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Wildlife Exposure Factors Handbook

Volume I of II

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WILDLIFE EXPOSURE FACTORS HANDBOOK

Volume I of II

Office of Health and Environmental Assessment
Office of Research and Development
U.S. Environmental Protection Agency
Washington, DC 20460

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FOREWORD

The Exposure Assessment Group (EAG) of EPA's Office of Research and Development has three main functions: (1) to conduct human health and ecological exposure and risk assessments, (2) to review exposure and risk assessments and related documents, and (3) to develop guidelines and handbooks for use in these assessments. The activities under each of these functions are supported by and respond to the needs of the various program offices, regional offices, and the technical community.

The Wildlife Exposure Factors Handbook was produced in response to the increased interest in assessing risks to ecological systems. Its purpose is to improve exposure assessments for wildlife and support the quantification of risk estimates. It is a companion document to the Exposure Factors Handbook, which contains information useful for quantifying exposure to humans. Because information and methods for estimating exposure are continually improving, we will revise these handbooks as necessary in the future.

Michael A. Callahan
Director
Exposure Assessment Group

PREFACE

The Exposure Assessment Group of the Office of Health and Environmental Assessment (OHEA) has prepared the Wildlife Exposure Handbook in support of the Office of Solid Waste and Emergency Response and the Office of Water. The Handbook provides information on various factors used to assess exposure to wildlife. The goals of the project are (1) to promote the application of risk assessment methods to wildlife species, (2) to foster a consistent approach to wildlife exposure and risk assessments, and (3) to increase the accessibility of the literature applicable to these assessments.

The bulk of the document summarizes literature values for exposure factors for 34 species of birds, mammals, amphibians, and reptiles. In addition, we include a chapter on allometric equations that can be used to estimate some of the exposure factors when data are lacking. Finally, we describe some common equations used to estimate exposure. The basic literature search was completed in May 1990 and was supplemented by targeted searches conducted in 1992.

We anticipate updating this Handbook and would appreciate any assistance in identifying additional sources of information that fill data gaps or otherwise improve the Handbook. Comments can be sent to:

Exposure Assessment Group
Wildlife Exposure Factors Handbook Project
USEPA (8603)
401 M Street, SW
Washington, DC 20460

AUTHORS, MANAGERS, CONTRIBUTORS, AND REVIEWERS

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AUTHORS

Dr. Margaret McVey
Kimberly Hall, Peter Trenham, Alexander Soast, Leslie Frymier, and Ansara Hirst
ICF, Incorporated

PROJECT MANAGER

Susan Braen Norton
Exposure Assessment Group, Office of Health and Environmental Assessment
Office of Research and Development
U.S. Environmental Protection Agency

TASK MANAGERS

Cynthia Nolt
Office of Science and Technology
Office of Water
U.S. Environmental Protection Agency

Ron Preston
Office of Emergency and Remedial Response
Office of Solid Waste and Emergency Response
U.S. Environmental Protection Agency

CONTRIBUTORS

Dr. Sarah Gerould
Office of Water Quality
U.S. Geological Survey

Dr. Ronald Kirby
Office of Information Transfer
U.S. Fish and Wildlife Service (USFWS)
Department of the Interior

REVIEWERS

Dr. Cynthia Annett, USFWS, Arkansas Cooperative Fish and Wildlife Research Unit, AR
Dr. Richard J. Aulerich, Michigan State University, MI
Dr. Richard Bennett, USEPA, Environmental Research Laboratory (ERL), Corvallis, OR
Dr. Christine A. Bishop, Canadian Wildlife Service, Ontario, Canada
Dr. Brad Bortner, USFWS, Office of Migratory Bird Management, MD
Dr. Steven Bradbury, USEPA, ERL-Duluth, MN
Dr. Robert Burr, USFWS, VA
Ms. Janet Burris, ABB Environmental Services, Washington, DC
Dr. Joseph Chapman, Utah State University, UT
Dr. Lewis Cowardin, USFWS, Northern Prairie Wildlife Research Center, ND
Ms. Deanna Dawson, USFWS, Patuxent Wildlife Research Center, MD
Dr. Donald L. DeAngelis, Oak Ridge National Laboratory, TN
Dr. Bruce Duncan, USEPA, Region 10, Seattle, WA
Dr. Robert Foley, USFWS, Annapolis Field Office, MD
Dr. Glen Fox, Canadian Wildlife Service, Ontario, Canada
Dr. J.H.B. Garner, USEPA, OHEA, Environmental Criteria and Assessment Office (ECAO), Research Triangle Park, NC
Dr. J. Whitfield Gibbons, University of Georgia, Savannah River Ecology Laboratory, GA
Mr. Keith A. Grasman, Virginia Polytechnic Institute and State University, VA
Dr. Fred Guthery, Caesar Kleberg Wildlife Research Institute, Texas A&I University, TX
Dr. Richard S. Halbrook, Oak Ridge National Laboratory, TN
Dr. Michael J. Hamas, Central Michigan University, MI
Dr. Charles J. Henny, USFWS, Pacific Northwest Research Station, OR
Dr. Paula F. P. Henry, USFWS, Patuxent Wildlife Research Center, MD
Dr. Gary Heinz, USFWS, Patuxent Wildlife Research Center, MD
Dr. Doug James, University of Arkansas, AR
Mr. K. Bruce Jones, USEPA, Environmental Monitoring Systems Laboratory, EMAP Terrestrial Ecosystems, CA
Dr. Dennis G. Jorde, USFWS, Patuxent Wildlife Research Center, MD
Dr. Norm Kowal, USEPA, OHEA, ECAO, Cincinnati, OH
Dr. Gary L. Krapu, USFWS, Northern Prairie Wildlife Research Center, ND
Dr. David Krementz, USFWS, Patuxent Wildlife Research Center, MD
Dr. James Kushlan, University of Mississippi, MS
Dr. John T. Lokemoen, USFWS, Northern Prairie Wildlife Research Center, ND
Dr. Dave Ludwig, EA Engineering, Inc., MD
Dr. Drew Major, USFWS, Concord, NH
Dr. Karen McBee, Oklahoma State University, OK

REVIEWERS (continued)

Dr. Linda Meyers-Schöne, International Technology Corp., NM
Mr. Jerry Moore, USEPA, OHEA, Washington, DC
Dr. Lewis Oring, University of Nevada at Reno, NV
Dr. Raymond Pierotti, University of Arkansas, AR
Dr. Richard M. Poché, Genesis Laboratories, WI
Dr. Douglas Reagan, Woodward-Clyde Consultants, CO
Dr. Lorenz Rhomberg, USEPA, OHEA, Human Health Assessment Group, Washington, DC
Dr. Robert Ringer, Mount Dora, FL
Dr. John L. Roseberry, Southern Illinois University at Carbondale, IL
Dr. Alan Sargeant, USFWS, Northern Prairie Wildlife Research Center, ND
Dr. Edward Schafer, USDA, Denver Wildlife Research Center, CO
Dr. Laird Schutt, Canadian Wildlife Service, Quebec, Canada
Ms. Anne Sergeant, USEPA, OHEA, EAG, Washington, DC
Dr. Kim Smith, University of Arkansas, AR
Dr. Mark Sprenger, USEPA, OSWER, Environmental Response Team, Edison, NJ
Dr. George A. Swanson, USFWS, Northern Prairie Wildlife Research Center, ND
Dr. Sylvia Talmage, Oak Ridge National Laboratory, TN
Dr. Bob Trost, USFWS, Office of Migratory Bird Management, MD
Dr. D.V. (Chip) Weseloh, Canadian Wildlife Service, Ontario, Canada
Dr. Nathaniel Wheelwright, Bowdoin College, ME
Dr. Donald H. White, USFWS, Southeast Research Station, GA
Dr. Stanley N. Wiemeyer, USFWS, Patuxent Wildlife Research Center, MD
Dr. Bill Williams, Environmental Planning and Toxicology, Corvallis, OR
Dr. Dean M. Wilkinson, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service
Dr. Jerry O. Wolff, USEPA, ERL, Corvallis, OR
Dr. John P. Wolfin, USFWS, Annapolis Field Station, MD

1. INTRODUCTION

The Wildlife Exposure Factors Handbook (hereafter referred to as the Handbook) provides data, references, and guidance for conducting exposure assessments for wildlife species exposed to toxic chemicals in their environment. It is the product of a joint effort by EPA's Office of Research and Development (ORD), Office of Solid Waste and Emergency Response (OSWER), and Office of Water (OW). The goals of this Handbook are (1) to promote the application of risk assessment methods to wildlife species, (2) to foster a consistent approach to wildlife exposure and risk assessments, and (3) to increase the accessibility of the literature applicable to these assessments.

1.1. PURPOSE AND SCOPE

The purpose of the Handbook is to provide a convenient source of information and an analytic framework for screening-level risk assessments for common wildlife species. These screening-level risk assessments may be used for several purposes, including: to assess potential effects of environmental contamination on wildlife species and to support site-specific decisions (e.g., for hazardous waste sites); to support the development of water-quality or other media-specific criteria for limiting environmental levels of toxic substances to protect wildlife species; or to focus research and monitoring efforts. The Handbook provides data (analogous to EPA's *Exposure Factors Handbook* for humans, USEPA, 1989c) and methods for estimating wildlife intakes or doses of environmental contaminants. Although the data presented in the Handbook can be used for screening analyses, we recommend that anyone establishing a cleanup goal or criterion on the basis of values contained herein *obtain the original literature on which the values are based to confirm that the study quality is sufficient to support the criterion.* This Handbook does not include data or extrapolation methods required to assess the toxicity of substances to wildlife species, nor does it include any chemical-specific data (e.g., bioavailability factors).

For the Office of Water, data gathered for the Handbook were used to identify wildlife species that are likely to be at greater risk from bioaccumulative pollutants in surface waters and to estimate likely exposures for these species. Data on diets and on

food and water ingestion rates can be used with chemical-specific information, such as bioaccumulation potential and wildlife toxicity, to calculate site- or region-specific concentrations of a chemical in water (or soil or sediment) that are unlikely to cause adverse effects.

For the Superfund program, this Handbook supplements the existing environmental evaluation guidance. EPA's *Risk Assessment Guidance for Superfund: Volume II--Environmental Evaluation Manual* (U.S. EPA, 1989a) provides an overview of ecological assessment in the Superfund process. It includes a description of the statutory and regulatory bases for ecological assessments in Superfund and fundamental concepts for understanding ecological effects of environmental contaminants. The *Environmental Evaluation Manual* also reviews elements of planning an ecological assessment and how to organize and present the results of the assessment. EPA's *Ecological Assessment of Hazardous Waste Sites: A Field and Laboratory Reference* (U.S. EPA, 1989b) and *Evaluation of Terrestrial Indicators for Use in Ecological Assessments at Hazardous Waste Sites* (U.S. EPA, 1992) are companion documents that describe biological assessment strategies, field sampling designs, toxicity tests, biomarkers, biological field assessments, and data interpretation. The *ECO Update* intermittent bulletin series (published by EPA's Office of Solid Waste and Emergency Response, publication no. 9345.0-05I, available from the National Technical Information Service, Springfield, Virginia) provides supplemental guidance for Superfund on selected issues. Although these documents have identified decreases in wildlife populations as potential endpoints for ecological assessments, they do not provide guidance on how to conduct a wildlife exposure assessment that is comparable to the guidance provided by the Superfund program for human health exposure assessments. This Handbook provides both guidance and data to facilitate estimating wildlife exposure to contaminants in the environment.

Exposure assessments for wildlife and humans differ in several important ways. One key distinction is that many different wildlife species may be exposed, as compared with a single species of concern for a human health assessment. Exposure varies between different species and even between different populations of the same species; behavioral attributes and diet and habitat preferences influence this variation. Second, whereas it is

seldom possible to confirm estimated levels of human exposure without invasive sampling of human tissues, confirmatory sampling for many chemicals can be done in wildlife species (protected species excepted). However, the tissue sampling required to quantify actual exposure levels can be costly, and interpretation of tissue concentrations can be complex.

For both human health and wildlife exposure assessments, the most cost-effective approach is often to first screen for potentially significant exposures using measures (or estimates) of environmental contamination (e.g., in soils, water, prey species) to estimate contaminant intakes or doses by significant routes of exposure. If estimated doses fall far below the toxicity values associated with adverse effects, especially from chronic exposures, further assessment may be unnecessary. If estimated doses far exceed reference toxicity values, it may be possible to determine appropriate actions on the basis of these estimates alone. When a screening-level exposure assessment indicates that adverse effects are likely, additional confirmatory data may be needed in the decision-making process. For humans, it is usually not practicable to obtain additional types of data (e.g., tissue concentrations, biomarkers), and human exposure estimates are often refined by using more site-specific data for exposure parameters. For wildlife, confirmatory data may be obtained from chemical analyses of tissue samples from potentially exposed wildlife or their prey and from observed incidence of disease, reproductive failure, or death in exposed wildlife. These are reviewed in EPA's field and laboratory reference and terrestrial indicators documents described above (EPA, 1989b, 1992). If this more direct approach is not possible, the exposure analysis can be refined on the basis of more site-specific data for the species of concern.

Wildlife can be exposed to environmental contaminants through inhalation, dermal contact with contaminated water or soil, or ingestion of contaminated food, water, or soil. Exposure assessment seeks to answer several questions, including:

- **What organisms are actually or potentially exposed to contaminants?**

- Which organisms or life stages might be most vulnerable to environmental contaminants (e.g., ingest the largest quantities of contaminated media relative to body size)?
- What are the significant routes of exposure?
- To what amounts of each contaminant are organisms actually or potentially exposed?
- How long is each exposure?
- How often does or will exposure to the environmental contaminants take place?
- What seasonal and climatic variations in conditions are likely to affect exposure?
- What are the site-specific geophysical, physical, and chemical conditions affecting exposure?

The parameters for which data are presented in the Handbook are intended to help a risk assessor answer these questions. The population parameter data (e.g., birth and death rates) may be useful for placing estimates of risks to wildlife populations in a broader ecological context and for planning monitoring activities.

This Handbook focuses on selected groups of mammals, birds, amphibians, and reptiles. Fish and aquatic or terrestrial invertebrates were not included in this effort. The profiles on amphibians and reptiles are, in general, less developed than those for birds and mammals. We emphasized birds and mammals because methods for assessing their exposure are more common and well developed. As more assessments are done for amphibians and reptiles, we anticipate that additional methods and supporting factors will be necessary. Until then, we hope the information presented here will encourage assessors to begin considering and quantifying their exposure.

For all exposure parameters and species in the Handbook, we try to present data indicative of the range of values that different populations of a species may assume across North America. For site-specific ecological risk assessments, it is important to note that the values for exposure factors presented in this Handbook may not accurately represent specific local populations. The species included in the Handbook have broad geographic ranges, and they may exhibit different values for many of the exposure factors in different portions of their range. Some species exhibit geographic variation in body size, survival, and reproduction. Breeding and migration also influence exposure. Site-specific values for these parameters can be determined more accurately using published studies of local populations and assistance from the U.S. Fish and Wildlife Service, state departments of fish and game, and organizations such as local Audubon Society chapters. In addition, The Nature Conservancy develops and maintains wildlife databases (including endangered species) in cooperation with all 50 states. Local information increases the certainty of a risk assessment. Thus, for site-specific assessments, we strongly recommend contacting local wildlife experts to determine the presence and characteristics of species of concern.

Finally, we do not intend to imply that risk assessments for wildlife should be restricted to the species described in this Handbook, or should always be conducted for these species. We emphasize that locally important or rare species not included in this Handbook may still be very important for site-specific risk assessments. To assist users who wish to evaluate other species, we list general references for birds, mammals, reptiles, and amphibians in North America. The Handbook also provides allometric equations to assist in extrapolating exposure factors (e.g., water ingestion rate, surface area) to closely related species on the basis of body size.

1.2. ORGANIZATION OF THE HANDBOOK

The Handbook is organized into four chapters. The remainder of this chapter provides an overview of the species and exposure factors included in the Handbook and discusses the literature search strategy used to identify factors. Chapter 2 presents exposure profiles for the selected species (described in greater detail below). Chapter 3 provides allometric models that may be used to estimate food and water ingestion rates, inhalation rates, surface areas, and metabolic rates for wildlife species on the basis of body size. Chapter 4 describes common equations used to estimate wildlife exposure to environmental contaminants. Included are methods for estimating diet-specific food ingestion rates on the basis of metabolic rate and for estimating exposure to chemicals in soil and sediment.

Chapter 2 is the core of the Handbook; it presents exposure profiles for selected birds (Section 2.1), mammals (Section 2.2), and reptiles and amphibians (Section 2.3), along with brief descriptions of their natural history. Each species profile includes an introduction to the species' general taxonomic group, qualitative description of the species, list of similar species, table of exposure factors, and reference list (which also covers that species' section in Volume II, the Appendix). The values included in the exposure factors tables are a subset of those we found in the literature and also include values that we estimated using the allometric equations presented in Chapter 3. We selected values for the tables in Chapter 2 based on a variety of factors including sample size, quantification of variability (e.g., standard deviations, standard errors, ranges), relevance of the measurement technique for exposure assessment, and coverage of habitats, subspecies, and the variability seen in the literature. A complete listing of the parameter values identified in our literature survey is provided in the Appendix. The Appendix also includes more details concerning sample size, methods, and qualifying information than the species profiles. Users are encouraged to consult the Appendix to select the most appropriate values for their particular assessment.

The remainder of this introductory chapter describes the species and exposure factors covered in the Handbook in greater detail. The literature search strategy is discussed in Section 1.6.

1.3. LIST OF SELECTED SPECIES

Wildlife species were selected for the Handbook to provide several types of coverage:

- Major taxonomic groups (major vertebrate groups, orders, and families);
- A range of diets (e.g., piscivore, probing insectivore) likely to result in contact with contaminated environmental media;

- A variety of habitat types (e.g., fields, marshes, woodlands, coastal areas); and
- Small to large body sizes.

Other attributes also were considered when selecting species for the Handbook, including:

- Species with wide geographic distribution within the United States (or replaced regionally by similar species);
- Species of concern to EPA or other regulatory agencies (managed by state or Federal agencies); and
- Species of societal significance (familiar or of concern to most people).

Tables 1-1, 1-2, and 1-3 list the birds, mammals, and reptiles and amphibians, respectively, included in the Handbook. The species are listed according to diet, general foraging habitat, and relative body size.

The species included in this Handbook were necessarily limited; *however, we do not recommend limiting wildlife exposure assessments to the species or similar species identified in the Handbook.* Instead, the Handbook should be used as a framework to guide development of exposure factors and assessments for species of concern in a risk assessment. Species selection criteria for site-specific risk assessments might include the following considerations:

- Species that play important roles in community structure or function (e.g., top predators or major herbivores);
- Diet, habitat preferences, and behaviors that make the species likely to contact the stressor;
- Species from different taxa that might exhibit different toxic effects from contaminants;
- Local species that are of concern to Federal and state regulatory agencies (e.g., endangered and threatened species);

Table 1-1. Characteristics of Selected Birds

Diet	General Foraging Habitat	Body Size	Selected Bird Species
Insectivore[a] probing/soil-dwelling invertebrates gleaning/insects	 woodlands, marshes marshes	 medium small	 American woodcock marsh wren
Herbivore gleaning/seeds grazing/shoots	 woodlands, fields and brush open fields	 medium large	 northern bobwhite Canada goose
Omnivore	open woodland, suburbs	small	American robin
Carnivore[b]	open fields, forest edge most open areas	medium medium	American kestrel red-tailed hawk
Carnivore/Piscivore/Scavenger small birds & mammals/fish/dead fish fish/invertebrates/small birds/garbage	 open water bodies Great Lakes and coastal	 large medium	 bald eagle herring gull
Piscivore[c]	most streams, rivers, small lakes most freshwater and saltwater bodies large water bodies	medium large large	belted kingfisher great blue heron osprey
Aquatic Insectivore[d] probing/soil-dwelling invertebrates diving/aquatic invertebrates	 most rivers and streams oceans and coastal areas	 small medium	 spotted sandpiper lesser scaup
Aquatic Herbivore/Insectivore	most wetlands, ponds	medium	mallard

[a]Includes consumption of insects, other arthropods, worms, and other terrestrial invertebrates.
[b]Includes consumption of terrestrial vertebrates and large invertebrates.
[c]Includes consumption of fish, amphibians, crustaceans, and other larger aquatic animals.
[d]Includes consumption of aquatic invertebrates and amphibian larvae by gleaning or probing.

Table 1-2. Characteristics of Selected Mammals

Diet	General Foraging Habitat	Body Size	Selected Mammal Species
Insectivore[a] gleaning/surface-dwelling invertebrates	most habitat types	small	short-tailed shrew
Herbivore gleaning/seeds grazing or browsing/shoots, roots, or leaves	most dry-land habitats grassy fields, marshes, bogs prairie grass communities most habitat types	small small small medium	deer mouse meadow vole prairie vole eastern cottontail
Omnivore	woodlands, suburbs mixed woodlands and open areas	medium medium	raccoon red fox
Carnivore[b]	most areas near water	medium	mink
Piscivore[c]	rivers coastal, estuaries, lakes	medium medium	river otter harbor seal
Aquatic Herbivore	most aquatic habitats	medium	muskrat

[a]Includes consumption of insects, other arthropods, worms, and other terrestrial invertebrates.
[b]Includes consumption of aquatic and terrestrial vertebrates and large invertebrates.
[c]Includes consumption of fish, amphibians, crustaceans, molluscs, and other large aquatic animals.

Table 1-3. Characteristics of Selected Reptiles and Amphibians

Adult Diet	General Foraging Habitat for Adults	Body Size	Selected Reptile or Amphibian Species
REPTILES			
Terrestrial Carnivore[a]	open woods, fields and brush	medium	racer
Aquatic Piscivore[b]	most types of water bodies	medium	northern water snake
Omnivore	open fields, forest edge, marshes most freshwater bodies	medium large	eastern box turtle snapping turtle
Aquatic Herbivore	most wetlands, ponds	medium	painted turtle
AMPHIBIANS			
Insectivore[c]	shallow freshwater bodies	small	green frog
Aquatic Piscivore/Insectivore[d]	lakes, ponds, bogs, streams small lakes, ponds, streams	medium small	bullfrog eastern newt

[a]Includes consumption of terrestrial vertebrates and invertebrates, insects, other arthropods, worms, and other terrestrial invertebrates.
[b]Includes consumption of fish, amphibians, and crustaceans.
[c]Includes consumption of insects, other arthropods, worms, and other terrestrial invertebrates.
[d]Includes consumption of fish, amphibians, crustaceans, molluscs, other aquatic animals, and terrestrial insects and other invertebrates.

- **Species of societal significance or concern (e.g., game species, familiar species); and**
- **Species that have been shown to be particularly sensitive to the stressor being addressed.**

When species of concern for a risk assessment include species for which data are presented in this Handbook, it can serve as a readily available source of data for screening-level exposure analyses.

1.4. LIST OF EXPOSURE FACTORS

Three routes of exposure may be of concern for wildlife in the vicinity of contaminated surface waters and terrestrial habitats: oral, inhalation, and dermal. Oral exposures might occur via ingestion of contaminated food (e.g., aquatic prey) or water or incidental ingestion of contaminated media (e.g., soils, sediments) during foraging or other activities. Inhalation of gases or particulates might be a significant route of exposure for some animals. Dermal exposures are likely to be most significant for burrowing mammals (i.e., via contact with contaminated soils) and animals that spend considerable amounts of time submerged in surface waters. This Handbook tabulates selected data for all three routes of exposure (Table 1-4), emphasizing oral exposures. It also provides quantitative information on population parameters and qualitative information related to seasonal activities, geographic ranges, habitats, and other life-history characteristics.

The exposure factors presented in the Handbook are conceptually separated into four types: normalizing factors (Section 1.4.1), contact rates (Section 1.4.2), population dynamics (Section 1.4.3), and seasonal activities (Section 1.4.4). Section 1.5 describes the format in which values for these exposure factors are presented in Chapter 2.

1.4.1. Normalizing Factors

Normalizing factors include body weight, growth rate, and metabolic rate, which are discussed in turn below.

Table 1-4. Wildlife Exposure Factors Included in the Handbook

Parameter Type	Exposure Route/ Factor Category	Factor
NORMALIZING FACTORS	Body Weight	body weight
		growth rate
	Metabolic Rate	metabolic rate
CONTACT RATES	Oral	food ingestion rate
		dietary composition
		water ingestion rate
		soil/sediment intake rate
	Inhalation	inhalation rate
	Dermal	surface area
POPULATION DYNAMICS	Distribution (by life stage and season)	social organization
		home range size
		population density
	Birth, Maturation, and Death Rates	annual fecundity
		age at sexual maturity
		annual mortality rates
		average longevity
SEASONAL ACTIVITIES	Timing of Activities (those that can modify habitat preferences and exposure)	mating season
		parturition/hatching
		molt/metamorphosis
		dispersal/migration/ hibernation

1.4.1.1. Body Weight

Body weights (in units of mass) are reported as fresh weight as might be obtained by weighing a live animal in the field. Several of the contact rate parameters are normalized to body weight. For example, both food and water ingestion rates are reported on a per body weight basis (e.g., gram of fresh food or water per gram of fresh body weight per day). Using empirical models, body weight data also were used to estimate contact rate parameters for which we could not find measured values.

Adult body weights are listed for all species. For birds, we also provide egg weight, weight at hatching, nestling or chick weights, and weight at fledging, when available, to assist risk assessors concerned with estimating exposures of embryos and young birds. For mammals, we also provide gestating female weight, birth weight, pup weights at various ages, weight at weaning, and weight at sexual maturity, when available, for a similar purpose. Finally, for reptiles and amphibians, we also provide egg weight, larval or juvenile weights with age, and weight at metamorphosis, if available and applicable. Body size for reptiles and amphibians is often reported as body length instead of body weight, so we also provide data on body length and the relationship between body length and body weight, when available.

1.4.1.2. Growth Rate

Young animals generally consume more food (per unit body weight) than adults because they grow and develop rapidly. Growth rates change as animals mature, whether expressed as absolute (g/day) or relative (percent body weight) terms. Weight gain is rapid after birth, but slows over time. Different types of animals exhibit different patterns of growth over time. Plots of body weight versus age for some animal groups are sigmoidal whereas others may approximate logistic functions or other shapes. As a result, investigators often report growth rates as various constants associated with particular mathematical models (e.g., Gompertz equation, von Bertalanffy equation; see Peters, 1983) that fit the growth pattern for a given species. Instead of presenting a variety of growth constants and models, however, we report growth rates for young animals, when available,

in grams per day for specific age groups. Growth rates also can be inferred from a series of juvenile body weights with age. These measures are included under body weight (see Section 1.4.1.1).

1.4.1.3. Metabolic Rate

Metabolic rate is reported on the basis of kilocalories per day normalized to body weight (e.g., kcal/kg-day). If metabolic rate was measured and reported on the basis of oxygen consumption only, we provide those values as liters O_2/kg-day. Normalized metabolic rates based on kilocalories can be used to estimate normalized food ingestion rates (see Section 4.1.2). Metabolic rates based on oxygen consumption can be used to estimate metabolic rates based on kilocalories for subsequent use in estimating food ingestion rates (see Section 3.6.3.1).

1.4.2. Contact Rate Factors

Table 1-5 summarizes the six contact rate factors included for the oral, inhalation, and dermal routes of exposure.

1.4.2.1. Oral Route

Three environmental media are the primary contributors to wildlife exposure by the oral route: food, water, and soils and sediments. Four contact rate exposure parameters related to these three exposure media are discussed below.

***1.4.2.1.1. Food ingestion rates*.** Food ingestion rates are expressed in this Handbook as grams of food (wet weight) per gram of body weight (wet weight) per day (g/g-day). Food ingestion rates can vary by age, size, and sex and by seasonal changes in ambient temperature, activity levels, reproductive activities, and the type of diet consumed. Food ingestion rates have not been measured for many wildlife species. Methods for estimating food ingestion rates on the basis of free-living (or field) metabolic rate, energy content of the diet, and assimilation efficiency are discussed in Section 4.1.2.

Table 1-5. Wildlife Contact Rate Exposure Factors

Exposure Route	Medium	Factor	Expression	Units
ORAL	Food	ingestion rate	fraction body weight	6 g/g-day
		dietary composition	fraction of total intake represented by each food type	
	Water	ingestion rate	fraction body weight	g/g-day
	Soil/Sediment	intake rate	fraction of total food intake	g/g-day
INHALATION	Vapor or Particulates	inhalation rate	daily volume	m^3/day
DERMAL	Water or Soil/Sediment	surface area	total area potentially exposed[a]	cm^2

[a]Total unprotected or permeable surface area that might be exposed under some circumstances (e.g., dust bathing), even though it would not be exposed under other conditions (e.g., swimming with a trapped air layer between the feathers or fur and skin).

1.4.2.1.2. Dietary composition. Dietary composition varies seasonally and by age, size, reproductive status, and habitat. Dietary composition (e.g., proportion of diet consisting of various plant or animal materials), often measured by stomach-content analyses, is expressed whenever possible as percentage of total intake on a wet-weight basis. This convention facilitates comparison with contaminant concentrations in dietary items reported on a wet-weight basis. Methods for converting other measures of dietary composition (e.g., percentage of total prey items captured, proportion of intake on a dry-weight basis) to estimates of dietary intake on a wet-weight basis are provided in Section 4.1.2.

1.4.2.1.3. Water ingestion rates. For drinking-water exposures, ingestion rates are expressed in this Handbook as grams of water per gram of wet body weight per day (g/g-day). Water consumption rates depend on body weight, physiological adaptations,

diet, temperature, and activity levels. It is important to remember that, under some conditions, some species can meet their water requirements with only the water contained in the diet and metabolic water production (see Section 3.2).

1.4.2.1.4. Incidental soil and sediment intakes. **Wildlife can incidentally ingest soils or sediments while foraging or during other activities such as dust bathing and preening or grooming. Data quantifying soil and sediment ingestion are limited; we present available values for selected species in Section 4.1.3.**

1.4.2.2. Inhalation Route

Average daily inhalation rates are reported in the Handbook in units of m^3/day. Inhalation rates vary with size, seasonal activity levels, ambient temperature, and daily activities. EPA's current approach to calculating inhalation exposures requires additional information on species' respiratory physiology to fully estimate inhalation exposures (see Section 4.1.4).

1.4.2.3. Dermal Route

Dermal contact with contaminated soil, sediment, or water is likely to be an exposure pathway for some wildlife species. An animal's surface area could be used to estimate the potential for uptake of contaminants through its skin. For some exposures (e.g., dust bathing), the entire surface area of the animal might be important. For other types (e.g., swimming), only the uninsulated portions (e.g., no fur or feathers that create a trapped air layer) of the animal might contact the contaminated medium. In the Handbook, we provide measures or estimates of the entire potentially exposed surface area of an animal, when possible. We have not attempted to determine what portions would be exposed and protected for swimming animals.

1.4.3. Population Dynamics

Several parameters can be used to describe the spatial distribution and abundance of a population of animals in relation to the spatial extent of contamination. Three parameters related to spatial distribution are social organization, home-range size, and population density. These are important for estimating the number of individuals or proportion of a population that might be exposed to a contaminated area. Parameters related to population size and persistence include age at sexual maturity and maturation, mortality, and annual fecundity rates. These parameters may be useful to assessors planning or evaluating field studies or monitoring programs.

1.4.3.1. Social Organization

The Handbook includes a qualitative description of each species' social organization, which influences how animals of various ages and sizes are distributed in space. In some species, individual home ranges do not overlap. In others, all individuals use the same home range. In between these extremes, home ranges can be shared with mates, offspring, or extended family groups.

Social organization can vary substantially among species that appear otherwise similar; therefore, it is not possible to extrapolate the social organization of similar species from the selected species in this Handbook. Consult the general bibliographies for information sources to determine the social organization of species not covered in the Handbook.

1.4.3.2. Home Range/Territory Size/Foraging Radius

Home range size can be used to determine the proportion of time that an individual animal is expected to contact contaminated environmental media. Home range is defined as the geographic area encompassed by an animal's activities (except migration) over a specified time. While home range values often are expressed in units of area, for species dependent on riparian or coastal habitats, a more meaningful measure can be foraging

radius, or the distances the animals are willing to travel to potential food sources. Although home ranges may be roughly circular in homogeneous habitats, it is important to remember that depending on habitat needs and conditions, home ranges may be irregular in shape. The size and spatial attributes of a home range often are defined by foraging activities, but also might depend on the location of specific resources such as dens or nest sites in other areas. An animal might not visit all areas of its home range every day or even every week, but over longer time periods, it can be expected to visit most of the areas within the home range that contain needed resources such as forage, prey, or protected resting areas.

Home range size for individuals within a population can vary with season, latitude, or altitude as a consequence of changes in the distribution and abundance of food or other resources. It generally varies with animal body size and age because of differences in the distribution of preferred forage or prey. It can also depend on habitat quality, increasing as habitat quality decreases to a condition beyond which the habitat does not sustain even sparse populations. Finally, home ranges can vary by sex and season. For example, if a female is responsible for most or all of the feeding of young, her foraging range might be restricted to an area close to her nest or den when she has dependent young, whereas the foraging range of males would not be so restricted.

Nonterritorial species may allow significant overlap of activity areas among neighboring individuals or groups. For example, several individuals or mated pairs may share the same area, although signalling behaviors may ensure temporal segregation. For these species, we report a home range size or foraging radius. Other species are strongly territorial and defend mutually exclusive areas: individuals, breeding pairs, or family units actively advertise identifiable boundaries and exclude neighboring individuals or groups. Foraging activities are usually restricted to the defended territories. For these species, we report the size of the defended territory and note whether foraging occurs outside of the territory.

1.4.3.3. Population Density

Population density (the number of animals per unit area) influences how many individuals (or what proportion of a local population) might be exposed within a contaminated area. For strongly territorial species, population density can be inferred from territory size in many cases. For species with overlapping home ranges, particularly colonially breeding animals (e.g., most seabirds), population density cannot be inferred from home range size.

1.4.3.4. Annual Fecundity

Attributes related to the number of offspring produced each year that reach sexual maturity (annual fecundity) are measured in different ways depending on the life history of the species. For birds, data are generally available for clutch size, number of clutches per year, nest success (generally reflecting predation pressure), number of young fledged per successful nest (generally reflecting food availability), and number of young fledged per active nest (reflecting all causes of mortality). For mammals, litter size in wild populations often is determined by placental scars or embryo counts, and the number of young surviving to weaning is seldom known. For reptiles that lay eggs, clutch size and percent hatching can be measured in the field. For viviparous reptiles, we report the number born in a litter. For amphibians, egg masses may include thousands of eggs, but these are seldom counted.

1.4.3.5. Annual Mortality and Longevity

Longevity can influence the potential for cumulative deleterious effects and the appropriate averaging times for chronic exposures. For birds, annual adult mortality tends to be constant. For large mammalian species, however, annual adult mortality tends to be constant for several years, and then increases rapidly with age. For reptiles and amphibians, annual adult mortality can decrease with age for some time as the animals continue to grow larger and become less susceptible to predation. In the Handbook, we

report annual mortality rates by age category and typical or mean and maximum longevities, when possible.

1.4.4. Seasonal Activities

Many life-cycle attributes affect an animal's activity and foraging patterns in time and space. For example, many species of birds are present in the northern hemisphere only during the warmer months or move seasonally between the northern and southern parts of North America. Some species of mammals, reptiles, and amphibians hibernate or spend a dormant period in a burrow or den during the winter months. The species profiles describe these and other seasonal activity patterns that can influence exposure frequency and duration.

For each species, we summarize information on the seasonal occurrence of several activities including breeding, molting, migration, dispersal, and occurrence of dormancy/denning (if applicable). Deposition and utilization of fat reserves are discussed where information is available. Trends in these factors with latitude are identified.

1.5. DATA PRESENTATION FORMAT

Species-specific values for the exposure factors are presented in Chapter 2. Quantitative data for each species are presented in tables arranged in four main sections:

- Normalizing and Contact Rate Factors;
- Dietary Composition;
- Population Dynamics; and
- Seasonal Activities.

The parameter values and units used for each exposure factor are described in the remainder of this section. In the species profiles and in the Appendix, all values are identified as measured or estimated, and references are provided.

1.5.1. Normalizing and Contact Rate Factors

Normalizing and contact rate factors are presented under the heading "Factors" in Chapter 2. Several of them apply to all animals included in the Handbook, whereas some apply only to specific groups, as described in Sections 1.5.1.1 through 1.5.1.4. The column headers for these factors are explained in Table 1-6.

Table 1-6. Column Headers for Tables of Normalizing and Contact Rate Factors

Age/Sex/ Cond./Seas.	**Age (e.g., A for adult, J for juvenile) Sex (e.g., M for male, F for female) Condition (e.g., I for incubating, NB for nonbreeding) Season (e.g., SP for spring, SU for summer). [Note: Only information needed to correctly interpret the value is included.]**
Mean	**Mean value for population sampled ± standard deviation (SD), if reported. If SD is not reported, mean value for population sampled ± standard error (SE) of the mean, if reported. For some studies, a range of typical values may be presented instead of a mean value (check the notes).**
Range or (95% CI of Mean)	**Range of values reported for the population sampled, or (95th percent confidence interval of the mean value).**
Location (subspecies)	**State(s) or province(s) in which the study was conducted (subspecies studied, if reported).**
Reference	**Reference for study.**
Note No.	**Footnote number.**

1.5.1.1. All Animals

Body weight (grams or kilograms)	**Measured values only. Although we use the term weight, all data are presented in units of mass. The age and sex of the animal are specified as appropriate, and**

	weights may include age-weight series for young animals.
Metabolic rate (liters O_2/kg-day)	Included only if measured values were available. These data can be used to estimate metabolic rate on a kcal basis.
Metabolic rate (kcal/kg-day)	Measured or estimated basal and free-living (or field) metabolic rates. Most of the free-living values were estimated from body weight using an appropriate allometric equation.
Food ingestion rate (g/g-day)	Measured on a wet-weight basis. For birds and mammals, values measured in captivity are generally lower than for free-ranging animals. For reptiles and amphibians, food ingestion rates can be higher in captivity than in the field. Food ingestion rates can also be different in captivity than in the wild if the diet differs substantially from that consumed in the wild (e.g., dry laboratory chow has a substantially lower water content than most natural diets).
Water ingestion rate (g/g-day)	Most of these values were estimated from body weight using an allometric equation.
Sediment/soil ingestion rate	These values are not presented in the individual species profiles in Chapter 2; instead, the limited data available for soil/sediment ingestion rates (as percent soil or sediment in diet on a dry weight basis) for selected species are presented in Section 4.1.3.
Inhalation rate (m^3/day)	Note that this value is not normalized to body weight, but is the total volume inhaled each day. Most values were estimated from body weight using an appropriate allometric equation.
Surface area (cm^2)	Most values were estimated from body weight using an appropriate allometric equation.

1.5.1.2. Birds

Egg weight (grams)	Included only if measured values were available.
Weight at hatching (grams)	Included only if measured values were available.

Chick or nestling growth rate (g/day)	Included only if measured values were available. The ages to which the growth rate applies are indicated.
Weight at fledging (grams)	Included only if measured values were available.

1.5.1.3. Mammals

Neonate weight (grams)	Included only if measured values were available.
Pup growth rate (g/day)	Included only if measured values were available. The ages to which the growth rate applies are indicated.
Weight at weaning (grams)	Included only if measured values were available.

1.5.1.4. Reptiles and Amphibians

Body length (mm)	Length is the most common measure of size and growth rate reported for reptiles and amphibians. Body length-weight relationships are reported whenever possible. Data for snakes include snout-to-vent lengths (SVL) and total lengths; for frogs, SVLs only; and for turtles, carapace (dorsal shell) and plastron (ventral shell) lengths.
Egg weight (grams)	Included only if measured values were available.
Weight at hatching (grams)	Included only if measured values were available.
Juvenile growth rate (g/day)	Included only if measured values were available. The ages to which the growth rate applies are indicated.
Tadpole weight (grams)	For frogs only; included only if measured values were available.
Larval or eft weight (grams)	For newts only; included only if measured values were available.

1.5.2. Dietary Composition

1.5.2.1. All Animals

The diet of all animals is separated by season whenever possible. Up to three months of data were combined for each of the four seasons, provided the animals were in the same location and habitat during the 3-month period (Table 1-7). The diet components are listed in the first column shaded in grey. The measure of dietary composition is enclosed in parentheses under the "Location (subspecies)/Habitat (measure)" column header.

Table 1-7. Column Headers for Tables on Dietary Composition

Dietary Composition	List of food types.
Spring	Dietary composition during spring (March, April, May).
Summer	Dietary composition during summer (June, July, August).
Fall	Dietary composition during fall (September, October, November).
Winter	Dietary composition during winter (December, January, February).
Location (subspecies)/ Habitat (measure)	State(s) or Canadian province(s) in which study was conducted (subspecies studied, if reported). Type of habitat associated with the reported values (measure used to quantify dietary composition).
Reference	Reference for study.
Note No.	Footnote number.

Dietary composition can be expressed in many ways. In the Appendix, we have presented all measures of dietary composition encountered in the literature review. In the species profiles in Chapter 2, we have emphasized dietary composition measured as the percentage of the total food intake of each food type on a wet-weight basis. These data

are usually determined by analysis of stomach or other digestive tract contents. For entries based on these measures, the total of the values listed under each seasonal column should approximate 100 percent. As Chapter 4 indicates, it is relatively simple to estimate contaminant intakes when dietary composition is measured on a wet-weight basis. Dietary composition may also be measured on a dry-weight basis; information on the relative water content of the different dietary items provided in Chapter 4 can be used to convert dry-weight composition to wet-weight composition if needed. Dietary composition is often reported as frequency of occurrence in digestive tract contents, scats, or regurgitated pellets. For these measures, the total of the values in the seasonal columns can exceed 100 (e.g., fish occurred in 90 percent of scats, amphibia in 75 percent of scats, and molluscs in 15 percent of scats). We do not provide guidance on how to estimate contaminant intakes based on these measures; however, studies using these measures can indicate seasonal and geographic differences in diet.

1.5.3. Population Dynamics

Distribution and mortality parameters can be defined similarly for birds, mammals, reptiles, and amphibians (Section 1.5.3.1). Reproductive parameters, however, differ among these groups (Sections 1.5.3.2 through 1.5.3.5). The column headers for population dynamics are described in Table 1-8.

1.5.3.1. All Animals

Home range size (ha)/ Territory size (ha)/ Foraging radius (m)	**Area usually listed in hectares, radius in kilometers. The home range for species such as mink or kingfishers, which spend most of their time along shoreline areas, is sometimes described as kilometers of shoreline. For some species with extremely small breeding territories, we used m^2 instead of hectares. For colonially nesting birds, foraging radii are listed in kilometers. For frogs, we found information only on male breeding territory size, which does not include the foraging range of either sex.**
Population density (N/ha)	**Usually listed as number (N) of individuals per hectare, although numbers of breeding pairs or nests per hectare are used for some species.**

Table 1-8. Column Headers for Tables of Factors for Population Dynamics

Age/Sex/ Cond./Seas.	**Age (e.g., A for adult, J for juvenile) Sex (e.g., M for male, F for female) Condition (e.g., I for incubating, NB for nonbreeding) Season (e.g., SP for spring, SU for summer). [Note: Only information needed to correctly interpret the value is included.]**
Mean	**Mean value for population sampled ± standard deviation (SD), if reported. If SD is not reported, mean value for population sampled ± standard error (SE) of the mean, if reported. For some studies, a range of typical values may be presented instead of a mean.**
Range	**Range of values reported for the population sampled.**
Location (subspecies)/ Habitat	**State(s) or province(s) in which the study was conducted (subspecies studied, if reported). Type of habitat associated with the reported values.**
Reference	**Reference for study.**
Note No.	**Footnote number.**

Age at sexual maturity — **Age at which first successful reproduction occurs. In many long-lived species, only a portion of the population breeds at this age.**

Annual mortality rates — **Usually listed as percent per year. Can vary with age and sex of the animal.**

Longevity — **Mean longevity of adult members of the population (does not include juvenile mortality). When available, an estimate of maximum longevity is also provided (usually from studies of captive individuals).**

1.5.3.2. Birds

Clutch size — **Number of eggs laid per active nest (usually the number laid per female, but in some species, more than one female may lay in a single nest).**

Clutches per year	**Number of successful clutches laid per year. Additional clutches may be laid if a clutch is lost early in incubation.**
Days incubation	**Measured from day incubation starts (often after laying of last egg) to hatching.**
Age at fledging	**Age at which young can maintain sustained flight. Parents usually continue to feed or to accompany young for some time after fledging.**
Number fledged per active nest	**Number fledged for each nest for which incubation was initiated.**
Percent nests successful	**Percent of active nests hatching eggs.**
Number fledged per successful nest	**Number fledged for each nest for which at least one young hatched.**

1.5.3.3. Mammals

Litter size	**Based on embryo counts whenever possible. Use of placental scars can result in overestimation of litter size and counts of live pups in dens can result in underestimation of litter size.**
Litters per year	**Number of litters born each year.**
Days gestation	**Days of active gestation. For species with delayed implantation, this period can be substantially shorter than the period from mating to birth.**
Pup growth rate	**Usually reported as grams per day during a specified age interval. May be reported instead as a series of weights for pups of specified ages.**
Age at weaning	**Age when the pups begin to leave the nest or den to actively feed for most of their food.**

1.5.3.4. Reptiles and Amphibians

Clutch or litter size	**Number of eggs laid per female for egg-laying species; number of live offspring born for species bearing live young (e.g., water snake). Reported by age and size of the female when appropriate.**

Clutches or litters per year	**Number of clutches or litters produced each year. Not limited to successful clutches because there is no parental care in most temperate species.**
Days incubation	**Measured from laying of last egg to hatching. The duration of incubation depends on the temperature of the substrate into which eggs are laid.**
Juvenile growth rate	**Usually reported as grams per day during a specified age (or size) interval. May be reported instead as a series of weights for juveniles of specified sizes if those are the only data available.**
Length at sexual maturity	**Length at which the first successful reproduction usually occurs (see above). More commonly reported than weight or age at sexual maturity.**

1.5.4. Seasonal Activities

The meaning of most of the factors included under seasonal activities are self-evident. Those requiring additional explanation are described in Sections 1.5.4.1 through 1.5.4.3. The column headers for this section of the table are shown in Table 1-9.

Table 1-9. Column Headers for Tables on Seasonal Activities

Begin	**Month that the activity usually begins.**
Peak	**Month(s) that the activity peaks (most of the population is involved).**
End	**Month that the activity usually ends.**
Location (subspecies)	**State(s) or province(s) in which the study was conducted (subspecies studied, if reported).**
Reference	**Reference for study.**
Note No.	**Footnote number.**

1.5.4.1. Birds

Mating/laying	**These two factors are combined because birds lay eggs within a day or two of mating (they begin mating a day or two prior to laying the first egg).**

1.5.4.2. Mammals

Mating	**Although for most mammals the mating season corresponds to conception and is followed immediately by gestation, some species exhibit delayed implantation.**
Parturition	**Birth of the pups (also known as whelping for canids).**

1.5.4.3. Reptiles and Amphibians

Mating	**Because fertilization is external for many amphibians (i.e., most toads and frogs and some salamanders), mating occurs at the same time as egg-laying for these species. For reptiles, fertilization is internal, and for some species, sperm may be stored for months or years following mating.**
Nesting	**Because many female reptiles can store sperm, nesting (i.e., egg-laying) often occurs weeks or months after mating.**

1.5.5. Abbreviations Used in Tables

Age (life stage)

A	**adult (for all groups)**
B	**both adults and juveniles/yearlings (for all groups)**
C	**chick (for birds)**
E	**eft (for newts)**
F	**fledgling (for birds)**
H	**hatchling (for birds, reptiles, and amphibians)**
J	**juvenile (for all groups)**
N	**nestling (for birds) or neonate (for mammals, water snakes)**
P	**pup (for mammals)**
T	**tadpole (for frogs)**
Y	**yearling (for all groups)**

Sex

B	both sexes
F	female
M	male

Units

time:		energy:		
d	day		cal	calorie
wk	week		kcal	kilocalorie
yr	year			
mass:		area:		
g	gram		ha	hectare
kg	kilogram		m^2	square meter
length:		volume:		
mm	millimeter		ml	milliliter
cm	centimeter		l	liter
m	meter			
km	kilometer			
temperature:				
°C	degrees Centigrade			

Other

NS	not stated

1.6. LITERATURE SEARCH STRATEGY

The profiles in this Handbook are intended to provide a readily available compendium of representative data for each selected species to assist in conducting screening-level exposure assessments. They are not intended to provide complete reviews of all available published and unpublished information or indepth biological summaries. Moreover, the Handbook is not intended to replace field guides or natural history or animal physiology texts. We have attempted to balance generalities, accuracy, and coverage of each species relative to the available literature to meet our stated purposes. We describe the process by which we identified literature for the Handbook below.

The U.S. Fish and Wildlife Service (USFWS) Office of Information Transfer conducted the primary literature search for species-specific information using their Wildlife Review/Fisheries Review database. The database is compiled by USFWS personnel from a review of over 1,130 publication sources (largely journals, but also USFWS publications) from the United States and other countries, most dating back to 1971. The search was conducted in May 1990 using common and scientific species names, but no further restrictions on search terms were applied. All titles identified for each species were reviewed to determine potential utility for the Handbook, and promising references were reviewed in full. Recent review articles, handbooks, and natural history texts were used to identify other relevant literature and literature from before 1971. Commercial databases were not searched initially. Following peer review of the Handbook in 1991 and 1992, all references submitted or identified by peer reviewers were evaluated, and additional relevant citations were obtained for review. Limited (1970 forward) literature searches for some species were conducted using commercial databases in 1992.

For information concerning physiology, allometric equations, energetics, and other general topics, literature was identified on the basis of recent review articles or books in the field suggested by experts in the field and by peer reviewers.

Because of resource limitations, we have included some values from secondary citations. In these cases, our intent was to carefully record the original source and to clearly indicate from which secondary source it was obtained. Users are encouraged to obtain the primary sources to verify these values.

We used certain field guides consistently throughout each taxonomic category to provide greater comparability of general species characteristics. The use of a specific field guide does not constitute endorsement.

Because our literature search strategy may not have included all journals of interest and did not consistently cover other sources of information (e.g., books, theses, dissertations, state wildlife reports, conference proceedings), we would appreciate any assistance that users might provide in identifying additional sources of information that

would help to fill data gaps or to improve the information in the Handbook. In particular, Ph.D. dissertations and master's theses often contain relevant but unpublished information.

1.7. REFERENCES

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U.S. Environmental Protection Agency. (1989b) Ecological assessment of hazardous waste sites: a field and laboratory reference. Corvallis, OR: Environmental Research Laboratory; EPA report no. EPA/600/3-89/013.

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2. EXPOSURE FACTORS AND DESCRIPTIONS OF SELECTED SPECIES

Chapter 2 includes exposure profiles for the selected species in three subsections: birds (Section 2.1), mammals (Section 2.2), and reptiles and amphibians (Section 2.3). Each species profile follows the same format, beginning with an introduction to the taxonomic group to which the species belongs and a qualitative description of relevant aspects of the species' natural history. Next, a list of similar species is provided to help identify species that might share certain exposure characteristics, although they may have different geographic ranges, diets, and habitat preferences. Each species profile then presents a series of tables presenting values for normalizing and contact rate factors, dietary composition, population dynamics, and seasonal activity patterns that represent the range of values that we identified in our literature review. Table format is described in Section 1.5. Data on soil and sediment ingestion are limited; we present these data in a separate section (4.1.3) for easy comparison among species. Finally, each profile includes the references cited in the species profile and in the corresponding Appendix tables.

2.1. BIRDS

Table 2-1 lists the bird species described in this section. For range maps, refer to the general references identified in individual species profiles. The remainder of this section is organized by species in the order presented in Table 2-1. The availability of published information varies substantially among species, as is reflected in the profiles. Some species include two or more subspecies; these are indicated in the profiles when reported by the investigators. For many studies, the subspecies, although not identified, can be inferred from the study location and geographic range of the subspecies. Average lengths of birds are reported from museum study skins measured from bill tip to tail tip. Body weight is reported as fresh wet weight with plumage, unless otherwise noted.

Table 2-1. Birds Included in the Handbook

Order Family	Common name	Scientific name	Section
Ciconiformes			
Ardeidae	great blue heron	*Ardea herodias*	2.1.1
Anseriformes			
Anatidae	Canada goose	*Branta canadensis*	2.1.2
	mallard	*Anas platyrhynchos*	2.1.3
	lesser scaup	*Aythya affinis*	2.1.4
Falconiformes			
Accipitridae	osprey	*Pandion haliaetus*	2.1.5
	red-tailed hawk	*Buteo jamaicensis*	2.1.6
	bald eagle	*Haliaeetus leucocephalus*	2.1.7
Falconidae	American kestrel	*Falco sparverius*	2.1.8
Galliformes			
Phasianidae	northern bobwhite	*Colinus virginianus*	2.1.9
Charadriiformes			
Scolopacidae	American woodcock	*Scolopax minor*	2.1.10
	spotted sandpiper	*Actitis macularia*	2.1.11
Laridae	herring gull	*Larus argentatus*	2.1.12
Coraciiformes			
Alcedinidae	belted kingfisher	*Ceryle alcyon*	2.1.13
Passeriformes			
Troglodytidae	marsh wren	*Cistothorus palustris*	2.1.14
Muscicapidae	American robin	*Turdus migratorius*	2.1.15

2.1.1. Great Blue Heron (herons)

<u>Order *Ciconiiformes*, Family *Ardeidae*</u>. Herons, egrets, and bitterns are medium to large wading birds with long necks and spear-like bills. Nearly all species feed primarily on aquatic animal life (e.g., fish, frogs, crayfish, insects) and are common along the margins of most freshwater and saltwater bodies and wetlands (Kushlan, 1978). Their long legs, necks, and bills are adapted for wading in shallow water and stabbing prey. Most species build their nests in trees near their foraging habitat, and many nest colonially. Members of this group range in size from the least bittern (28 to 36 cm bill tip to tail tip) to the great blue heron (106 to 132 cm tall). The sexes are similar in size and appearance.

Selected species

The great blue heron (*Ardea herodias*) is the largest member of the group in North America and feeds primarily on aquatic animals. It is widely distributed in both saltwater and freshwater environments. There are four subspecies in the United States and Canada: *A. h. wardi* (Kansas and Oklahoma across the Mississippi River to Florida), *A. h. herodias* (remainder of the North and Central American range), *A. h. fannini* (Pacific coast of North America from Alaska to Washington), and *A. h. occidentalis* (extreme south of Florida) (Bancroft, 1969, cited in Hancock and Kushlan, 1984). *A. h. occidentalis* (the great white heron) is an all white color morph that was formerly considered a separate species (National Geographic Society, 1987).

***Body size*. Males average slightly heavier in weight than females (Hartman, 1961; Palmer, 1962). Northern continental herons are somewhat smaller than those found in the south (Palmer, 1962). Quinney (1982) determined a relationship between age and body weight for nestling great blue herons (r = 0.996, N = 16 nestlings, and 274 measurements):**

$$BW = 55.6 \times A - 47.4$$

where BW equals body weight in grams and A equals age in days.

***Habitat*. Great blue herons inhabit a variety of freshwater and marine areas, including freshwater lakes and rivers, brackish marshes, lagoons, mangroves, and coastal wetlands, particularly where small fish are plentiful in shallow areas (Spendelow and Patton, 1988; Short and Cooper, 1985). They are often seen on tidal flats and sandbars and occasionally forage in wet meadows, pastures, and other terrestrial habitats (Palmer, 1962). Great blue herons tend to nest in dense colonies, or heronries. The location of the heronry is generally close to foraging grounds, and tall trees are preferred over shorter trees or bushes for nest sites (Bent, 1926; Palmer, 1962; Gibbs et al., 1987). They also may nest on the ground, on rock ledges, or on sea cliffs (Palmer, 1962).**

***Food habits*. Fish are the preferred prey, but great blues also eat amphibians, reptiles, crustaceans, insects, birds, and mammals (Alexander, 1977; Bent, 1926; Hoffman, 1978; Kirkpatrick, 1940; Peifer, 1979). When fishing, they mainly use two foraging techniques: standing still and waiting for fish to swim within striking distance or**

slow wading to catch more sedentary prey (such as flounder and sculpin) (Bent, 1926; Willard, 1977). To fish, they require shallow waters (up to 0.5 m) with a firm substrate (Short and Cooper, 1985). Fish up to about 20 cm in length were dominant in the diet of herons foraging in southwestern Lake Erie (Hoffman, 1978), and 95 percent of fish consumed by great blues in a Wisconsin population were less than 25 cm in length (Kirkpatrick, 1940). Great blues sometimes forage in wet meadows and pastures in pursuit of lizards, small mammals, and large insects (Palmer, 1962; Peifer, 1979). In northern areas, small mammals such as meadow voles may be an important part of the diet early in the breeding season, possibly because some aquatic foraging areas may still be partially frozen when the herons arrive (Collazo, 1985). Consumption of larger prey (fish, frogs, rodents) is often followed by drinks of water (Hedeen, 1967); terrestrial prey such as voles are usually dunked in water before they are swallowed (Peifer, 1979). Adult herons tend to deliver the same type and size of food to their nestlings that they consume themselves, but they deliver it well digested for young nestlings and less well digested as the nestlings grow (Kushlan, 1978). Adults tend to feed solitarily, although they may feed in single or mixed species flocks where there are large concentrations of prey (Bayer, 1978; Krebs, 1974; Kushlan, 1978; Willard, 1977); fledglings are frequently seen foraging together (Dowd and Flake, 1985). Kushlan (1978) developed a regression equation relating the amount of food ingested per day to body weight for wading birds (N = seven species):

$$\log(FI) = 0.966 \log(BW) - 0.640$$

where FI equals food ingestion in grams per day and BW equals body weight in grams.

***Molt*. Adults undergo a complete molt in the late summer and fall and a partial molt of the contour feathers in the late winter and early spring (Bent, 1926). Young herons attain full adult plumage in the summer/fall molt at the end of their second year (Bent, 1926).**

***Migration*. In the northern part of its range, most great blues are migratory, some moving to the southern Atlantic and Gulf States to overwinter with the resident populations of herons (Bent, 1926; Palmer, 1962), others continuing on to Cuba and Central and South America (Hancock and Kushlan, 1984). Most migrating herons leave their breeding grounds by October or November and return between February and April (Bent, 1926).**

***Breeding activities and social organization*. The male great blue heron selects the site for the breeding territory, and nests generally consist of a stick platform over 1 m in diameter (Palmer, 1962). Great blues often use a nest for more than 1 year, expanding it with each use (Palmer, 1962). Mean clutch sizes range from three to five (see table); in general, clutch size tends to increase with latitude (Pratt, 1972). Only one brood is raised per year; however, if a clutch is destroyed, great blues may lay a replacement clutch, usually with fewer eggs than the initial clutch (Palmer, 1962; Pratt and Winkler, 1985). Both parents incubate and feed the young (Palmer, 1962; Hancock and Kushlan, 1984). During the breeding season, great blues are monogamous and colonial, with from a few to hundreds of pairs nesting in the same area or heronry (Gibbs et al., 1987). Colonies may**

include other species, such as great egrets or double-crested cormorants (Pratt and Winkler, 1985; Mock et al., 1987).

***Home range and resources*. Breeding colonies are generally close to foraging grounds (Bent, 1926; Palmer, 1962; Gibbs et al., 1987). Mathisen and Richards (1978) found the distance between heronries and possible feeding areas in Minnesota lakes to range from 0 to 4.2 km, averaging 1.8 km. Another study found that most heronries along the North Carolina coast were located near inlets with large concentrations of fish, an average of 7 to 8 km away (Parnell and Soots, 1978, cited in Short and Cooper, 1985). Fifteen to 20 km is the farthest great blue herons regularly travel between foraging areas and colonies (Gibbs et al., 1987; Gibbs, 1991; Peifer, 1979). In the northern portion of their range, great blue herons often build nests in tall trees over dry land, whereas in the southern part of their range, they usually nest in swamp trees, including mangroves (Palmer, 1962). Each breeding pair defends a small territory around the nest, the size of which depends on local habitat and the birds' stage of reproduction (Hancock and Kushlan, 1984). Herons in some areas also defend feeding territories (Peifer, 1979). In other areas, great blues appear to be opportunistic foragers, lacking strict fidelity to particular feeding sites (Dowd and Flake, 1985). A study in North Dakota found that herons often returned to the same general areas, but different individuals often used the same areas at different times (Dowd and Flake, 1985).**

***Population density*. Because great blues nest colonially, local population density (i.e., colony density, colony size, and number of colonies) varies with the availability of suitable nesting habitat as well as foraging habitat. On islands in coastal Maine, Gibbs and others (1987) found a significant correlation between colony size and the area of tidal and intertidal wetlands within 20 km of the colonies, which was the longest distance herons in the study colonies traveled on foraging trips. In western Oregon, the size of heronries was found to range from 32 to 161 active nests; the area enclosed by peripheral nest trees within the colonies ranged from 0.08 to 1.21 ha (Werschkul et al., 1977).**

***Population dynamics*. Most nestling loss is a result of starvation, although some losses to predation do occur (Collazo, 1981; Hancock and Kushlan, 1984). In a study of 243 nests in a coastal California colony, 65 percent of the chicks fledged, 20 percent starved, 7 percent were taken by predators, and 7 percent were lost to other causes (Pratt and Winkler, 1985). Estimates of the number of young fledged each year by breeding pairs range from 0.85 to 3.1 (Pratt, 1970; Pratt, 1972; McAloney, 1973; Pratt and Winkler, 1985; Quinney, 1982). Based on banding studies, about two-thirds of the fledglings do not survive more than 1 year, although they may survive better in protected wildlife refuges (Bayer, 1981a). Values for later years indicate that about one-third to one-fifth of the 2-year-old and older birds are lost each year (Bayer, 1981a; Henny, 1972; Owen, 1959).**

Similar species (from general references)

- **The great egret (*Casmerodius albus*) is almost the same size (96 cm length) as the great blue heron and is found over a limited range in the breeding season, including areas in the central and eastern United States and the east and west coasts. It winters in coastal areas of the United States and in**

Mexico and farther south. The great egret's habitat preferences are similar to those of the great blue heron.

- The snowy egret (*Egretta thula*), one of the medium-sized herons (51 to 69 cm), shuffles its feet to stir up benthic aquatic prey. It is found mostly in freshwater and saltwater marshes but also sometimes follows cattle and other livestock as does the cattle egret. It breeds in parts of the western, southeastern, and east coasts of the United States and winters along both coasts of the southern United States and farther south.

- The cattle egret (*Bubulcus ibis*) is seen in agricultural pastures and fields, where it follows livestock to pick up insects disturbed by grazing. An Old World species, it was introduced into South America and reached Florida in the 1950's. It reached California by the 1960's and has been continuing to expand its range.

- The green-backed heron (*Butorides striatus*), one of the smaller herons (41 to 56 cm), breeds over most of the United States except for the northwest and southern midwest. It has a winter range similar to that of the snowy egret and seems to prefer water bodies with woodland cover.

- The tricolored heron (*Egretta tricolor*) (formerly known as the Louisiana heron) is common in salt marshes and mangrove swamps of the east and gulf coasts, but it is rare inland.

- The little blue heron (*Egretta caerulea*) is common in freshwater ponds, lakes, and marshes and coastal saltwater wetlands of the Gulf Coast States. Juveniles are easily confused with juvenile snowy egrets. This species hunts by walking slowly in shallow waters, and its diet typically includes fish, amphibians, crayfish, and insects.

- The black-crowned night heron (*Nycticorax nycticorax*), characterized by a heavy body, short thick neck, and short legs (64 cm), is a common heron of freshwater swamps and tidal marshes, roosting by day in trees. It typically feeds by night, predominantly on aquatic species, fish, amphibians, and insects. This heron is extremely widespread, occurring in North and South America, Eurasia, and Africa. It breeds over much of the United States and parts of central Canada and winters along both coasts of the United States and farther south.

- The yellow-crowned night heron (*Nyctanassa violacea*) (61 cm) is similar to the black-crowned but is more restricted in its range to the southeastern United States. It roosts in trees in wet woods, swamps, and low coastal shrubs.

- The American bittern (*Botaurus lentiginosus*), another of the medium-sized herons (58 to 70 cm), is a relatively common but elusive inhabitant of freshwater and brackish marshes and reedy lakes. It is a solitary feeder,

consuming fish, crayfish, reptiles, amphibians, insects, and even small mammals. Its breeding range includes most of Canada and the United States, although much of the southern United States is inhabited only during the winter.

- **The least bittern (*Ixobrychus exilis*), the smallest of the North American herons (33 cm), also is an elusive inhabitant of reedy areas. Its breeding range is restricted largely to the eastern half of the United States.**

General references

Hancock and Kushlan (1984); Robbins et al. (1983); National Geographic Society (1987); Palmer (1962); Short and Cooper (1985).

Great Blue Heron *(Ardea herodias)*

Factors	Age/Sex/ Cond./Seas.	Mean	Range or (95% CI of mean)	Location	Reference	Note No.
Body Weight (g)	A B	2,229 ± 762 SD		eastern North America	Quinney, 1982	
	A F A M	2,204 ± 337 SD 2,576 ± 299 SD		NS	Hartman, 1961	1
	yearlings juveniles	2,340 ± 490 SD 1,990 ± 550 SD	1,940 - 2,970 1,370 - 2,750	central Oregon	Bayer, 1981b	
	nestlings: day 1 day 5 day 10 day 15 day 20 day 25 day 30 day 35 day 40	 86 170 567 983 1,115 1,441 1,593 1,786 2,055		Nova Scotia, Canada	McAloney, 1973	
Metabolic Rate (kcal/kg-day)	A B basal	62			estimated	2
	A B free-living	165	(78 - 353)		estimated	3
Food Ingestion Rate (g/g-day)	A B	0.18		NS	Kushlan, 1978	4
Water Ingestion Rate (g/g-day)	A B	0.045			estimated	5
Inhalation Rate (m^3/day)	A B	0.76			estimated	6
Surface Area (cm^2)	A B	1,711			estimated	7

Great Blue Heron *(Ardea herodias)*

Dietary Composition	Spring	Summer	Fall	Winter	Location/Habitat (measure)	Reference	Note No.
trout non-trout fish crustaceans/amphibians		59 39 2			lower Michigan/lake (% wet weight; stomach contents)	Alexander, 1977	
trout non-trout fish crustaceans amphibians birds and mammals		89 5 1 4 1			lower Michigan/river (% wet weight; stomach contents)	Alexander, 1977	
Atlantic silverside mummichog American eel *Gaspereaux* pollack yellow perch		3.6 2.4 52.6 29.9 8.9 2.6			Nova Scotia/Boot Island (% wet weight; items regurgitated by nestlings)	Quinney, 1982	
staghorn sculpin small medium large starry flounder small medium large other small medium		 27.8 7.6 2.2 15.0 8.1 5.2 30.6 3.5			Vancouver, BC/coastal island (% of fish observed caught; small = less than 1/3 beak length; medium = about 1/2 beak length; large = longer than beak; other includes shiner sea perch and penpoint gunnels)	Krebs, 1974	

Great Blue Heron *(Ardea herodias)*

Population Dynamics	Age/Sex Cond./Seas.	Mean	Range	Location/Habitat	Reference	Note No.
Size Feeding Territory	A B fall A B winter	0.6 ± 0.1 SD ha 8.4 ± 5.4 SD ha		Oregon/freshwater marsh Oregon/estuary	Bayer, 1978	
Foraging Distance from Colony	A B summer A B summer	3.1 km 7 to 8 km	up to 24.4 km	South Dakota/river & streams North Carolina/coastal	Dowd & Flake, 1985 Parnell & Soots, 1978	 8
Population Density	summer along stream along river summer summer	 2.3 birds/km 3.6 birds/km 149 ± 53 SD nests/ha 461 nests/ha	 447 - 475	North Dakota/rivers & streams Maine/coastal islands Oregon/coastal island	Dowd & Flake, 1985 Gibbs et al., 1987 Werschkul et al., 1977	
Clutch Size		3.16 ± 0.04 SE 4.17 ± 0.85 SD 4.37	1 - 5 3 - 6 3 - 6	California/coastal canyon Nova Scotia/island Pennsylvania/NS	Pratt & Winkler, 1985 McAloney, 1973 Miller, 1943	 9
Clutches/Year		1		Pennsylvania; Oregon/NS	Miller, 1943; English, 1978	10
Days Incubation		27.1 28	25 - 30	Nova Scotia/island United States/NS	McAloney, 1973 Bent, 1926	
Age at Fledging (days)		45 60 49 to 56		Nova Scotia/island NS/NS Nova Scotia/island	McAloney, 1973 Hancock & Kushlan, 1984 Quinney, 1982	11
Number Fledge per Pair		1.7 1.96 2.8		central California/coastal northwest Oregon/river Nova Scotia/island	Pratt, 1972 English, 1978 Quinney, 1982	

Population Dynamics	Age/Sex Cond./Seas.	Mean	Range	Location/Habitat	Reference	Note No.
Number Fledge per Successful Nest		2.19 ± 0.25 SD 2.43 3.09	2 - 3	central California/coastal northwest Oregon/river Nova Scotia/island	Pratt & Winkler, 1985 English, 1978 McAloney, 1973	
Age at Sexual Maturity	B	2 years		NS	Bent, 1926	
Annual Mortality Rates (percent)	during 1st yr during 2nd yr during 3rd yr	64 36 22		United States and Canada/NS	Henny, 1972	

Seasonal Activity	Begin	Peak	End	Location	Reference	Note No.
Mating/Laying	Nov. to Dec. mid-February mid-March late March mid-April	 mid-March early May	April June early April late May	Florida central California northwest Oregon Pennsylvania Nova Scotia	Howell, 1932 Pratt & Winkler, 1985 English, 1978 Miller, 1943 McAloney, 1973	9 9
Hatching	 mid-April mid-May	early May 	 mid-July	northwest Oregon Idaho Ohio	English, 1978 Collazo, 1981 Hoffman & Curnow, 1979	
Migration (fall) (spring arrival)	mid-Sept. mid-February mid-March late March		late October mid-March	northern US western Oregon Wisconsin; Minnesota Nova Scotia	Palmer, 1962 Werschkul et al., 1977 Bent, 1926 Bent, 1926	

1 As cited in Dunning, 1984.
2 Estimated using equation 3-28 (Lasiewski and Dawson, 1967) and body weights from Quinney (1982).
3 Estimated using equation 3-37 (Nagy, 1987) and body weights from Quinney (1982).
4 Estimated from Kushlan's (1978) allometric equation for wading birds, assuming a body weight of 2,230 g.
5 Estimated using equation 3-15 (Calder and Braun, 1983) and body weights from Quinney (1982).
6 Estimated using equation 3-19 (Lasiewski and Calder, 1971) and body weights from Quinney (1982).

Great Blue Heron *(Ardea herodias)*

7 Estimated using equation 3-21 (Meeh, 1879 and Rubner, 1883, as cited in Walsberg and King, 1978) and body weights from Quinney (1982).
8 Cited in Short and Cooper (1985).
9 Cited in Palmer (1962).
10 May replace clutch if eggs are lost, but only rear one brood (Henny, 1972).
11 Young fed around colony for 10 days after leaving nest at 45 days of age.

Great Blue Heron *(Ardea herodias)*

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2.1.2. Canada Goose (geese)

<u>Order *Anseriformes*, Family *Anatidae*</u>. Geese are large herbivorous waterfowl that feed on grains, grass sprouts, and some aquatic vegetation. Although adapted for life on the water, they forage primarily in open fields. They breed in open forested areas near lake shores and coastal marshes from the arctic tundra through temperate climates. These birds migrate in noisy flocks in the familiar V-formation, stopping in cultivated fields, wetlands, and grasslands to feed. Geese show a wide variation in size even within a species; the sexes look alike.

Selected species

The Canada goose (*Branta canadensis*) is the most widespread and abundant goose in North America. It is a popular game species and is commonly encountered on cultivated fields, golf courses, other parklands, and wetland refuge areas. Depending on subspecies, these geese can range in size from 64 to 114 cm (bill tip to tail tip), the larger geese breeding in more southerly locations than the smaller subspecies. The reverse is true in winter, with the larger subspecies wintering in the more northerly parts of the range (Palmer, 1962). The number of existing recognized subspecies varies, but most ornithologists agree that there are 11: *canadensis* (Atlantic Canada goose), *fulva* (Vancouver Canada goose), *hutchinsii* (Richardson's Canada goose), *interior* (interior Canada goose), *leucopareia* (Aleutian Canada goose), *maxima* (giant Canada goose), *minima* (cackling Canada goose), *moffitti* (Great Basin or western Canada goose), *occidentalis* (dusky Canada goose), *parvipes* (lesser Canada goose), and *taverneri* (Taverner's Canada goose) (Bellrose, 1976; Johnson et al., 1979; Palmer, 1962). Several subspecies usually mingle during migration and in wintering areas, but they breed in geographically distinct ranges. Six of the subspecies breed in Alaska (*fulva, leucopareia, minima, occidentalis, parvipes*, and *taverni*) (Johnson et al., 1979). The *leucopareia* subspecies, found in Oregon, Washington, California, and Alaska, currently is a United States federally designated threatened species (50 CFR 17.11, 1992). It is only known to breed on one of the western Aleutian islands off Alaska (Byrd and Woolington, 1983). See Bellrose (1976) for ranges, migration corridors, and wintering areas of specific subspecies and populations.

***Body size*. Canada geese subspecies vary greatly in size, but males are on average larger than females (see table). Body weight reaches its maximum just prior to or during the spring migration and then declines during egg-laying and incubation, sometimes by as much as 20 percent (Mainguy and Thomas, 1985; McLandress and Raveling, 1981). Most of the weight lost during incubation reflects loss of fat, which can provide over 80 percent of the energy requirements for the incubating females (Mainguy and Thomas, 1985; Murphy and Boag, 1989). Young are similar to parents in size by 2 months of age (Palmer, 1962).**

***Habitat*. Breeding habitat includes tundra, forest muskeg in the far north, tall- and shortgrass prairie, marshes, ponds, and lakes. Most nesting sites are close to open water with high visibility in all directions (Palmer, 1962; Steel et al., 1957). In many areas, Canada geese nest predominantly on islands in ponds or lakes (Geis, 1956). Former**

muskrat houses often serve as nest sites in marshes (Steel et al., 1957). Brood-rearing habitats, on the other hand, require adequate cover, and riparian areas are used more frequently than open water (Eberhardt et al., 1989a). During the fall and winter in Maryland, Harvey et al. (1988) found Canada geese to spend 57 percent of their time in farmlands (mostly corn, soybeans, and winter wheat fields) and 24 percent in forested areas.

***Food habits*. Canada geese are almost exclusively vegetarian, and feeding activity is concentrated in areas where food is plentiful (e.g., standing crops, scattered whole grain) (Palmer, 1962). They are primarily grazers, but must consume grit at some point to assure proper digestion (Palmer, 1962). They prefer certain foods, but will change their diet depending on the availability of a food type (Coleman and Boag, 1987). For example, when water levels are low in the south Yukon (Canada) river delta, Canada geese forage on rhizomes of *Potamogeton richardsonii* even though other forage is available; at higher water levels when the *Potamogeton* is unreachable, the geese will feed on other plants (Coleman and Boag, 1987). During fall, geese often consume green crops (e.g., winter wheat). During winter, however, they consume more energy-rich foods such as corn (Harvey et al., 1988; McLandress and Raveling, 1981). In late winter and early spring, green crops that are high in nitrogen and other important nutrients again constitute an important part of the diet (McLandress and Raveling, 1981). Canada geese often feed preferentially on the blade tips of many plants, which are higher in nitrogen than other parts of the plant (Buchsbaum et al., 1981). In Minnesota, Canada geese begin consuming green grasses as soon as they are exposed by the melting snow (McLandress and Raveling, 1981). In Maryland, on the other hand, Harvey et al. (1988) found that Canada geese did not begin consuming green crops before migration to the breeding grounds, indicating that this population may rely on green forage available at staging areas to obtain the protein and lipids required for reproduction. In the spring in Falmouth Harbor, Massachusetts, Canada geese initially consume predominantly the marsh grasses *Spartina spp.* and rushes *Juncus gerardi*, which are high in protein (Buchsbaum and Valiela, 1987). As the summer progresses, however, they feed increasingly on submerged eelgrass, *Zostera marina*, which provides more carbohydrates (Buchsbaum and Valiela, 1987).**

***Molt*. Nonbreeders and yearlings migrate to a separate molting ground soon after arrival at the breeding grounds, while breeding birds molt on the brood-rearing grounds (Bellrose, 1976). Molting occurs earlier in nonbreeders, at least a month earlier in the larger subspecies (Palmer, 1962). Molting parents do not regain flight feathers until just prior to the time when their young first attain flight (Palmer, 1962). The flightless period of *B. c. interior* is estimated to be 32 days. For *B. c. maxima* and *B. c. moffitti*, the flightless period lasts from 39 to 40 days (Balham, 1954; Hanson, 1965, as cited in Palmer, 1962).**

***Migration*. Migratory Canada geese leave their breeding grounds during late summer and early autumn; they return in the spring around the time the first water is opening (i.e., ice melting) but well before snow cover has disappeared (Bellrose, 1976). Spring migration begins later for northerly populations, with geese that winter in mild climates departing as early as mid-January, while those wintering in the coldest areas do not move northward until the beginning of March (Bellrose, 1976). The bulk of the migrants typically arrive on the summer breeding grounds 3 weeks after the first birds**

(Bellrose, 1976). Some populations have become resident year-round, for example, *B. c. maxima* in Missouri (Brakhage, 1965) and in southeast Georgia and southwest Alabama (Combs et al., 1984). During both the spring and fall migrations, geese tend to gather in large flocks and feed for several weeks in "staging" areas along major waterfowl flyways (Bellrose, 1976).

***Breeding activities and social organization*. Canada geese arrive on the breeding grounds in flocks, and soon after, the male becomes territorial and aggressive toward other birds (Palmer, 1962). Lifelong monogamy following their first breeding is the general rule with these geese (Palmer, 1962). Nests are built on the ground in a position with good visibility (Palmer, 1962). During incubation the male stands guard, while the female incubates the eggs, which she normally leaves two or three times daily to feed, bath, drink, and preen (Murphy and Boag, 1989). Both parents accompany the young through the brood period (Bellrose, 1976; Brakhage, 1965). Canada geese return to the breeding grounds as family units, but the yearlings leave their parents soon after arrival (Bellrose, 1976).**

***Home range and resources*. The foraging home range of Canada geese varies with season, latitude, and breeding condition. Soon after hatching, goose families move away from the nesting sites to other areas with adequate cover and forage to rear their broods (Byrd and Woolington, 1983). Newly hatched families may have to travel 10 to 20 km from the nest site to reach areas with adequate aquatic vegetation or pasture grasses (Geis, 1956). Although the families stay predominantly on land, often in riparian areas, they usually are close to water. Eberhardt et al. (1989a) found goslings within 5 m of water most of the time; only 7 percent of sightings were farther than 50 m away. During the spring and fall migrations and in winter, Canada geese can be found on open water or refuges near grain fields or coastal estuaries (Leopold et al., 1981).**

***Population density*. Breeding population densities of Canada geese vary widely. Low nesting densities (i.e., less than 0.005 per hectare) are common in the Northwest Territories of Canada (Smith and Sutton, 1953, 1954) and intermediate densities (i.e., 0.02 to 0.7 per hectare) have been reported for Alaska (Cornley et al., 1985). In some more southerly locations (e.g., California), colonial nesting situations have been reported, with as many as 32 nests located on half an acre (Naylor, 1953, as cited in Palmer, 1962).**

***Population dynamics*. The earliest Canada geese begin breeding is around 2 to 3 years of age (MacInnes and Dunn, 1988; Brakhage, 1965). In the larger subspecies, only a small proportion of the birds under 4 years may attempt to breed. For example, in Manitoba, Moser and Rusch (1989) found that only 7 percent of 2-year-old and 15 percent of 3-year-old *B. c. interior* laid eggs. Canada geese only attempt to rear one brood per year. In the more southerly latitudes, Canada geese will renest if a clutch is lost prior to incubation (Brakhage, 1965; Geis, 1956). In general, both clutch size and success at rearing goslings increase with the age of the breeder (Brakhage, 1965). Raveling (1981) found that older *B. c. maxima* (4 plus years) raised more than twice as many goslings to fledging as did younger (2 to 3 years) birds. Population age structure and annual mortality vary with hunting pressure as well as natural factors.**

Similar species (from general references)

- **The Brant goose (*Branta bernicla*) is approximately the size of the smaller Canada geese subspecies (length 25 cm). It is primarily a sea goose and is rare inland. It winters along both the east and west coasts of the United States, where it feeds on aquatic plants in shallow bays and estuaries. It breeds in the high arctic.**

- **The greater white-fronted goose (*Anser albifrons*) is limited to certain areas west of the Mississippi River and averages 71 cm in length. Its habits are similar to those of other geese.**

- **The snow goose (*Chen caerulescens*) breeds in the Arctic and winters in selected coastal areas across the United States. However, this average-sized goose (71 cm) is a migratory visitor to much of the central United States.**

- **The Ross' goose (*Chen rosii*) breeds in the high arctic tundra and winters in some areas of the southwest United States. This relatively small (58 cm) goose is a rare visitor to the mid-Atlantic States and is always seen with snow geese.**

General references

Bellrose (1976); Kortright (1955); National Geographic Society (1987); Palmer (1962).

Canada Goose (*Branta canadensis*)

Factors	Age/Sex/ Cond./Seas.	Mean	Range or (95% CI of mean)	Location (subspecies)	Reference	Note No.
Body Weight (g)	A M late sum. A F late sum.	1,443 ± 32 SE 1,362 ± 54 SE	1,260 - 1,605 1,195 - 1,590	Alaska (*minima*)	Raveling, 1979	
	A M winter A F winter	2,769 ± 30 SE 2,472 ± 23 SE		Colorado (*parvipes*)	Grieb, 1970	
	A M not spec. A F not spec.	3,992 3,447		NS (*canadensis*)	Webster (unpublished) in Bellrose, 1976	
	A M fall A F fall	4,212 ± 35 SE 3,550 ± 31 SE	3,799 - 4,727 3,147 - 3,856	Illinois (*interior*)	Raveling, 1968	
	A M late sum. A F late sum.	4,960 4,160		Missouri (*maxima*)	Brakhage, 1965	
	M at hatching F at hatching	108.7 109.5		Alberta (*moffitti*)	LeBlanc, 1987b	
	B day 10 B day 20 B day 30 B day 40 B day 47	150 450 755 950 1,050		Alaska (*minima*)	Sedinger, 1986	1
	B day 0 B day 9 B day 16 B day 30 B day 44 B day 51	110 240 440 1,400 2,400 2,600		NS (*moffitti*)	Williams (unpublished) in Palmer, 1976	
	M at fledging F at fledging	87% adult wt 89% adult wt		Alaska (*minima*)	Sedinger, 1986	

Canada Goose (*Branta canadensis*)

Factors	Age/Sex/ Cond./Seas.	Mean	Range or (95% CI of mean)	Location (subspecies)	Reference	Note No.
Body Fat (g lipid)	F fall migr. F winter F spring migr. F prelaying F end incub. F early molt	182 ± 24 SE 57 ± 6 SE 172 ± 25 SE 171 (no SE; N=2) 33 ± 5 SE 108 ± 13 SE	117 - 264 34 - 71 68 - 362 136 - 205 14 - 51 62 - 179	Alaska in winter (*minima*) California in summer	Raveling, 1979	
	F prelaying F incubating F late incub. F molting	751 ± 45 SE 611 ± 40 SE 166 ± 18 SE 485 ± 37 SE		Ontario, Canada (*maxima*)	Thomas et al., 1983	
Egg Weight (g)		96 127 163		NS (*minima*) NS (*leucopa*) Alberta, Canada (*moffitti*)	Owen, 1980 Owen, 1980 LeBlanc, 1987a	2 2
Metabolic Rate (kcal/kg-day)	free-living: A M winter A M spring A M summer A M fall		105 - 209 105 - 203 115 - 253 100 - 209	Illinois in winter (*interior*) Ontario, Canada in summer	Williams & Kendeigh, 1982	3
	A F spring A F summer		130 - 220 143 - 274	(*interior*)	Williams & Kendeigh, 1982	3
	free-living: A M A F	185 187	(87 - 391) (88 - 397)	(*minima*)	estimated	4a
	A M A F	141 147	(65 - 304) (69 - 316)	(*interior*)	estimated	4b
	A M A F	135 142	(63 - 292) (66 - 305)	(*maxima*)	estimated	4c

Canada Goose (*Branta canadensis*)

Factors	Age/Sex/ Cond./Seas.	Mean	Range or (95% CI of mean)	Location (subspecies)	Reference	Note No.
Food Ingestion Rate (g/g-day)	A M winter A F winter	0.030 0.033		(*interior*) captive	Joyner et al., 1984	5
	A M spring A F spring	0.030 0.031		(*interior*) captive	Joyner et al., 1984	5
Water Ingestion Rate (g/g-day)	A M A F	0.052 0.053		(*minima*)	estimated	6a
	A M A F	0.035 0.037		(*maxima*)	estimated	6b
Inhalation Rate (m^3/day)	A M A F	0.54 0.52		(*minima*)	estimated	7a
	A M A F	1.40 1.22		(*maxima*)	estimated	7b
Surface Area (cm^2)	A M A F	1,280 1,230		(*minima*)	estimated	8a
	A M A F	2,920 2,590		(*maxima*)	estimated	8b

Dietary Composition	Spring	Summer	Fall	Winter	Location/Habitat (measure)	Reference	Note No.
sedges				63	North Carolina/lake	Yelverton & Quay, 1959	
native grasses				11			
corn kernels				22	(% volume; crop and gizzard contents)		
animal				0.01			
other				4			

Canada Goose (*Branta canadensis*)

Dietary Composition	Spring	Summer	Fall	Winter	Location/Habitat (measure)	Reference	Note No.
Equisetum sp. (shoot)	9.2				Ontario, Canada/bay (% dry weight; esophagus and proventriculus contents)	Prevett et al., 1985	
Triglochin palustris (root)	3.4						
grasses (root)	23.4						
(shoot)	2.1						
sedges (shoot)	25.3						
(root)	5.3						
(reed)	17.9						
Plantago maritima (root)	6.5						
unidentified plants	6.1						
invertebrates	0.7						
corn			23		Wisconsin/marsh (% dry volume; gizzard and proventriculus contents)	Craven & Hunt, 1984	
unidentified plants			8.6				
alfalfa			10.4				
Gramineae			12.6				
oats			25.1				
Setaria lutescens			8.4				
Trifolium repens			10.9				

Population Dynamics	Age/Sex/ Cond./Seas.	Mean	Range	Location (subspecies)/ habitat[a]	Reference	Note No.
Home Range Size	A F & brood	983 ± 822 SD ha	290 - 2,830	Washington (*moffitti*)/river	Eberhardt et al., 1989a	
	A F & brood	8.8 ± 4.4 SD km	2.8 - 18.1	Washington (*moffitti*)/river	Eberhardt et al., 1989a	

Canada Goose (*Branta canadensis*)

Population Dynamics	Age/Sex/ Cond./Seas.	Mean	Range	Location (subspecies)/ habitat[a]	Reference	Note No.
Population Density	summer		0.02-12.4 nests/ha	various locations	Cooper, 1978	9
		16.6 nests/ha		Montana (*moffitti*)/ on 0.2-0.8 ha island	Geis, 1956	
		1.3 nests/ha		Montana (*moffitti*)/ on 8-121 ha island		
		0.35 nests/ha		Alaska (*leucopus*)/ island preferred habitat	Byrd & Woolington, 1983	
	fall	22 birds/ha		Missouri/wildlife refuge	Humburg et al., 1985	
	winter	4 birds/ha		Missouri/wildlife refuge	Humburg et al., 1985	
Clutch Size		4.7		Alaska (*minima*)	Spencer et al., 1951	10
		5.6 ± 0.1 SE	2 - 8	Alaska (*leucopa*)	Byrd & Woolington, 1983	
		4.6		Ontario, Canada (*interior*)	Raveling & Lumsden, 1977	2
		5.6		Alabama, Georgia (*maxima*)	Combs et al., 1984	
Clutches/Year		1		Missouri	Brakhage, 1985	
Days Incubation		25		NS (*minima*)	Laidley, 1939	10
		28		Missouri (*maxima*)	Brakhage, 1965	
Age at Fledging (days)		40-46		Alaska (*minima*)	Mickelson, 1973	11
		55		NS (*leucopa*)	Lee (pers. comm.) in Byrd & Woolington, 1983	
		63		Ontario, Canada (*interior*)	Hanson, 1965	11
		71-73		Michigan (*maxima*)	Sherwood, 1965	11
Percent Nests Successful		91	89 - 93	Alaska/island (*leucopa*)	Byrd & Woolington, 1983	
		44	27 - 64	Alabama, Georgia (*maxima*)	Combs et al., 1984	
Number Fledge per Active Nest		2.19 ± 2.42 SD	0 - 7	Washington (*moffitti*)	Eberhardt et al., 1989b	

Canada Goose (*Branta canadensis*)

Population Dynamics	Age/Sex/ Cond./Seas.	Mean	Range	Location (subspecies)/ habitat[a]	Reference	Note No.
Number Fledge per Successful Nest		4.0 ± 0.008 SE	1 - 7	Alaska (*leucopa*)	Byrd & Woolington, 1983	
		2.2		IL, WI (*interior*)	Hardy & Tacha, 1989	12
		3.9 ± 1.9 SD	1 - 7	Washington (*moffitti*)	Eberhardt et al., 1989b	
Age at Sexual Maturity	B	2 - 3		Northwest Territories (smaller subspecies)	MacInnes & Dunn, 1988	
	F	4 - 5	> 2	Manitoba, Canada (*interior*)	Moser & Rusch, 1989	
	M	2 - 3	> 1	Missouri (*maxima*)	Brakhage, 1965	
	F	2 - 3	> 2			
Annual Mortality Rates (percent)	A B	35.9		Alaska (*minima*)	Nelson & Hansen, 1959	11
	J B	46.0				
	A B	28 ± 0.8 SD		California, Nevada (*moffitti*)	Rienecker, 1987	
	J B	49 ± 3.7 SD				
	A B	22.9		Ohio (*maxima*)	Cummings, 1973	11
	J B	37.0				

Seasonal Activity	Begin	Peak	End	Location (subspecies)	Reference	Note No.
Mating/Laying	late February	March - April	mid-May	Georgia, Alabama (*maxima*)	Combs et al., 1984	
	early March	late March		OR, WA, CA (*moffitti*)	McCabe, 1979; Bellrose, 1976	
	mid-March	late March - April	May	Montana (*moffitti*)	Geis, 1956	
	early April	mid-April	early May	Idaho (*moffitti*)	Steel et al., 1957	
	early April		mid-April	Ontario, Canada (*maxima*)	Mainguy & Thomas, 1985	
	late May	late May	early June	Alaska (*leucopa*)	Byrd & Woolington, 1983	
Hatching	March	April - May	early June	Georgia, Alabama (*maxima*)	Combs et al., 1984	
	mid-April	late April - May	late May	Montana (*moffitti*)	Geis, 1956	
	early May	mid-May	late June	Idaho (*moffitti*)	Steel et al., 1957	
		early July		Alaska (*leucopa*)	Byrd & Woolington, 1983	

Canada Goose (*Branta canadensis*)

Seasonal Activity	Begin	Peak	End	Location (subspecies)	Reference	Note No.
Molt (fall)	mid-June mid-July late June	mid-August	late August late October	Idaho (*moffitti*) Alaska (*leucopa*) Illinois (*interior*)	Steel et al., 1957 Byrd & Woolington, 1983 Williams & Kendeigh, 1982	
Migration fall	mid-Sept. October	November early November	mid-December	arrive south Illinois (*interior*) arrive CO, TX (*parvipes*)	Bell & Klimstra, 1970 Grieb, 1970	
spring	February late March	early March early April		leave Illinois (*interior*) leave Minnesota (*maxima*)	Bell & Klimstra, 1970 Raveling, 1978b	

1 Weights estimated from graph.
2 Cited in Dunn and MacInnes (1987).
3 Estimated range of existence to maximum free-living metabolism at typical breeding ground (Ontario, Canada in spring and summer) and at typical wintering ground (south Illinois in fall and winter). Estimated using regression equations developed by the authors, measures of metabolic rates at temperatures from -40 to 41°C, and temperatures typical for the season and location.
4 Estimated using equation 3-37 (Nagy, 1987) and body weights from (a) Raveling (1979); (b) Raveling (1968); and (c) Brakhage (1965).
5 Reported as grams dry weight of feed; corrected to grams wet weight of feed using the measured moisture content of 11 percent (on average) of the feed items (i.e., corn, sunflower seeds, wheat, and milo).
6 Estimated using equation 3-15 (Calder and Braun, 1983) and body weights from (a) Raveling (1979) and (b) Brakhage (1965).
7 Estimated using equation 3-19 (Lasiewski and Calder, 1971) and body weights from (a) Raveling (1979) and (b) Brakhage (1965).
8 Estimated using equation 3-21 (Meeh, 1879 and Rubner, 1883, as cited in Walsberg and King, 1978) and body weights from (a) Raveling (1979) and (b) Brakhage (1965).
9 Summarizing several studies, cited in Byrd & Woolington (1983).
10 Cited in Palmer (1976).
11 Cited in Bellrose (1976).
12 For parents older than 5 years of age.

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