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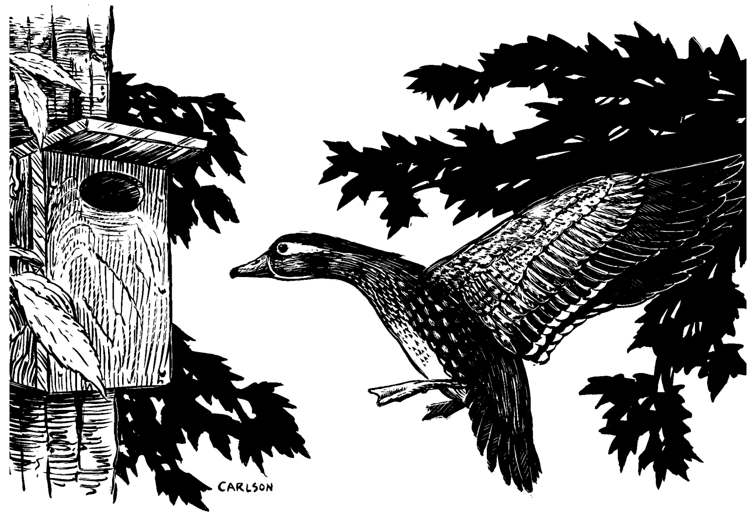

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Over 40 species of North American waterfowl use wetland habitats throughout their annual cycles. Survival, reproduction, and growth are dependent on the availability of foods that meet nutritional requirements for recurring biological events. These requirements occur among a wide variety of environmental conditions that also influence nutritional demands. Recent work on nesting waterfowl has identified the female's general nutrient needs for egg laying and incubation. Far less is known about nutritional requirements for molt and other portions of the life cycle, particularly those during the nonbreeding season. Although information on specific requirements for amino acids and micronutrients of wild birds is meager, the available information on waterfowl requirements can be used to develop waterfowl management strategies. For example, nutrient content of foods, nutritional requirements of waterfowl, and the cues waterfowl use in locating and selecting foods are all kinds of information that managers need to encourage use of habitats by feeding waterfowl. Waterfowl nutritional needs during the annual cycle and the nutritional values of natural foods and crops will be discussed below.

Composition of Waterfowl Foods

Compared to the nutritional information on many agricultural crops, the composition of wild foods is poorly documented. Nevertheless, the available information on nutritional quality of wild foods, in conjunction with known waterfowl requirements, provides general guidelines for management. Terminology commonly used when discussing the nutritional values of foods or requirements for waterfowl include the following:

Basal metabolic rate (BMR)—The lowest level of metabolism necessary for basic body functions for an animal at rest.
Gross energy—The amount of energy (often expressed in 1000 calories = 1 kcal) produced when a food sample is ignited in a bomb calorimeter. Gross energy represents the most common nutritional information available, because techniques to determine gross energy are relatively simple and costs are minimal.
Metabolizable energy—The amount of energy that can be utilized for metabolic processes by an animal. Metabolizable energy is more complicated to determine than gross energy—animals must be fed a diet of food containing a known amount of gross energy, and the portion excreted as feces, urine, and gases must be identified and quantified.
Proximate analysis—A chemical process to identify the major components in foods. Samples must be handled carefully to ensure that chemical composition represents the nutritional content. The food is first ground to a fine homogenate, then dried to determine water content. Components identified by proximate analysis include the following:

- *Fats or lipids* —The most concentrated energy sources in foods. Fats occur as structural components and serve as insulation or as energy stores.
- *Ash*—Mineral content.

- *Crude Fiber*—Least digestable fraction in foods that includes cellulose, hemicellulose, or lignin. Waterfowl lack rumens; thus, little fiber is digested.
- *Nitrogen-free extract* (*NFE*)—Highly digestible carbohydrates.
- *Protein*—Compounds containing nitrogen that are major components of muscle tissue, animal cell membranes, and feathers; also active as enzymes, hormones, and clotting factors in blood. These serve many different functions.

More sophisticated testing provides identification of the specific composition of proteins and fats:

- *Amino acids*—Mixtures of 20 to 25 different amino acids, linked by peptide bonds, form plant and animal proteins.
- *Essential amino acids* —The 10 amino acids that must come from the diet because of the inability of an animal's metabolic pathway to produce them.
- *Fatty acids*—Components of fats with varying molecular weight and number of double bonds. Unsaturated fatty acids such as palmitoleic, oleic, and linoleic acids are important in waterfowl.

Information is generally available on the gross energy of foods (Tables 1 and 2), but metabolizable energy and outputs of proximate analyses including the amount of fat, fiber, ash, or nitrogen-free extract of these same foods are rarely identified (Table 3). Proteins supply the essential amino acids and are in high demand during egg laying and molt. Fats or lipids serve as energy reserves, as structural elements in cells, and as sterol hormones. Ash indicates the mineral content. Crude fiber is a measure of the least digestible food components, whereas NFE provides an estimate of the highly digestible carbohydrates.

Food quality is best predicted when information is available on metabolizable energy, ash, protein, fat, and NFE. Protein values are reported for about half of the foods that have energy values, but the content of fat, fiber, ash, or NFE is identified for less than one-third. Foods with a very high fiber content generally have lower levels of metabolizable or usable energy because fiber is poorly digested by waterfowl. In some cases, values from chemical analyses can be misleading. Crude protein content may be high, but the form of the protein or chemical inhibitors within the food may reduce the amount usable by the bird. For example, soybeans have a high level of crude protein, but only a small portion is available to waterfowl because of inhibitors. Waterfowl require a balance of amino acids. Some foods, such as crustaceans, usually have a better balance of amino acids than do insects and spiders. Certain

Table 1. *Chemical composition of some common waterfowl plant foods. Values represent averages from the literature.*

Common name[a]	Gross energy (kcal/g)	Fat	Fiber	Ash	NFE	Protein
Sticktights	5.177	15.0	19.7	7.2	27.5	25.0
Schreber watershield	3.790	2.9	36.7	4.8	45.9	9.3
Pecan hickory	7.875	40.8	19.0	12.6	35.1	8.4
Chufa flatsedge (tubers)	4.256	6.9	9.0	2.5	55.4	6.7
Hairy crabgrass	4.380	3.0	11.1	9.7	59.4	12.6
Barnyardgrass	3.900	2.4	23.1	18.0	40.5	8.3
Rice cutgrass	3.982	2.0	10.6	9.5	57.8	12.0
Fall panicum	4.005	3.1	16.8	16.1	50.1	12.3
Smartweed	4.423	2.8	22.0	7.5	—	9.7
Pennsylvania smartweed	4.315	2.3	21.8	4.9	65.3	9.0
Pin oak	5.062	18.9	14.7	1.6	58.6	6.4
Willow oak	5.296	20.6	14.0	1.7	55.3	5.1
Curly dock	4.278	1.2	20.4	6.9	—	10.4
Duck potato	4.736	9.0	10.8	4.9	55.5	20.0
Milo	4.228	3.1	6.0	3.5	72.2	10.2
Corn	4.435	3.8	2.3	1.5	79.8	10.8
Common soybean	5.451	20.5	5.4	6.2	27.1	39.6
Common duckweed	4.235	3.5	11.3	10.7	49.8	25.7
River bulrush (rhizomes)	4.010	—	—	—	—	—

[a] For alternative common names and scientific names consult Appendix.

Table 2. *Chemical composition of some common waterfowl invertebrate foods.*

Invertebrate	Gross energy (kcal/g)	Protein (%)
Water boatmen	5.2	71.4
Back swimmers	5.7	64.4
Midges	4.6	61.2
Water fleas	4.0	49.7
Amphipods (*Hyallela azteca*)	4.9	47.6
Amphipods (*Gammarus* spp.)	3.8	47.0
Cladocera (unclassified)	2.7	31.8
Pond snails	1.0	16.9
Orb snails	1.0	12.2

amino acids can be synthesized by waterfowl, but the essential amino acids must be acquired in the diet.

Because values for metabolizable energy are reported for individual food items rather than as combinations of foods normally consumed by wild waterfowl, nutritional information is not always accurate. Synergistic interactions among foods during digestion are more difficult to identify compared to the usable energy available from a single food item fed separately. Thus, providing a nutritionally balanced diet from wild and domestic foods, alone or in combination, continues to be a perplexing challenge facing wetland managers.

The Energetic Costs of Waterfowl Activities

Wild animals must provide for general body maintenance and for processes that require additional nutrients, such as growth, reproduction, and migration. The BMR includes the demands for energy of an animal that is at rest. Basal costs for locomotion, digestion, reproduction, or thermoregulation at extreme temperature ranges are not included. Large body sizes allow waterfowl to use their body reserves to meet the demands of maintenance and other demanding processes. For example, arctic–nesting geese transport all of their protein and energy needs for laying and incubation with them to arctic nesting grounds. Such species may lose nearly 50% of their body weight by the time their clutches hatch. Reserves for migration are particularly important in some waterfowl such as Pacific populations of brant. In their 3,000–mile journey from Alaska to Mexico, they lose one-third of their body weight (about 1.87 lb of fat) in a few days.

Waterfowl engage in a variety of activities that have high energetic costs. The locality and the environmental conditions under which these activities occur determine the energetic expenditures for each event. These are usually expressed in relation to the basal metabolic rate for an animal at rest.

Activities such as swimming, preening, foraging, or courtship are more energetically costly. Flight is the most expensive activity with estimates ranging from 12–15 × BMR. Diving is less costly (i.e., 3.5 × BMR). Furthermore, temperatures have important effects on energetic requirements. For example, captive mallards will increase their metabolic rate above the basal level by 2.1 × at 0°C and by 2.7 × at –20°C. Wild ducks and geese reduce the frequency of their feeding flights under extreme cold to conserve energy. Determining actual energetic costs of activities is difficult in the field; hence, the values for wild birds are usually based on estimates rather than actual measurements.

The general nutritional requirements for biological events in the annual cycle are known for an increasing number of waterfowl. The best estimates are those for breeding birds (Table 4), whereas far less is known about nonbreeding requirements.

Table 3. *Metabolizable energy of some common waterfowl foods.*

Taxon	Test animal	Metabolizable energy (kcal/g)
Water flea	Blue-winged teal	0.82
Amphipod (*Gammarus* spp.)	Blue-winged teal	2.32
Pond snail	Blue-winged teal	0.59
Coast barnyardgrass	Duck (male)	2.63
Coast barnyardgrass	Duck (female)	2.99
Rice cutgrass	Duck (male)	3.00
Common duckweed	Blue-winged teal	1.07
Pennsylvania smartweed	Dabbling duck (male)	1.12
Pennsylvania smartweed	Dabbling duck (female)	1.10

Table 4. *Nutritional requirements for breeding waterfowl compared to the composition of corn and common native foods.*

	Requirements breeding ducks/geese	Plants Foods			
		Corn	Acorns	Barnyardgrass	Pigweed
Energy	2,900[a]	3,430[a]	5,577[b]	4,442[b]	4,623[b]
Protein (%)	19	8.7	6.0	12.5	22.0
Methionine[c]	2.0	0.18	—	—	—
Ca (%)	2.7	0.02	0.24	0.13	1.72
Mg (ppm)	350	5	—	69	35

[a] = kcal ME/kg
[b] = Gross energy (not metabolizable energy)
[c] = % of protein

Note that no single food supplies a diet that meets all energy, protein, or micronutrient needs of breeding waterfowl. Likewise, activities other than breeding have varying costs in relation to specific nutrient energy and differ greatly from reproduction, where a mix of energy, minerals, and protein are required to supply the needs of egg-laying females.

Food Quality in Relation to Deterioration and Habitat Conditions

The quality of plant foods is largely determined by heredity, but other factors, such as soil nutrients and environmental conditions during the growing season, are important. For example, seeds having a high fat content may vary greatly in energy content among seasons because of environmental conditions. The supply of minerals is closely related to the mineral concentrations in water.

One of the major problems facing waterfowl managers is deterioration of seeds during flooding, but information on rates of deterioration is only available for a few seeds. Soybeans break down very rapidly; nearly 90% of the energy content is lost during 3 months of flooding, whereas corn loses only 50% during a similar period of flooding (Table 5). Breakdown of wild seeds is variable. Hard seeds such as bulrush decompose slowly, whereas softer seeds such as common barnyardgrass deteriorate 57% after 90 days under water. Such variations have important implications for the timing of flooding for waterfowl (Table 6). If some seeds are submerged for a month or more before waterfowl are present, much of the food value will be lost because of deterioration.

Supplying Nutritional Needs for Waterfowl

The large body sizes of waterfowl enable them to store nutrients as body reserves. In some cases nutrients for an upcoming stage in the life cycle are acquired at a distant wetland and transported as body reserves. The best known examples are the transport of fats, calcium, and protein by arctic-nesting geese from wintering and migrational stopovers to breeding habitats. Because waterfowl store body reserves, managers should make an effort to supply required nutrients throughout the annual cycle rather than supplying nutrients solely for events at the time they occur.

Identifying shortfalls in nutritional needs is becoming more of a reality as the requirements for free-living animals are identified. Waterfowl are well adapted to the dynamics of natural wetland systems. Mobility and foraging adaptability are behav-

Table 5. *Deterioration of selected seeds after 90 days of flooding.*

Plant name	Decomposition (%)
Soybean	86
Barnyardgrass	57
Corn	50
Common buckwheat	45
Milo	42
Giant bristlegrass	22
Pennsylvania smartweed	21
Cultivated rice	19
Water oak (acorns)	4
Hemp sesbania	4
Horned beakrush	2
Saltmarsh bulrush	1

Table 6. *Comparison of deterioration of 100 lb of five selected seeds in relation to different flooding schedules. Estimates assume a constant daily rate of deterioration.*

	Percent Remaining			
	15 September	15 October	15 Novemeber	15 December
Flooding Date				
18 August				
Soybeans	71	43	14	0
Corn	83	67	50	33
Millet	81	62	43	24
Giant bristlegrass	93	85	78	71
Smartweed	93	85	79	72
Total percent remaining	84	68	53	40
15 September				
Total percent remaining		84	68	53
15 October				
Total percent remaining			84	68
15 November				
Total percent remaining				84

ioral characteristics that enable waterfowl to acquire needed resources. Dynamic wetlands supply a variety of food resources that allow waterfowl to feed selectively and to formulate nutritionally adequate diets from a variety of sites. Although a single wetland site may not provide adequate food for all requirements, management areas with a variety of wetlands or flooding regimes usually have a mix of habitats that provide all nutritional requirements.

Because a variety of strategies exists within and among waterfowl species (wintering, migration, or breeding), not all individuals or species require similar resources simultaneously. Thus, a diverse habitat base is a logical approach to meet the various needs of waterfowl. Furthermore, when suitable food and cover are within daily foraging range, acquisition of required resources is enhanced. A good rule of thumb is to provide many wetland types or food choices within a 10-mile radius of waterfowl concentrations. Some species such as snow geese have far greater foraging ranges, but they are the exception rather than the rule.

Appropriate management requires preservation, development, and manipulation of manmade and natural wetland complexes. Such an approach provides nutritionally balanced diets for diverse waterfowl populations. Where natural wetlands remain intact, they should be protected as unique components of the ecosystems. The protection of natural systems and the development and management of degraded systems increases choices of habitats and foods for waterfowl. Likewise, the provision of adequate refuge areas where birds are protected from disturbance is an essential ingredient to ensure that food resources are available to waterfowl and can be used efficiently.

Suggested Reading

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Appendix. Common and Scientific Names of Plants and Animals Named in Text.

Plants	
Pigweed	*Amaranthus* sp.
Devils beggarticks *or* sticktights	*Bidens frondosa*
Schreber watershield	*Brasenia schreberi*
Pecan hickory	*Carya illinoensis*
Chufa flatsedge	*Cyperus esculentus*
Hairy crabgrass	*Digitaria sanguinalis*
Common barnyardgrass *or* Japanese millet	*Echinochloa crusgalli*
Coast barnyardgrass, wild millet, *or* watergrass	*Echinochloa walteri*
Common buckwheat	*Fagopyrum esculentum*
Common soybean	*Glycine max*
Rice cutgrass	*Leersia oryzoides*
Common duckweed	*Lemna minor*
Cultivated rice	*Oryza sativa*
Fall panicum *or* panic grass	*Panicum dichotomiflorum*
Curltop ladysthumb *or* smartweed	*Polygonum lapathifolium*
Pennsylvania smartweed	*Polygonum pensylvanicum*
Pin oak	*Quercus palustris*
Willow oak	*Quercus phellos*
Water oak	*Quercus nigra*
Horned breakrush	*Rhynchospora corniculata*
Curly dock	*Rumex crispus*
Common arrowhead *or* duck potato	*Sagittaria latifolia*
River bulrush *or* three-square bulrush	*Scirpus fluviatilus*
Saltmarsh bulrush *or* bulrush	*Scirpus robustus*
Hemp sesbania	*Sesbania exalta*
Giant bristlegrass *or* giant foxtail	*Setaria magna*
Common sorghum *or* milo	*Sorghum vulgare*
Indian corn *or* corn	*Zea mays*
Birds	
Blue-winged teal	*Anas discors*
Mallard	*Anas platyrhynchos*
Brant	*Branta bernicla*
Snow goose	*Chen caerulescens*
Invertebrates (Families)	
Midges	Chironomidae
Water boatmen	Corixidae
Water fleas	Daphnidae
Pond snails	Lymnaeidae
Back swimmers	Notonectidae
Orb snails	Planorbidae

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