its food (Donoghue 2006).
- Commercial products for tortoises often contain fishmeal and other products that are difficult for herbivores to digest. One product marketed as "Land Turtle and Tortoise Food" contains fishmeal, yet the label sports a totally herbivorous sulcata tortoise (*Geochelone sulcata*).
- Commercial foods often contain high levels of protein that are unsuitable for species with lower protein requirements. Excess protein can put stress on kidneys, contribute to abnormal growth, and even lead to gout (Figureres 1997). The "Land Turtle and Tortoise Food" product mentioned above has a high protein content. It is interesting to note that the pictured *sulcata* has an abnormally pyramided shell. One of the suspected causes of pyramiding is...wait for it...a high protein diet.

Reading the Label. A popular commercial turtle food label says it is for "aquatic turtles, newts, and frogs." How can a diet suitable for a carnivorous frog also be appropriate for an herbivorous adult cooter (Lunsford 2007)? There is no one–size–fits–all in chelonian nutrition.

Pet food labels must list ingredients in order of weight. Generally, the first five ingredients will make up the majority of the product. One turtle food lists its first five ingredients as fishmeal, wheat starch, dried yeast, corn flour, and shrimp meal. Looking at what these ingredients actually are makes an interesting study.

Fishmeal—According to the Food and Agriculture Organization of the United Nations Animal Feed Resources Information System, fishmeal can be classified as two basic types: fishery waste associated with processing of fish for human consumption (salmon, tuna, etc.) *or* fish that are used only for the production of fishmeal (herring, menhaden, pollock, etc.). There is no way to know which type of fishmeal is used in this product.

The quality, vitamin, and mineral composition of fishmeal can vary considerably depending on which type of fish is used, the season of harvest, and whether it is whole fish or fish scraps.

Wheat starch, dried yeast, and corn flour—These three ingredients are used by the animal feed industry as cheap, poor quality protein fillers.

Shrimp meal—This can be made from either whole shrimp that is unsuitable for human consumption *or* from the by–products of a shrimp fishery (shrimp heads and scales). Again, there is no way to know which type of shrimp meal is used in this product.

A further look at labels will reveal other ingredients such as corn gluten meal, artificial colors, and ethoxyquin.

Corn gluten meal (CGM)—The infamous pet food recalls in 2007 were caused by imported corn gluten and wheat gluten that was contaminated with melamine. CGM is a by–product of the corn wet–milling process. Its two main uses are as an herbicide to prevent weed seeds from sprouting, and as a cheap source of protein substituted for costlier meat protein in animal feed (decidedly strange bedfellows). CGM has an unpleasant taste and odor, which has prevented its widespread acceptance in human food (Wu et al 2006), but it still is used widely in animal feeds.

CGM contains higher concentrations of sulfur–containing amino acids that produce acidic urine when fed to cats (Funaba et al 2005). While it is unknown if CGM produces the same effect in chelonians, acidic urine increases the excretion of calcium and may cause a calcium deficiency in hatchling and juvenile chelonians.

Artificial colors—There is growing concern over the use of artificial colors in foods for humans. Artificial food colors have been linked to allergies, asthma, and are a possible carcinogen in humans (Tuormaa 1994). A recent study showed that artificial food color and additives commonly found in children's food exacerbate hyperactive behaviors (McCann et al 2007. In April 2008, the Food Standards Agency of Britain recommended that government ministers call for manufacturers to remove six artificial colors by the end of 2009 and lobbied for a European Union–wide ban.

Ethoxyquin—Ethoxyquin is used as a preservative. Ethoxyquin is toxic to fish (EPA Office of Pesticide Programs 2000), and is listed as a hazardous chemical by the United States Labor Department's Occupational Safety and Health Administration. Of the 22 countries in the Pesticides Action Network of North America database, only three permit the use of ethoxyquin—United States, Canada, and Hungary. The United States Food and Drug Administration's Center for Veterinary Medicine has asked pet food producers to voluntarily lower their maximum level of ethoxyquin in dog food from 150 ppm to 75 ppm while more studies are being conducted on this preservative (Bren 2001).

There is a growing body of evidence that these ingredients and additives are harmful in human and pet foods. What potential damage is done to wild chelonians fed these foods? The effects of these diets are unknown and there is no long–term evidence of their suitability or safety (Highfield 1996). With the current availability of fresh live foods, quality greens, vegetables, fruits, aquatic plants, vitamin and mineral supplements, and even seeds to grow chelonian weed gardens, wildlife rehabilitators must re–examine the appropriateness of using commercial products in the diet of wild turtles and tortoises.

Wild Diets

A crucial piece of the nutritional puzzle can be found by studying the foods that turtles and tortoises eat in the wild. There are 50 chelonian species native to the United States (excluding sea turtles, which are beyond the scope of this paper). Among those 50 are carnivores, herbivores, insectivores, and omnivores. Sounds so simple, but definitions can be tricky things.

Common snapping turtles often are called carnivores, but studies both old and new document that snapping turtles routinely consume vegetation (Alexander 1943; Budhabhatti et al 1990). They eat various algae and at least 13 species of plants (Ernst et al 1994). One of the plants on a snapper's menu is duckweed (*Lemna* sp.), sometimes in large quantities (Budhabhatti et al 1990). Newly–harvested duckweed plants contain up to 43 percent protein by dry weight

(Yilmaz et al 2004). As a natural protein source, duckweed has a better array of essential amino acids than most other vegetable proteins and more closely resembles animal protein (Hillman et al 1978). So, a snapper's diet in captivity should reflect the nutritional content of its wild diet, which consists of both animal and plant proteins.

To make things even more interesting, chelonian wild diets can vary with species, age, geographic location, and even gender. Painted turtles in general are omnivorous, but the young consume more animal protein while the adults eat more vegetation (Ernst et al 1994).

Female and male smooth softshell turtles (*Apalone muticus*) can have significantly different wild diets. In one area, the females ate 71 percent aquatic prey, but the males ate 67 percent terrestrial items (Plummer et al 1981).

Geographic location also can influence food preferences. The false map turtle (*Graptemys pseudogeographica*) is an omnivore in the northern part of its range where it competes for food with other *Graptemys* species; yet it is a mollusk specialist in the southern part where it lacks competition (Vogt 1981).

Some turtles are dietary specialists even within the same genus and species. The Sabine map turtle (*Graptemys ouachitensis sabinensis*) is a subspecies of the Ouachita map turtle (*Graptemys ouachitensis*); yet adult male Sabines are primarily insectivorous, whereas Ouachitas are omnivorous (Shively et al 1985).

Finally, some turtles combine a number of the above qualities. Adult Escambia map turtles (*Graptemys ernesti*) exhibit both diet specialization and gender differences—females subsist almost entirely on mussels, while the males are primarily insectivorous (Moll et al 2004).

So what does all this mean? It means that to even *begin* to understand nutrition for chelonians a thorough study of their food preferences and eating habits in the wild is needed. It means that turtles and tortoises in rehabilitation will not thrive unless close attention is paid to their specific food requirements. It means that chelonians must be treated as the individual species they are, just as is done for birds and mammals.

Feeding Turtles During Rehabilitation

Proper nutrition is vital to the recovery process of ill or injured turtles and tortoises, but it is not the first step in emergency turtle care.

The first and most important aspect is warmth. As noted previously, turtles are ectotherms and depend on external sources to regulate the body temperature. Medications, fluids, and food are useless to a cold turtle; all turtles must be brought up to the preferred optimal temperature zone (POTZ) before other steps are taken.

Hydration is the next step. If the turtle is already well–hydrated, place it in the water bowl to soak. If the turtle is dehydrated, administer fluids by mouth, subcutaneously, or intracoelomically, depending on degree of dehydration.

The third step is nutrition. Turtles in good condition can receive 75 to 100 percent of the required calories within the first 24 to 48 hours. Debilitated turtles should receive only 50 to 75 percent of daily calories to avoid digestive and metabolic upsets, then gradually be brought up to full nutritional goals, usually over two to five days.

Chelonians in rehabilitation should be fed every day. Good nutrition helps in healing wounds and alleviating stress. One of the keys to good nutrition is variety, so offer a wide selection of foods based on the nutritional requirements and dietary preferences of the individual species.

When formulating diets for chelonians in rehabilitation, there are many factors to consider—natural foods, protein, carbohydrate, and fat requirements, vitamins and minerals, caloric needs, variety, and enrichment all play a role in ensuring correct nutrition.

The snapping turtle examples mentioned earlier again can be useful. Snappers wild diet consists of insects, spiders, isopods, amphipods, crayfish, fiddler crabs, shrimp, water mites, clams, snails, earthworms, leeches, tubificid worms, planarians, freshwater sponges, carrion, fish (adults, fry, and eggs), frogs and toads (adult, fry, and eggs), salamanders, small turtles, snakes, birds, small mammals, and plants.

Yet, it is often recommended that their captive diet consist of raw liver, steak, beef heart, cooked chicken, hamburger, and other similar items. The heavy reliance on meat products, with no addition of plant material, does not fully address the snapper's nutritional needs. The calcium to phosphorus (Ca:P) ratio alone demonstrates the inadequacy of this diet. The chelonian diet must provide an overall calcium to phosphorus ratio of at least 2:1. Organ meat (liver, heart, or gizzards) and meat without bones (chicken, steak, or hamburger) have extremely poor Ca:P ratios—beef heart 1:30, hamburger 1:16, chicken breast 1:18.

In contrast, one of the snapper's natural foods, a whole green frog, has a 2.5:1 Ca:P ratio. The frog also has high amounts of Vitamin A and significant levels of iron and zinc (Dierenfeld et al 2002). Using whole

*Figure 3. Eastern box turtle (*Terrapene carolina carolina*) enjoying a cuttlebone, which supplies iodine as well as calcium.*

rodents, frogs, or fish provide a good Ca:P ratio due to the skeletal bones.

Assist Feeding. Turtles that cannot or will not eat on their own require assist feeding. Tube feeding supplies the necessary nutrition until chelonians regain an appetite.

Some circumstances prevent tube feeding by hand—broken jaws, highly aggressive turtles, or turtles that are unduly stressed by handling. In those cases, a surgically placed feeding tube may be necessary. This makes feeding easy, quick, and less stressful. It has the added advantage that the turtle also can eat on its own with the tube in place.

Oxbow (Oxbow Animal Health, Murdock, NE) has two formulas for tube feeding: Carnivore Care (obviously for carnivores) and Critical Care (for herbivores). When feeding omnivores, the two products can be mixed together. For box turtles, mix one part carnivore and one part herbivore. For adult red–eared sliders, mix one part carnivore and three parts herbivore.

Supplements. The purpose of all the above research and study is to formulate a varied diet based on the nutritional content of a wild diet. There are still a number of aspects of wild diets that are not completely understood. Supplements can be used to ensure that a recovering turtle or tortoise has adequate vitamin and mineral intake.

Always be aware that the calcium/phosphorus ratio must be at least 2:1. When phosphorus levels are too high, the body takes calcium out of the bones to bind with the phosphorus to facilitate its removal from the bloodstream. Calcium supplements can be used every other day for adults, every day for hatchlings and juveniles. Calcium supplements should not contain phosphorus since phosphorus is abundant in food. A good product that meets this requirement is Rep–Cal® Calcium Supplement–Phosphorus Free (Rep–Cal® Research Labs, Los Gatos, CA).

Two kinds of calcium supplements are available—with and without the addition of vitamin D3. Calcium *without* D3 can be used if the turtle or tortoise spends time outside in the sun; use calcium *with* D3 if the turtle or tortoise is kept indoors without UVB lighting. If UVB lighting is used indoors, use a supplement *without* D3 for most feedings, then use the supplement *with* D3 once every two weeks. This ensures adequate D3 coverage in case of poor quality full–spectrum bulbs, older bulbs emitting less UVB, or in case a chelonian

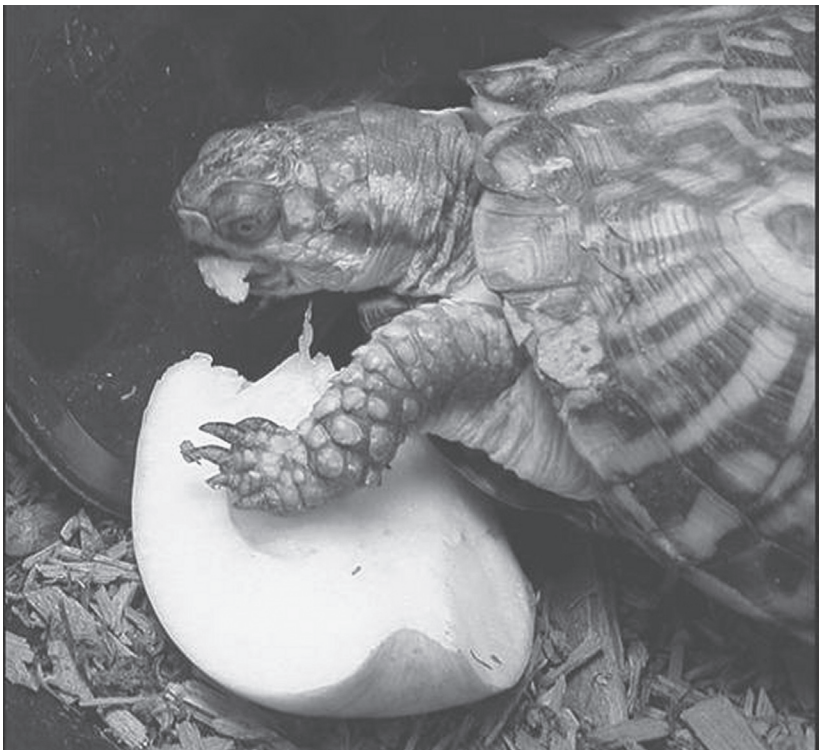

*Figure 4. Eastern box turtle (*Terrapene carolina carolina*) tackling an apple.*

is not spending enough time basking.

An additional source of calcium is to use cuttlebones, which are usually sold for pet birds. As a free–choice item, cuttlebones supply calcium and also help to keep beaks trim. Remove and discard the hard backing before placing the cuttlebone in the habitat enclosure (Figure 3.). Cuttlebone can be used with aquatic turtles by simply floating a piece in the water.

There are a number of good vitamin and mineral supplements for chelonians, such as Rep–Cal® Herptivite (Rep–Cal® Research Labs, Los Gatos, CA), and the Miner–All products (Sticky Tongue Farms, Sun City, CA). If chelonians are fed a good varied diet, vitamins are necessary only every third day.

Food as an Environmental Enrichment Tool.

Mealtime is a great environmental enrichment opportunity for chelonians in rehabilitation. Engage their senses by using a variety of colorful, natural foods in the diet. Once a turtle or tortoise is on the road to recovery, there is no need to chop food into small pieces. Make the turtle work by using large food items such as half an apple (Figure 4.), a wedge of greens, or a whole mouse that takes time and effort to tear apart and eat. Put food in different places each day, so there is no boring routine. Hide the food (worms in hollow logs, greens between rocks, strawberries behind a plant) so the turtle must search for it. Use live foods that must be hunted down and captured (e.g., worms and crickets for box turtles; fish for aquatics).

Conclusion

Good nutrition requires much more than just supplying food. An understanding of the many facets of nutrition are necessary: what the chelonian eats in the wild, how each species varies in its eating habits, how all the elements of nutrition fit together, and what foods are needed to meet the energy requirements during rehabilitation. This study of turtle nutrition is amply rewarded when one releases healthy, active, well–fed turtles and tortoises back to the wild.

Literature Cited

Alexander, M. M. 1943. Food Habits of the Snapping Turtle in Connecticut. *Journal of Wildlife Management.* 7: 278–282.

Bernard, J. B., and M. E. Allen. 1997. Feeding Captive Insectivorous Animals: Nutritional Aspects of Insects as Food. *Nutrition Advisory Group of the American Zoo and Aquarium Association.* Available from: <http://www.nagonline.net/Technical Papers/NAGFS00397Insects–JONIFE>.

Bren, Linda. 2001. Pet Food: The Lowdown on Labels. *FDA Consumer Magazine May–June.* U.S. Food and Drug Administration. Available from: <http://www.fda.gov/fdac/features/2001/301_pet.html>.

Budhabhatti, J., and E. O. Moll. 1990.Common Snapping Turtle (*Chelydra serpentina)* Feeding Behavior. *Herpetological Review.* 21: 19.

Burghardt, G. M. 1977. Learning Processes in Reptiles. Pp. 555–707 in *Biology of the Reptilia*, volume 7. (C. Gans and T. S. Parsons, editors.). Academic Press: New York, NY.

Burghardt, G. M., and E. H. Hess. 1966. Food Imprinting in the Snapping Turtle, *Chelydra serpentina*. *Science.* 151: 108–109.

Dierenfeld, E. S., H. L. Alcorn, and K. L. Jacobsen. Nutrient Composition of Whole Vertebrate Prey Fed in Zoos. Available from: <http://www.nal.usda.gov/awic/zoo/WholePreyFinal02May29.pdf>.

Donoghue, S. 2006. Nutrition. Pp. 251–298 in *Reptile Medicine and Surgery* (D. Mader, editor.). W. B. Saunders Company: Philadelphia, PA.

EPA Office of Pesticide Programs. 2000. Pesticide Ecotoxicity Database. Environmental Fate and Effects Division, United States Environmental Protection Agency, Washington, D.C. Available from: <http://www.epa.gov/pesticides/>.

Ernst, C. H., J. E. Lovich, and R.W. Barbour. 1994. *Turtles of the United States and Canada*. Smithsonian Institution Press: Washington, D.C.

Figureres, J. M. 1997. Treatment of Articular Gout in a Mediterranean Pond Turtle, *Mauremys leprosa*. *Association of Reptilian and Amphibian Veterinarians.* 7(4).

Funaba, M., Y. Oka, S. Kobayashi, M. Kaneko, H. Yamamoto, K. Namikawa, T. Iriki, Y. Hatano, and M. Abe. 2005. Evaluation of Meat Meal, Chicken Meal, and Corn Gluten Meal as Dietary Sources of Protein in Dry Cat Food. *Canadian Journal of Veterinary Research*. October. 69(4): 299–304.

Hansen, R. M., M. K. Johnson, and T. R. Van Devender. 1976. Foods of the Desert Tortoise *Gopherus agazzissi* in Arizona and Utah. *Herpetologica.* 32: 247–251.

Highfield, A.C. 1996. *Practical Encyclopedia of Keeping and Breeding Tortoises and Freshwater Turtles*. Carapace Press: London, England.

Highfield, A.C. 2002. *A Practical Guide to Avoiding Dietary Disasters*. Available from: <http://www.tortoisetrust.org/articles/>.

Hillman, W. S., and D. D. Culley. 1978. The Uses of Duckweed. *American Scientist.* 66: 442–451.

Lunsford, R. 2007. *USA Native Turtle Menu Options*. Available from: <http://www.austinsturtlepage.com/Articles/menu.htm>.

McCann, D., A. Barrett, A. Cooper, D. Crumpler, et al. 2007. Food Additives and Hyperactive Behaviour in 3–Year–Old and 8/9–Year–Old Children in the Community: A Randomised, Double–blinded, Placebo–controlled Trial. *The Lancet*, 3 November 2007. 370(9598): 1560–1567.

Moll, Don, and Edward O. Moll. 2004. *The Ecology, Exploitation, and Conservation of River Turtles*. Oxford University Press: New York, NY.

Nutrition Data information. Available at <www.nutritiondata.com>.

Pesticide Action Network North America. *PAN Pesticide Database*. Available from: <http:www.pesticideinfo.org>.

Plummer, M. V., and D. B. Farrar. 1981. Sexual Dietary Differences in a Population of *Apalone muticus*. *Journal of Herpetology*. 15: 175–179.

Pough, H. F., R. M. Andrews, J. E. Cadle, M. L. Crump, A. H. Savitzky, and K.D. Wells. 1998. *Herpetology*. Prentice Hall, Inc: Upper Saddle River, NJ.

Shively, S. H., and J. F. Jackson. 1985. Factors Limiting the Upstream Distribution of the Sabine Map Turtle. *American Midland Naturalist*. 114: 292–303.

Tuormaa, T. 1994. The Adverse Effects of Food Additives on Health: A Review of the Literature with Special Emphasis on Childhood Hyperactivity. *Journal of Orthomolecular Medicine*. 9(4): 225. Available from: <http://orthomolecularthерapy.com/library/jom/1994/pdf/1994–v09n04–p225.pdf>.

Vogt, R. C. 1981. Food Partitioning in Three Sympatric Species of Map Turtle, Genus *Graptemys*. *American Midland Naturalist*. 105: 102–111.

Webb, R. G. 1961. Observations on the Life Histories of Turtles (Genus *Pseudemys* and *Graptemys*) in Lake Texoma, Oklahoma. *American Midland Naturalist*. 65: 193–214.

Willmer, P., G. Stone, and I. Johnston. 2000. P. 141 in *Environmental Physiology of Animals*. Blackwell Publishing: Oxford, England.

Woody, J. B. 1990. Is 'Headstarting' a Reasonable Conservation Measure? On the Surface, Yes; in Reality, No. *Marine Turtle Newsletter*. 50: 8–11.

Wu, Y. V., Wahl K. Payne, and S. Vaughn. 2006. Corn Gluten Meal Odorants and Volatiles After Treatments to Improve Flavor. *Cereal Chemistry*. 83: 228–234. United States Department of Agriculture: Washington, DC.

Yilmaz, E., I. Akyurt, and G. Günal. 2004. Use of Duckweed, *Lemna minor*, as a Protein Feedstuff in Practical Diets for Common Carp, *Cyprinus carpio*, Fry. *Turkish Journal of Fisheries and Aquatic Sciences*. 4: 105–109.

Recommended Reading

Finke, M. 2002. Complete Nutrient Composition of Selected Invertebrates Commonly Fed to Insectivores. *Zoo Biology*. 21(2): 269–85.

Finke, M. 2002. Gut Loading to Enhance the Nutrient Content of Insects as Food for Reptiles: A Mathematical Approach. *Zoo Biology*. 22(2): 147–62.

Finke, M., S. Dunham, and J. Cole. 2004. Evaulation of Various Calcium–fortified High Moisture Commercial Products for Improving the Calcium Content of Crickets, *Acheta domesticus*. *Journal of Herpetological Medicine and Surgery*. 14(2): 6–9.

Winn, D., S. Dunham, and S. Mikulski. 2003. Food for Insects and Insects as Food: Viable Strategies for Achieving Adequate Calcium. *Journal of Wildlife Rehabilitation*. 26(1): 4–13.