Chapter 1
Introduction: Common Themes Across Diverse Taxa

Concerns about animal populations by various audiences, from elected officials and policy boards to the general public, often result in two disarmingly simple questions for wildlife biologists:

- What does a population need?
- Will that population grow or decline, and why?

The ability to answer these questions rests on a synthesis of nutritional ecology and physiology.

Nutritional ecology and physiology track the dynamic supply and demand of energy and nutrients in wildlife and their habitats. Our integrative approach to wildlife nutrition attempts to answer two general questions:

- How do animals contend with variations in the supply of resources and the environmental challenges in their habitat?
- What structures, metabolic pathways and life history parameters constrain or limit animal responses?

This first chapter introduces the topics of nutrient composition and nutrient requirements of wildlife. Table 1.1 lists the general groups of animals that are managed for control or conservation of populations. Functional relationships between food resources and animals are discussed in Part I from the scale of the population down to the individual digestive system (Chapters 2 to 5). Chemical components that provide energy substrates or tissue constituents are discussed in Part II (Chapters 6–9). Part III (Chapters 10 and 11) discusses energy flow and the adaptations of animals to changing environments and supplies of food.

1.1 Resource Supply and Organismal Demand

Supply and demand are features of both the environment and wildlife. The environment supplies food but also exerts demands on the animal. For example, low ambient temperatures increase the demand for energy to heat the body whereas

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Table 1.1 General groups of animals

Taxa	Group	Energy demand	Trophic level	Typical application[1]
Fish	Marine: reef fish	Ectotherm	Carnivore	Conservation
Fish	Marine: salmon, bream, tuna, shark, herring, halibut, pollock	Ectotherm	Carnivore	Control
Fish	Freshwater: catfish, cichlids, trout, barramundi	Ectotherm	Omnivore	Control
Amphibian	Frogs, salamanders	Ectotherm	Carnivore	Conservation
Reptile	Snakes, lizards, crocodiles	Ectotherm	Carnivore	Conservation
Reptile	Iguanine lizards, chelonians	Ectotherm	Herbivore	Conservation
Bird	Passerines: songbirds	Endotherm	Omnivore	Conservation
Bird	Ratites: emus, ostrich, rhea	Endotherm	Omnivore	Control
Bird	Upland game birds: grouse, ptarmigan, pheasants	Endotherm	Herbivore	Control
Bird	Waterfowl: geese, ducks	Endotherm	Herbivore	Control
Bird	Seabirds: waders, albatross, gulls	Endotherm	Carnivore	Conservation
Bird	Cranes, raptors	Endotherm	Carnivore	Conservation
Mammal	Marine: seals, whales	Endotherm	Carnivore	Conservation
Mammal	Marsupials: grazing kangaroos	Endotherm	Herbivore	Control
Mammal	Marsupials: wallabies, wombats, possums	Endotherm	Herbivore	Conservation
Mammal	Marsupials: bandicoots, quolls	Endotherm	Carnivore	Conservation
Mammal	Rodents	Endotherm	Omnivore	Control
Mammal	Hares, rabbits	Endotherm	Herbivore	Control
Mammal	Ruminants: deer, sheep, bison, giraffes	Endotherm	Herbivore	Control
Mammal	Horses, rhinos, elephants	Endotherm	Herbivore	Control
Mammal	Primates, lemurs	Endotherm	Omnivore	Conservation
Mammal	Cats: lions, lynx	Endotherm	Carnivore	Conservation
Mammal	Bears, wolves, hyena	Endotherm	Carnivore	Control

[1]Control = monitored and often manipulated to control a population for maximum sustainable harvest or minimal adverse effects of overabundance. Conservation = monitored and often manipulated to conserve minimal viable population size.

high ambient temperatures increase the need for water to cool the animal. The patterns of energy and nutrient availability in an ecosystem provide the context for environmental supply and demand for wildlife. These patterns may be defined by the average abundance of the resource (high to low), the range of variation (broad to narrow), spatial distribution (uniform to patchy) and timing of resource availability (frequent to infrequent; constant to erratic). Wildlife diversity and abundance are high in rainforest ecosystems that are characterized by moderate temperature and high availability of water and nutrients, conditions that promote continuous plant production. Conversely, hot deserts typically support smaller populations of fewer species of wildlife because temperature and precipitation are highly variable and less conducive to plant production (Fig. 1.1)

Fig. 1.1 Primary production of plants varies widely with patterns of temperature, water availability and soils. **a** Mild temperatures and rich soils support diverse communities of plants and animals in wetlands when weather patterns are relatively stable. **b** Extreme temperatures of cold or heat combined with low and infrequent rains limit plant and animal communities in montane and desert habitats

The demands of the animal are ultimately met with food from the environment. These demands include the maintenance of body tissues that follows the genetic program of the species throughout the life of each individual. Life-history patterns reflect the allocation of energy and nutrients to the tissues and the activities and time required for survival, growth and reproduction. For example, among northern elephant seals, adult males awaiting the arrival of females at the breeding beach appear to expend little energy or nutrients but are nonetheless maintaining their muscles and organs even as they lie motionless. Female seals incur additional costs of energy and nutrients for production of milk soon after they arrive at the beach and deliver their pups (Boness et al. 2002). The costs of growth in seal pups are likewise a programmed productive demand that will continue until they in turn begin reproduction at adulthood. The ability to support maintenance or production of tissues when environmental supplies are inadequate depends on the supply of energy and nutrients from internal stores. Female seals use body fat and protein to produce milk when fasting or eating very little.

The ability of wildlife to contend with environmental variations depends on behavioral and physiological flexibility. Estuarine species of fish contend with daily tidal flows by tolerating a wide range of salinity (Spicer and Gaston 1999). Desert reptiles contend with infrequent rainfall by tolerating a wide range of internal fluid concentrations and by accumulating water stores in the urinary bladder after each rain (Bradshaw 2003). Environmental conditions that alter the abundance and timing of food and water select for an operational range that varies both among and within species. Variation within species is often associated with phenotypic plasticity, such as the amount of body fat in songbirds at the start of winter (Rogers et al. 1994). Persistent environmental change over multiple generations may favor one phenotype over another, resulting in population drift. For example, a population of birds may increase body fat or begin migration earlier as winters become colder and the period of snow cover lengthens for each generation. The combination of demography and genetics may ultimately result in speciation. In the austere and erratic environment of the Galapagos islands, beak size within a population of finches varies with the availability and form of their diet of seeds (Grant 1999). Similarly, energy expended at rest in wild mice can vary with primary plant production in their environment (Mueller and Diamond 2001). Phenotypic and genotypic differences among animals therefore alter their demands for energy and nutrients as well as their vulnerability to environmental changes.

1.2 Principal Components of Animals and Plants

The transfer of nutrients and energy from the environment to wildlife is reflected in the chemical composition of materials from soils through plants to herbivores, omnivores and predators. The elements of food are ultimately returned to the environment in excreta and tissues lost by animals throughout their lives. Tissues synthesized at one level of this trophic hierarchy are the food for the next level. The chemical composition of ingested animals and plants reflects the costs of depositing tissues as well as their value to a consumer. This section introduces the components of water, nutrients and energy in plants and animals.

Water is the principal interface between animals and their environment because organisms absorb and excrete matter across a wet interface. Removal of water (moisture) from living tissue preserves the nutrients contained in the remaining dry material (dry matter or dry mass; DM). In human agriculture, desiccation of plant seeds and stems in late summer and autumn produces grain and hay for winter storage. Similarly, the natural desiccation of seeds allows many birds and rodents to cache a stable source of food for winter. Moisture may be the largest fraction of plant and animal tissues, and is typically measured in grams per hundred grams ($g \cdot 100\,g^{-1}$) whole mass or percent (%). Water content is greatest for aquatic plants such as algae (Fig. 1.2), and for some parts of terrestrial plants such as nectar, flowers, fruits and budding leaves. Dietary sources of water may be important for hydration of animals, but excess moisture in food can dilute the nutrients and energy in a diet. Nectarivores such as hummingbirds must therefore consume large volumes of

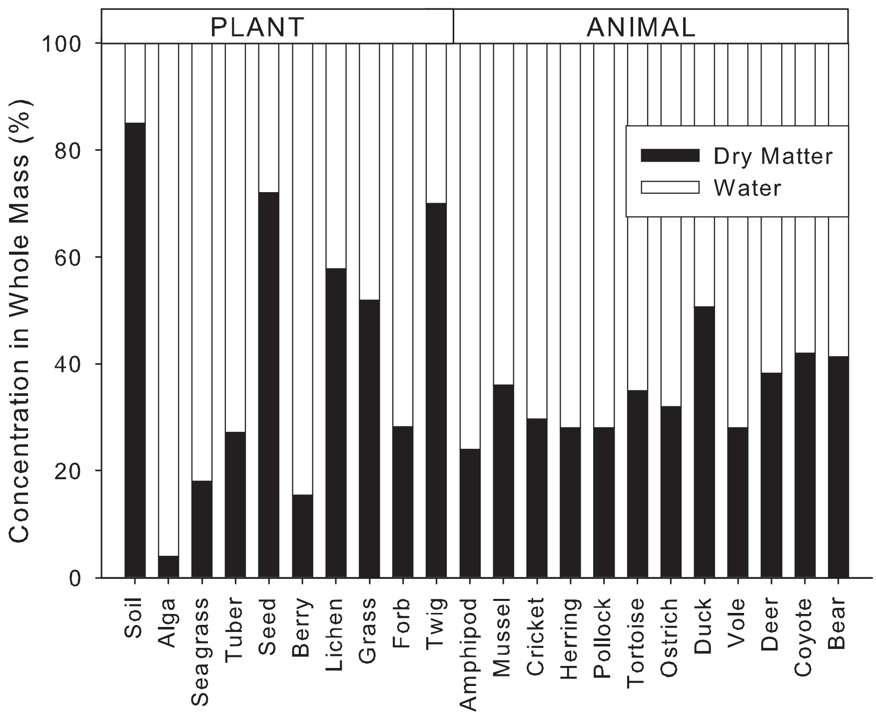

Fig. 1.2 Content of water (moisture) and dry matter in selected plants and animals in comparison with rich terrestrial soils (Chapin et al. 2002). Plants: blue-green alga (National Research Council 1983); leaves of sea grass (Mason et al. 2006); tubers of sweet potato (National Research Council 2003); seeds of corn (National Research Council 1996); blueberries (National Research Council 2003); terricolous lichen (Barboza, unpublished); aerial parts of *Schismus* grass and the leaves of the forb globemallow in spring (Barboza 1996); twigs of Barclay willow in winter (Spaeth et al. 2002). Animals: aquatic and terrestrial invertebrates (an amphipod, blue mussel and the mormon cricket) (Jorde and Owen 1990; National Research Council 2003); marine fish (herring and pollock) (Trumble et al. 2003); a reptile (the desert tortoise) (Barboza, unpublished); birds (ostrich and black duck) (Swart et al. 1993b; Barboza and Jorde 2002); and mammals (northern red-backed vole, white-tailed deer, coyote, black and brown bears) (Robbins et al. 1974; Farley and Robbins 1994; Huot et al. 1995; Zuercher et al. 1999)

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