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Preliminary Assessment of the Ecological Risks to Wide-ranging Wildlife Species on the Oak Ridge Reservation

1996 Update

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Preliminary Assessment of the Ecological Risks to Wide-ranging Wildlife Species on the Oak Ridge Reservation

1996 Update

B. E. Sample
R. L. Hinzman
B. L. Jackson
L. Baron

Environmental Restoration Division
P.O. Box 2003
Oak Ridge, Tennessee 37831-7298

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Prepared by
Environmental Sciences Division
Oak Ridge National Laboratory
Oak Ridge, Tennessee

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LOCKHEED MARTIN ENERGY SYSTEMS, INC.
managing the
Environmental Management Activities at the
Oak Ridge K-25 Site Paducah Gaseous Diffusion Plant
Oak Ridge Y-12 Plant Portsmouth Gaseous Diffusion Plant
Oak Ridge National Laboratory
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PREFACE

This report, *Preliminary Assessment of the Ecological Risks to Wide-ranging Wildlife Species on the Oak Ridge Reservation: 1996 Update*, DOE/OR/01-1407&D2, was prepared as a technical report documenting work performed under the Oak Ridge Reservation Ecological Assessment Program. This work was performed under work breakdown structure 1.4.12.2.3.4 (activity data sheet 8304, "Technical Integration"). Publication of this document meets an activity data sheet milestone of September 13, 1996. This document provides the Environmental Restoration Program with a preliminary evaluation of the ecological risks that contaminants on the Oak Ridge Reservation present to selected wide-ranging species. These results will aid in the understanding of the magnitude of ecological risks to populations at larger spatial scales and will assist in the prioritization of source operable units for investigation and remediation.

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ACRONYMS

BEIDMS	Bechtel Environmental Information Data Management System
BCK	Bear Creek kilometer
BC	Bear Creek
BCV	Bear Creek Valley
BMAP	Biological Monitoring and Abatement Program
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COPECs	Chemicals of Potential Ecological Concern
CR	Chestnut Ridge
DOE	U. S. Department of Energy
EFPC	East Fork Poplar Creek
EFK	East Fork kilometer
EMAP	Ecological Monitoring and Assessment Program
EPA	U.S. Environmental Protection Agency
ESD	Environmental Sciences Division
ER	Environmental Restoration
EROD	ethoxyresorufin-o-deethylase
FCAP	Filled Coal Ash Pond
FFA	Federal Facilities Agreement
GIS	geographic information system
HQ	hazard quotient
MEK	Melton Branch Kilometer
MIK	Mitchell Branch Kilometer
NOAEL	no observed adverse effects level
NTK	Northwest Tributary Kilometer
LEFPC	Lower East Fork Poplar Creek
LOAEL	Lowest Observed Adverse Effects Level
OREIS	Oak Ridge Environmental Information System
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
OU	operable unit
PLE	product limit estimator
RI	remedial investigation
SAIC	Science Applications International Corporation
SCF	South Campus Facility
STD	Standard Deviation
T&E	Threatened or Endangered
TWRA	Tennessee Wildlife Resources Agency
UEFPC	Upper East Fork Poplar Creek
UCL	upper confidence limit
WAG	Waste Area Grouping
WCK	White Oak Creek kilometer
WOC	White Oak Creek
WOL	White Oak Lake

ACKNOWLEDGMENTS

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EXECUTIVE SUMMARY

Historically, ecological risk assessment at Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites [such as the Oak Ridge Reservation (ORR)] has focused on species that may be definitively associated with a contaminated area or source operable unit. This is necessary to identify areas where risk is sufficiently high to warrant remediation. Consequently the species that are generally considered are those with home ranges small enough such that multiple individuals or a distinct population can be expected to reside within the boundaries of the contaminated site. This approach is adequate for sites with single, discrete areas of contamination that only provide habitat for species with limited spatial (i.e., small home range) requirements. This approach is not adequate however for large sites with multiple, spatially separated contaminated areas that provide habitat for wide-ranging wildlife species. Because wide-ranging wildlife species may travel between and use multiple contaminated sites, they may be exposed to and be at risk from contaminants from multiple locations. Use (and therefore exposure and risk) of a particular contaminated site by wide-ranging species will be dependant upon the amount of suitable habitat available at that site. Therefore to adequately evaluate risks to wide-ranging species at the ORR-wide scale, the use of multiple contaminated sites must be weighted by the amount of suitable habitat on operable units (OUs). Highly contaminated OUs that provide little habitat are unlikely to be significant contributors to ORR-scale contaminant-associated risk. Conversely, moderately contaminated sites that contain considerable habitat may significantly contribute to ORR-scale contaminant-associated risk.

In spring of 1994, a series of meetings were held among the Federal Facilities Agreement parties to develop an approach and plan for assessing risks to wide-ranging species that could not be adequately addressed at the source OU level. The results of these discussions are presented in the ORR ecological risk assessment strategy document (Suter et al. 1994a). This report is based on this document and presents the preliminary assessment of ecological risks to wide-ranging species from contaminants on the ORR.

The reservation-wide ecological risk assessment is intended to serve several purposes, including identifying (1) which endpoints are significantly at risk, (2) which contaminants are responsible for this risk, and (3) which OUs significantly contribute to risk. To address these issues, this report contains the following information:

- an evaluation of the potential use of OUs by 57 endpoint species identified in Suter et al. (1994a),
- a preliminary ranking of OUs according to those that may present the greatest ecological risk,
- a preliminary assessment of risks to selected piscivorous wildlife (i.e., mink, river otter, belted kingfisher, great blue heron, osprey),
- a preliminary assessment of risks to selected vermivorous, herbivorous, and predatory wildlife (i.e., American woodcock, short-tailed shrew, white-tailed deer, wild turkey, red fox, red-tailed hawk), and
- a proposed revision schedule.

Data used in this preliminary assessment included a reservation-wide land use/land cover classification (Washington-Allen et al. 1995), reservation-wide fish bioaccumulation data from the Biological Monitoring Programs, and soil contamination data for 12 of 37 OUs. These data were derived from ORR computer databases (the Oak Ridge Environmental Information System and the Bechtel Environmental Information Data Management System).

Potential use of OUs by the endpoint species listed in Suter et al. (1994a) was estimated by comparing habitat requirements for the endpoint species (obtained from the literature) to the nine landcover types identified in Washington-Allen et al. (1995). An OU was considered to provide habitat for an endpoint species if at least one of the habitat types required by the species was present on the OU. OUs were ranked by the number of species for which they could potentially provide habitat, and endpoint species were ranked by the number of OUs on which suitable habitat was available. Conclusions of this evaluation include the following: (1) The largest OUs on the ORR generally have the most diverse habitat and consequently can support the greatest number of potential endpoint species; and (2) Species that can use urban habitats or that have broad habitat requirements have the highest potential to experience exposure as a result of the large numbers of OUs that provide suitable habitat.

Risks to piscivorous wildlife were assessed by using contaminant concentrations in fish from four watersheds on the ORR [i.e., Bear Creek, East Fork Poplar Creek, the K-25 vicinity, White Oak Creek (including White Oak Lake)]. Additional data used in this assessment included toxicity tests performed on mink and field surveys of mink, great blue heron, belted kingfisher, and osprey. Monte Carlo simulations of contaminant exposure estimates were calculated for each species by watershed. The resulting exposure distributions were then combined with literature-derived population density data for each endpoint species to estimate the number of individuals of each species likely to experience adverse effects within each watershed. These numbers were then summed for the reservation as a whole to estimate the proportion of the ORR population potentially at risk. By combining the multiple lines of evidence available to assess risks to piscivores, the following conclusions may be made:

- Mercury presents a hazard to mink in East Fork Poplar Creek and consequently to a significant portion (30%) of the ORR-wide mink population. Risks to mink from PCBs are not significant (Chap. 4).

- Evaluation of the potential risks to a future ORR-wide population of otter indicates that mercury presents a risk in all watersheds on the ORR. Because the river otter is a state threatened species, effects to any individual are significant. Therefore the weight of evidence suggests that mercury is a significant risk to individual river otter that may occupy the ORR in the future (Chap. 4)

- Comparison of exposure estimates to lowest observed adverse effects level (LOAELs) indicates a significant risk from mercury in all watersheds except White Oak Creek. This translates into a risk to 81.5% of the ORR-wide kingfisher population. The limited biomonitoring data indicate that kingfisher on the ORR (particularly in the White Oak Creek area) are accumulating mercury to potentially nephrotoxicty levels. The weight of evidence suggests mercury in all watersheds presents a significant risk to the ORR-wide belted kingfisher population. Risks from PCBs are not significant (Chap. 4).

- Although mercury in fish is estimated to represent a significant risk to great blue heron within the East Fork Poplar Creek watershed and, consequently, to an estimated 37% of the heron population on the ORR, studies on two of five colonies adjacent to the ORR (i.e., <10 km from the ORR) indicate that reproduction at these locations is not impaired. Contaminant bioaccumulation and reproductive success are unknown at the three additional colonies adjacent to the ORR. Additionally, the primary foraging locations for herons at the two studied colonies are unknown. Because herons can travel long distances in search of food (>15 km), they are likely to forage at off-site as well as on-site locations, reducing both the exposure they receive and the risk they experience. If birds from the unstudied colonies forage more extensively on the ORR, they may experience greater risk. Because of the high risk estimated for mercury exposure on the ORR, the lack of data for three of five heron colonies adjacent to the ORR, and uncertainty as to where birds from the five ORR colonies forage, a conclusion concerning whether or not great blue heron on the ORR are at risk cannot be made.

- Comparison of exposure estimates to LOAELs for osprey indicates no significant risk from mercury or PCBs in any area on the ORR that provides suitable habitat (i.e., White Oak Lake and embayment, the K-25 area). Biomonitoring data indicates that the reproductive success at osprey nests adjacent to the ORR, along Melton Hill Lake and in Poplar Creek, is greater than the average observed in the United States. The weight of evidence suggests that mercury and PCB do not present significant risks to osprey on or near the ORR.

On the ORR, although most wide-ranging wildlife species reside primarily in the uncontaminated terrestrial habitats outside of source OUs, they may also use those source OUs on which suitable habitat is present. The degree to which a source OU is used (and therefore the risk that it may present) is dependant upon the availability of suitable habitat on the OU. OUs with little or no habitat will experience little use (and will present minimal risk), whereas those with considerable habitat are likely to experience considerable use (and depending upon the degree of contamination, may present significant risks). Although *individuals* may experience adverse effects through exposures received at source OUs, the primary concern for ecological risk assessment is for effects at the population-level To evaluate effects to the ORR-wide wildlife populations, habitat suitability and population density on the ORR and within OUs must be considered. A general, six-step, habitat-based approach was developed that is applicable to all wildlife species on the ORR. The approach is outlined below:

1. Individual-based contaminant exposure estimates are generated for each OU by using the generalized exposure model outlined in Sample and Suter (1994).

2. Contaminant exposure estimates are compared to no observed adverse affects levels or LOAELs to determine the magnitude and nature of effects that may result from exposure at the OU. If the exposure estimate is greater than LOAEL, then individuals at the OU may experience adverse effects.

3. Availability and distribution of habitat on the ORR and within each OU is determined by using the ORR landcover map presented in Washington-Allen et al. (1995).

4. Habitat requirements for the endpoint species of interest are compared with the ORR habitat map to determine the area of suitable habitat on the ORR and within OUs.

5. The area of suitable habitat on the ORR and within OUs is multiplied by population density values (ORR-specific or obtained from the literature) for the selected endpoints to generate estimates of the ORR-wide population and the numbers of individuals expected to reside within each OU.

6. The number of individuals for a given endpoint species expected to be receiving exposures is greater than LOAELs for each measured contaminant is totaled. This is performed by using the OU-specific population estimate from step 5 and the results from step 2. This number is then compared with the ORR-wide population to determine the proportion of the ORR-wide population that is receiving hazardous exposures. By using the 20% criterion outlined in Suter et al. (1994a), if the proportion of the ORR-wide population receiving hazardous exposures is ≥20%, then an adverse population-level effect is assumed to be present.

Because contaminant concentrations in soil were the most readily available type of data and contaminant concentrations in plants and earthworms can be easily estimated with soil-plant or soil-worm uptake factors, vermivores and herbivores were selected as endpoint categories to demonstrate the applicability of the habitat-based approach. Conclusions of this assessment were that while there are significant risks to individuals of selected herbivore, vermivore, and predator endpoint species resident on OUs, the reservation-wide populations of these endpoints are unlikely to be significantly affected (<20% of the ORR population is affected). This conclusion must be viewed with caution, however, because data were evaluated for only 13 of 37 OUs. Inclusion of additional OUs is likely to increase the proportion of the ORR populations exposed and at risk.

Finally, this preliminary assessment of risk to wide-ranging wildlife species on the ORR is based on only a small portion of the data available for the reservation. To accurately evaluate the nature and magnitude of risks on the ORR, all available data should be incorporated and considered. It is recommended that this report be revised and updated annually until all existing data have been incorporated. Following this, revisions should be produced on a 5-year schedule to incorporate new data that become available.

1. INTRODUCTION

More than approximately 50 years of operations, storage, and disposal of wastes generated by the three facilities on the Oak Ridge Reservation (ORR) (the Oak Ridge K-25 Site, Oak Ridge National Laboratory, and the Oak Ridge Y-12 Plant) has resulted in a mosaic of uncontaminated property and lands that are contaminated to varying degrees. This contaminated property includes source areas [source operable units (OUs) that are the industrial facilities themselves and the waste disposal or waste storage areas] and the terrestrial and aquatic habitats down gradient from these source areas (integrator OUs; Fig. 1.1). Although the integrator OUs generally contain considerable habitat for biota, the source OUs provide little or no suitable habitat.

Historically, ecological risk assessment at Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites has focused on species that may be definitively associated with a contaminated area or source OU. This is necessary to identify areas where risk is sufficiently high to warrant remediation. Figure 1.1 outlines a conceptual model for contaminant transfer both within and through a source OU. Endpoints considered in source OUs include plants, soil/litter invertebrates and processes, aquatic biota found in on-OU sediments and surface waters, and small herbivorous, omnivorous, and vermivorous (i.e., feeding on ground, litter, or soil invertebrates) wildlife. All of these endpoints have limited spatial distributions or home ranges such that numerous individuals or a distinct population can be expected to reside within the boundaries of the source OU. Contaminants move from the source to either surface soil, groundwater or surface water, or sediments (Fig. 1.1). Aquatic biota may be exposed to contaminants through direct contact with water and sediment; small herbivores, omnivores, and vermivores may be exposed through ingestion of contaminated surface water. Contaminants in soil may be taken up by plants and soil/litter invertebrates; consequently small herbivores, omnivores, and vermivores that feed on these food types may be exposed. These small terrestrial wildlife species may also be exposed to contaminants through incidental or purposeful ingestion of soil.

Assessment of the endpoints outlined above is adequate for source OUs and for sites with single, discrete areas of contamination that only provide habitat for species with limited spatial (i.e., small home range) requirements. It is not adequate however for large sites with multiple, spatially separated contaminated areas the ORR that provide habitat for wide-ranging wildlife species. Because wide-ranging wildlife species may travel between and use multiple contaminated sites, they may be exposed to and be at risk from contaminants from multiple locations. Use (and therefore exposure and risk) of a particular contaminated site by wide-ranging species will be dependant upon the amount of suitable habitat available at that site. Therefore to adequately evaluate risks to wide-ranging species at the reservation-wide scale, the use of multiple contaminated sites must be weighted by the amount of suitable habitat on OUs. Highly contaminated OUs that provide little habitat are unlikely to be significant contributors to ORR-scale contaminant-associated risk. Conversely, moderately contaminated sites that contain considerable habitat may significantly contribute to ORR-scale contaminant-associated risk.

In spring of 1994, a series of data quality objectives meetings were held among the Federal Facilities Agreement (FFA) parties [i.e., U.S. Department of Energy (DOE), U.S. Environmental Protection Agency (EPA), Tennessee Department of Environment and Conservation] to develop an approach and plan for assessing risks to wide-ranging species that could not be adequately addressed

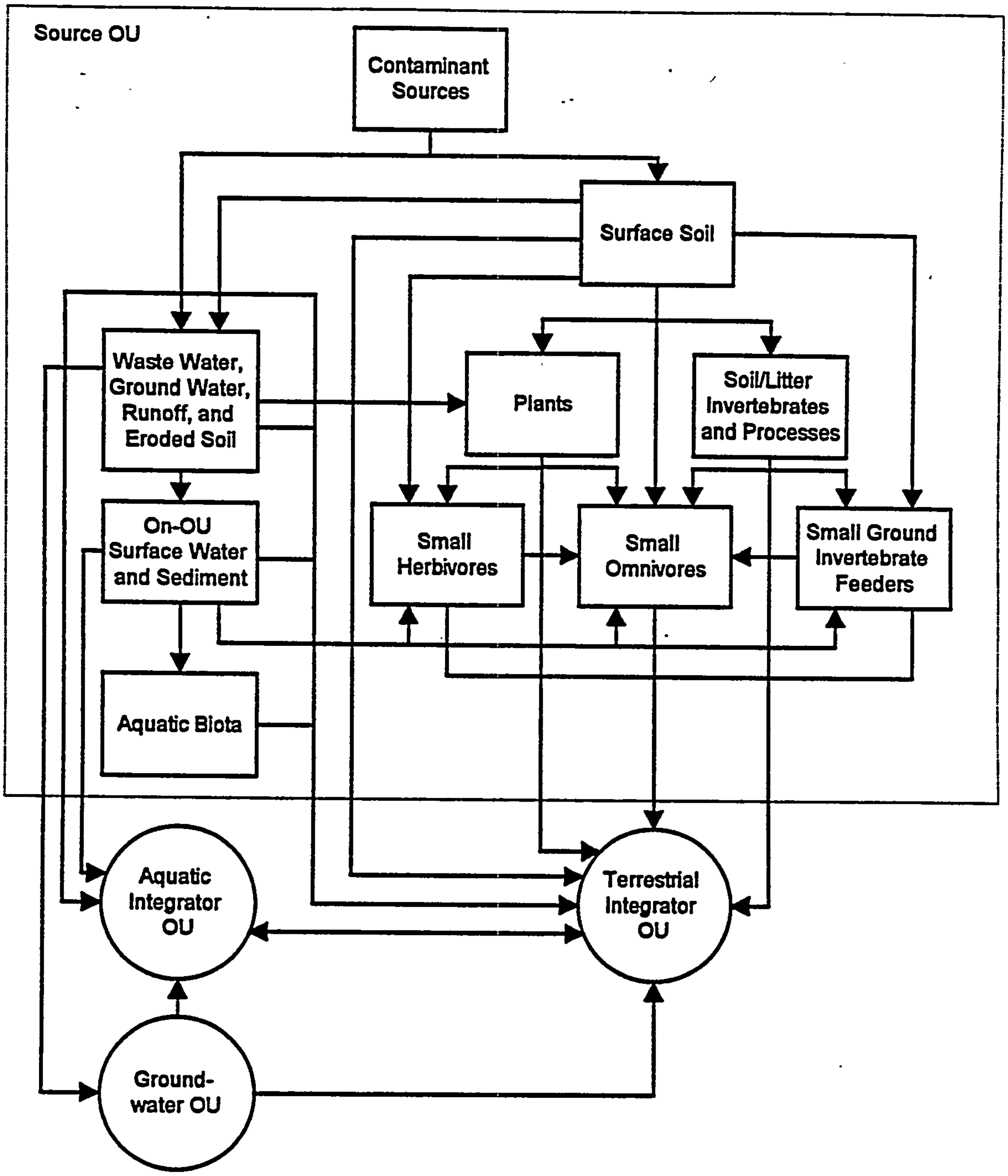

Fig. 1.1. Conceptual model of the transfer of contaminants through a source OU and into integrator OUs.

at the source OU level. The results of these discussions are presented in the ORR ecological risk assessment strategy document (Suter et al. 1994). This report is based on that document and presents the preliminary assessment of ecological risks to wide-ranging species from contaminants on the ORR.

The reservation-wide ecological risk assessment is intended to serve several purposes, including identifying (1) which endpoints are significantly at risk, (2) which contaminants are responsible for this risk, and (3) which OUs significantly contribute to risk. To address these issues, this report contains the following information:

- **An evaluation of the potential use of OUs by 57 endpoint species identified in Suter et al. (1994a)**—This is to identify endpoint species that may require additional attention in future assessments and is based on a comparison of species-specific habitat requirements and the amount of suitable habitat within OUs.

- **A preliminary ranking of OUs according to those that may present the greatest ecological risk**—This is to aid in the prioritization of OUs for potential remediation and is also based on habitat in OUs and the number of species for which this habitat is suitable.

- **A preliminary assessment of risks to piscivorous wildlife**—Because contaminants accumulate in aquatic systems, if reservation-scale risks are likely, they should be most evident among piscivores.

- **A preliminary assessment of risks to carnivorous, vermivorous, and herbivorous wildlife**—This is to demonstrate the applicability of habitat-based assessment methodology.

- **A proposed revision schedule**—Because this assessment is based on only a portion of the data available for the ORR and because remedial investigations (RIs) are currently in progress for two potential significant OUs [Waste Area Grouping (WAG) 2 and Bear Creek], periodic updates should be performed until all available data have been assembled, incorporated, and evaluated.

Detailed assessments of risk were not performed for all 57 endpoint species for which habitat availability on OUs was evaluated. Risks were evaluated only for selected piscivores, carnivores, vermivores, and herbivores. Selection of these trophic groups was determined by availability of data (i.e., fish body burdens, soil contaminant concentrations, soil-plant or soil-earthworm uptake factors). Risks to selected species from other trophic groups identified in Suter et al. (1994a) (i.e., aquatic herbivores, aquatic invertebrate feeders, flying insectivores, arboreal insectivores, large omnivores, scavengers) will be assessed in future revisions of this report.

The species for which detailed risk assessments were performed include mink, river otter, belted kingfisher, great blue heron, osprey, red fox, red-tailed hawk, wild turkey, white-tailed deer, American woodcock, and short-tailed shrew. These species were selected because they are known or expected to be sensitive to contaminants that are present on the ORR (i.e., mink, otter), are representative of groups that are likely to be highly exposed [i.e., piscivores (mink, otter, kingfisher, and heron) and vermivores (woodcock and shrew)], are threatened or endangered (T&E) species (i.e., osprey, otter) or a surrogates for related T&E species (i.e., red-tailed hawk, short-tailed shrew), or are well characterized on the ORR (site-specific data exists for mink, great blue heron, white-tailed deer, and wild turkey).

It should be emphasized that the results presented in this report are preliminary (i.e, based on only a subset of all data that exists on the ORR). The most relevant and accessible data have been selected for use at this time. As additional data are collected, made available, and incorporated, conclusions concerning the presence or magnitude of risks to wide-ranging species on the ORR may change. The quality and completeness of data used will be discussed in each chapter as it relates to the uncertainty of the risk assessment.

Assessment of ecological risks from radionuclides are not considered at this time. In human health risk assessment, the primary concern from exposure to radionuclides is increased incidence of cancer at the individual level. In ecological risk assessment, the concern is for population-level effects (except for T&E species, however). Because there is little evidence that cancer plays any significant role in wildlife populations, radionuclides were not considered at this time. Because of the importance and prevalence of radionuclide contamination on the ORR, risks associated with radionuclide exposure will be evaluated in future revisions of this report.

2. DATA

To identify data that would be useful for this project, a data search was initiated in which OU project managers were contacted and queried concerning the existence, status, nature, and availability of data concerning their OU. The search emphasized data concerning concentrations of contaminants in soil, water, sediment, and biota. The results of this survey are summarized in Appendix A. Briefly, although considerable data have been collected at OUs on the ORR, aside from data that currently reside in the Oak Ridge Environmental Information System (OREIS) or in the Bechtel Environmental Information Data Management System (BEIDMS)[1], much data were not readily available. The lack of availability was primarily a result of data being stored and maintained in multiple forms (electronic vs hard copy; various database programs, etc.). Compilation and standardization of the voluminous data for the ORR was beyond the current scope of this project. The data availability issue is currently being addressed through the Environmental Information Management Program as part of the ORR environmental restoration program.

Three general categories of data were identified, acquired, and used for this assessment. These include an reservation-wide land use/land cover classification (Washington-Allen et al. 1995), fish bioaccumulation data from the Biological Monitoring Programs, and soil contamination data derived from ORR computer databases (OREIS and BEIDMS).

The reservation-wide land use/land cover classification is presented in Washington-Allen et al. (1995). Availability and distribution of nine land use/land cover types (Table 2.1) on the ORR was determined through the use of satellite imagery and ground-truthing. These data were incorporated into a geographic information system (GIS) to produce a map of the available cover types on the ORR. OU boundaries were then overlaid on the reservation-wide cover map to produce OU-specific cover maps. Finally the area (ha) of each cover type on the ORR as a whole and within each OU was calculated.

Fish bioaccumulation data consisted of contaminant concentrations in fish and were derived from five sources. Descriptions of these data sets are presented here.

- **Name: Bear Creek OU4**
  - Spatial coverage: three locations in Bear Creek (BCK 12.4, BCK 9.4, and BCK 3.3) and one off-site location (Hinds Creek)
  - Analytes: metals and PCBs
  - Species: stone rollers
  - Principal investigator: George Southworth.

- **Name: Biological Monitoring and Abatement Program (BMAP) Bioaccumulation Task**
  - Spatial coverage: reservation-wide; 8 locations in vicinity of K-25, 2 locations in Bear Creek, 8 locations in White Oak Creek basin, and 7 locations in East Fork Poplar Creek
  - Analytes: primarily mercury and PCBs
  - Species: sunfish, largemouth bass, and carp
  - Principal investigators: George Southworth and Mark Peterson.

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[1]Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof.

Table 2.1. The land use/landcover classes used in habitat classification

Land use/landcover	Description
Urban land	Mixture of administrative buildings, laboratories, heavy commercial and industrial buildings, lawns, and clumped shade trees
Deciduous forest land	Areas of hardwood forest types
Mixed Forest Land	Areas of a mixture of hardwoods and pine trees
Evergreen forest land	Areas dominated by mature pine forest type with trees generally older than 35 years (in 1994) and having an uneven canopy
Evergreen plantation	Areas of pine trees which are row planted, are of uniform age, and are generally younger than 35 years (in 1994)
Pasture land	Fields of pasture grasses, grassland, row crops, and/or shrub land cover
Transitional areas	Secondary early successional sites, usually grassland to grassland shrub mix; generally mowed along power line corridors
Barren land	Cropped fields, plowed or bare ground areas, or areas where vegetation has been removed, such as construction sites or quarries

- **Name: Clinch River RI Program**
  Spatial coverage: Multiple locations in the Clinch and Tennessee rivers, and Poplar Creek. Data from one location in the Clinch River, near K-25, and 7 locations in Poplar Creek were used in this assessment.
  Analytes: metals, PCBs, pesticides, and other organics
  Species: sunfish, largemouth bass, catfish, carp, and shad

- **Name: K-901 Holding Pond**
  Spatial coverage: 1 location (K-901 pond)
  Analytes: metals, radionuclides, PCBs, pesticides, and other organics
  Species: shad, largemouth bass, and carp
  Principal investigator: Science Applications International Corporation

These data were combined into one large data set. While all small fish (stonerollers, shiners, and shad) were analyzed whole, all large fish (sunfish, largemouth bass, catfish, and carp) were analyzed as fillets only. Whole-body contaminant concentrations in large fish were estimated by using fillet-to-whole equations developed by Bevelheimer et al. (1996)

The last data set used in this report consists of contaminant concentrations in soil from OUs. These data were extracted from the OREIS and BEIDMS databases. The data were restricted to include only the top 2 ft of soil. This was assumed to include the soil horizons that wildlife species were most likely to be exposed to. Data were obtained for the following OUs: Bear Creek OU 2, Lower East Fork Poplar Creek, Upper East Fork Poplar Creek OU 2, WAG 1, WAG 6, South Campus Facility, K-1407, K-1414, and K-1420. In addition, soil data from risk assessments completed at four OUs (Chestnut Ridge OU 2, Bear Creek Valley OU, WAG 2, and WAG 5) were evaluated.

Again it should be noted that these data do not represent all available data. They simply represent a subset of the total that could be assembled, collated, and prepared at this time. Additional data will be acquired and incorporated in future revisions of this report.

3. EVALUATION OF POTENTIAL USE OF OPERABLE UNITS ON THE OAK RIDGE RESERVATION BY WILDLIFE

One of the primary factors determining the presence or absence of wildlife species in any area is the availability of suitable habitat. If suitable habitat is available (and the wildlife species of interest are present in the area), use of a site by wildlife is likely. Conversely, if no suitable habitat is available, use of the site is unlikely. In terms of risk to wildlife on the ORR, if an OU contains habitat for wildlife, it is likely to be used, and therefore wildlife that use the site may be exposed to contaminants and potentially be at risk. By comparing the habitat requirements of wildlife endpoints with the habitats available on OUs on the ORR, OUs that *may* present risk and endpoints that *may* be at risk can be identified.

Uncertainty associated with identifying OUs or endpoints as presenting or being at risk must be emphasized because contaminant data are not used in this evaluation; it is simply based on a co-occurrence of factors that increase the *potential* for an OU to present a risk or for an endpoint to be at risk. Although this evaluation can identify those species that are not at risk and OUs that do not present on-OU risk (if an OU contains no suitable habitat, use and exposure are unlikely, therefore risks are unlikely; it should be noted, however that OUs that do not contain any suitable habitat may act as sources of contamination to down gradient areas; therefore, although there may be no on-OU risks, they may contribute significantly to off-OU risks), without incorporating OU-specific contaminant data and estimating exposure, the actual nature and magnitude of risk at an OU cannot be determined.

Information concerning the habitat requirements for the 57 endpoint species identified in Suter et al. (1994) was obtained from the literature (Table B.1). These data were then compared to the nine landcover types identified on the ORR in Washington-Allen et al. (1995) to identify landcover types on the ORR that an endpoint is likely to use (Table B.2). Habitat requirements information for endpoint species was generally far more detailed than the landcover types identified on the ORR. Consequently some assumptions and professional judgments were applied in matching habitat requirements with available habitat types. For example, many species are listed as requiring floodplain, bottom land, or riparian forest (Table B.1). This habitat type is not specifically delineated in Washington-Allen et al. (1995). Because the dominant forest habitat types at the three OUs that are located in floodplains [WAG 2, Bear Creek, and Lower East Fork Poplar Creek (LEFPC)] are deciduous and mixed forest (Table B.3), if a species was identified as requiring floodplain forest, it was assigned to these habitats. This approach is conservative, because deciduous and mixed forests are not restricted to floodplain locations. A similar approach was used for other landcover types not specifically identified in Washington-Allen et al. (1995).

The amount of habitat (in ha) in each of the nine categories observed at each OU is summarized in Table B.3. The presence or absence of habitat for the 57 endpoint species at OUs at the K-25 Site, Oak Ridge National Laboratory (ORNL), and the Y-12 Plant are summarized in Tables B.4, B.5, and B.6, respectively. Tables B.7 and B.8 present the total number of OUs that provide habitat for each species and the total number of species with habitat on each OU, respectively. An OU was considered to have habitat for a species if any one of the landcover categories from Tables B.2 and B.3 coincided. Professional judgement was employed in determining if the habitat at an OU was suitable for an endpoint. For example, if the species required large bodies of water, and while water was present on an OU but consisted of a small stream, the habitat was considered unsuitable. Habitat was considered only on a presence/absence basis—the amount of habitat was not incorporated into the evaluation of whether or not an species would use an OU. It is recognized that this approach is overly simplistic and conservative. Use of an OU by a species will depend on the amount of habitat available (not just suitability), the connectivity of the on-OU habitat to similar habitat off the OU (isolated patches will receive less use than contiguous patches), and the amount of human activity in the vicinity (use by many species is inversely related to human activity). This evaluation was performed to determine simply if an endpoint could use an OU. A more detailed evaluation of the quality and quantity of habitat at an OU will be performed in a manner similar to that discussed in Chap. 5 as part of a future revision of this report.

As would be expected, OUs with high diversity of landcover types (i.e., many landcover types present on the OU) were determined to be able to support the greatest number of endpoint species (Table B.8). These OUs were also the largest on the ORR (Table B.3). Small OUs located within the plant sites [i.e., Upper East Fork Poplar Creel (UEFPC) OU 2 and OU 3] were estimated to support the lowest number of endpoint species. If potential on-OU risk is determined simply by the number of species that might use an OU, WAG 2, K-901, LEFPC, Bear Creek, and WAGs 4, 5, 6, and 7 present the greatest risk (Table B.8). OUs that present the least risk (based solely on number of endpoints) include K-1413, K-1004, K-1401, K-1420, UEFPC OU 2 and UEFPC OU 3.

Endpoint species estimated to be present at all 37 OUs are either habitat generalists (i.e., starlings, raccoons), tolerant of human activities (e.g., groundhog, American robins, Canada geese), or make use of structures (e.g., barn owl, Rafinesque's big-eared bat) (Table B.7). The next most common group of endpoint species (expected to be found at 31 OUs), consists of species with broad habitat preferences. These species use both forested and open (i.e., pasture and transitional) habitats. Species that require aquatic habitat (e.g., ponds, streams) are expected at 16 OUs, and only 3 OUs (K-901, K-1007, and WAG 2) are suitable for those species that need large bodies of water (bald eagle, osprey, double-crested cormorant, and gray bat) (Table B.7). Only three endpoint species are not expected to be present on any OUs on the ORR: golden eagles and cougars (the ORR as a whole probably does not provide sufficient suitable habitat for these species) and the Tennessee cave salamander (no caves are currently known to exist on any OU, therefore there is no habitat for this aquatic troglodytic salamander). The last endpoint, the green salamander, requires moist rock outcroppings. Locations and possible distributions of this habitat feature within OUs is unknown at this time.

3.1. QUALITY AND COMPLETENESS OF DATA

The completeness of data for this portion of the assessment is adequate; however, the quality of data needs improvement. Although a highly significant first step, the level of detail in the ORR landcover map is far less than what is needed to accurately estimate the actual presence of suitable habitat on each OU. Incorporation of aspect and elevation data in the ORR landcover map would be useful to differentiate dry upland sites from moist bottom lands. It would also allow floodplain habitats to be delineated. Additional, more detailed data on habitat requirements (and their relative value) for each endpoint species would also increase the precision in the habitat use predictions for each OU. By combining the relative habitat preferences for each endpoint species with the amounts of each habitat type present on each OU, a better estimate of the likelihood of use (and therefore the potential for exposure and risk) may be obtained.

4. ASSESSMENT OF RISKS TO PISCIVORES ON THE OAK RIDGE RESERVATION

Numerous, significant changes have been made throughout this section. To facilitate the flow of the document, they are summarized below but are not specifically identified in the text. The major changes in this section include the following:

- Use of BMAP bioaccumulation data only from 1994 and 1995;
- Exclusion of LEFPC RI fish data
- Inclusion of Clinch River RI fish data
- Focus on only two contaminants: mercury and PCBs. All others not considered because of a lack of ORR-wide data
- Estimated whole fish contaminant concentrations using models developed by Bevelheimer et al. (1996) instead of simple fillet–whole fish ratios.
- Use of updated benchmarks that reflect regulator comments concerning scaling factors.
- Inclusion in assessment of osprey for areas where appropriate habitats were available.
- Weighted piscivore exposures by the relative density or biomass of fish in sampling areas as per regulator comments.

4.1 PROBLEM FORMULATION

This section discusses the attributes and selection of appropriate ecological endpoints, describes the ecological setting, provides information on the sources and hazards to which organisms may be exposed, and integrates this information into a conceptual model that portrays the interaction among sources and endpoints at the sites. The information provided here sets the stage for the exposure assessment section that follows.

4.1.1 Ecological Assessment Endpoints

The hazard identification phase of an ecological risk assessment must identify both the assessment endpoints, which are explicit statements of the characteristics of the environment that are to be protected, and the measurement endpoints, which are quantitative summaries of a measurement or series of measurements that are related to effects on an assessment endpoint.

4.1.1.1 Assessment endpoints

The following assessment endpoints were selected for the assessment of risks to piscivorous wildlife: toxicity to mink (*Mustela vison*), river otter (*Lutra canadensis*), belted kingfisher (*Ceryle alcyon*), great blue heron (*Ardea herodias*), and osprey (*Pandion haliaetus*) resulting in a reduction in population abundance or production. These assessment endpoints are those that have been agreed to be appropriate for the ORR by the FFA parties (Suter et al. 1995). The criteria for selection of the entities are those recommended by EPA (1992), plus considerations of scale and practical considerations.

Both osprey and river otter are listed as a threatened species by the Tennessee Wildlife Resources Agency (TWRA). Osprey are found along the Clinch River and Poplar Creek adjacent to the ORR and use larger bodies of water on the ORR. Although otter are not known to occur on the ORR at the present time, they have been included in this assessment because the ORR contains suitable habitat, a reintroduction program is underway in East Tennessee, and they may become established on the ORR in the future. To determine if the ORR could support this threatened species, the nature and magnitude of risk that contaminants on the ORR may present to otter must be evaluated.

The appropriate properties of the entities selected by these criteria depend on the level of organization of the entity and the criteria that led to their selection. **Organism level**—In general, protection of individual organisms is appropriate only for threatened and endangered species. Two of the selected species, osprey and river otter, are T&E species; therefore, organism-level properties were used for these assessment endpoints. **Population level**—The appropriate endpoint properties for populations of endpoint species are abundance and production.

Finally, the level of effects on these properties of the endpoint entities that is considered to be potentially significant is 20% as agreed by the FFA parties (Suter et al. 1995). This level is consistent with current regulatory practice.

Assessment of piscivores is a logical first step to evaluate reservation-wide risks. Contaminants present on the ORR are known to accumulate readily in aquatic foodwebs (i.e., mercury and PCBs). Some piscivores (mink in particular) are known to be sensitive to mercury and PCBs. The diet of piscivores frequently consists exclusively of fish or other aquatic prey, therefore members of this group are likely to be highly exposed. Finally, most piscivores are highly mobile, they therefore may be exposed to contaminants from multiple locations.

The ORR was partitioned into four watersheds: Bear Creek, East Fork Poplar Creek, the K-25 area (consisting of the K-25 ponds, Mitchell Branch, and Poplar Creek and the Clinch River adjacent to the K-25 plant), and White Oak Creek (including White Oak Lake and the White Oak Lake embayment). Risks were evaluated within each watershed, and these results were used to determine risks to piscivores across the ORR as a whole.

4.1.1.2 Measurement endpoints

Three basic types of effects data are potentially available to serve as measurement endpoints: results of biological surveys, toxicity tests performed using fish from the ORR, and literature-derived toxicity test results for chemicals found on the ORR. The following are measurement endpoints for each assessment endpoint:

- **Mink**
  - Biological survey data—Limited data concerning presence/absence, movements, and bioaccumulation of contaminants are available for mink on the ORR.
  - Media toxicity data—Results of reproductive toxicity tests are available for ranch mink fed fish obtained from the Poplar Creek embayment.
  - Single chemical toxicity data—These data consist of chronic toxicity thresholds for contaminants of concern in mammals with greater weight given to data from long-term feeding studies with wildlife species. Preference was also given to tests that included reproductive endpoints. These test endpoints are assumed to correspond to the assessment endpoint after allometric scaling.

- **River otter**
  - Biological survey data—None.
  - Media toxicity data—Results of reproductive toxicity tests are available for ranch mink fed fish obtained from the Poplar Creek embayment. Because both mink and otter are mustelids,

the test endpoints for mink are assumed to correspond to the assessment endpoint (otter) after allometric scaling.
- — Single chemical toxicity data—These data consist of chronic toxicity thresholds for contaminants of concern in mammals with greater weight given to data from long-term feeding studies with wildlife species. Preference was also given to tests that included reproductive endpoints. These test endpoints are assumed to correspond to the assessment endpoint after allometric scaling.

- **Belted kingfisher**
  - — Biological survey data—Limited data concerning bioaccumulation of contaminants are available for belted kingfisher on the ORR.
  - — Media toxicity data—None.
  - — Single chemical toxicity data—These data consist of chronic toxicity thresholds for contaminants of concern in birds with greater weight given to data from long-term feeding studies with wildlife species. Preference was also given to tests that included reproductive endpoints. These test endpoints are assumed to correspond to the assessment endpoint after allometric scaling.

- **Great blue heron**
  - — Biological survey data—Field data concerning contaminant bioaccumulation and reproductive success were available for 4 heron rookeries near the ORR (2 rookeries <10 km and 2 rookeries >10 km from ORR; an additional 3 rookeries are located <10 km from the ORR. No data are available from these locations).
  - — Media toxicity data—None.
  - — Single chemical toxicity data—These data consist of chronic toxicity thresholds for contaminants of concern in birds with greater weight given to data from long-term feeding studies with wildlife species. Preference was also given to tests that included reproductive endpoints. These test endpoints are assumed to correspond to the assessment endpoint after allometric scaling.

- **Osprey**
  - — Biological survey data—Field data concerning reproductive success was available for three osprey nests adjacent to the ORR (2 located on Melton Hill Reservoir, and one in Poplar Creek, near K-25).
  - — Media toxicity data—None.
  - — Single chemical toxicity data—These data consist of chronic toxicity thresholds for contaminants of concern in birds with greater weight given to data from long-term feeding studies with wildlife species. Preference was also given to tests that included reproductive endpoints. These test endpoints are assumed to correspond to the assessment endpoint after allometric scaling.

4.1.2 Ecological Conceptual Model

The ecological conceptual model graphically represents the relationships between the contaminant sources and the endpoint receptors. It integrates the information in the other subsections of the hazard identification and presents them graphically. It is not intended to show all of the possible sources, routes of transport, modes of exposure, or effects. Rather, it includes the only identified CERCLA source, the receptors that are designated as assessment endpoint species or communities, and the major routes that result in exposure to contaminants from the ORR.

The conceptual model for exposure of piscivores to contaminants is presented in Fig. 4.1. Components of this model include aquatic biota (aquatic plants, invertebrates, fish, and amphibians) that reside in ponds and streams on the ORR and the piscivorous wildlife that feeds on aquatic biota. The aquatic biota are exposed to contaminants from surface water and sediments. Contaminants are bioaccumulated in lower trophic levels (i.e., plants or invertebrates) and transferred to higher trophic levels (i.e., invertebrates, fish, or amphibians). Piscivorous wildlife consume fish, amphibians, and invertebrates and are therefore exposed to accumulated contaminants (Fig. 4.1).

4.2 EXPOSURE ASSESSMENT

Piscivorous wildlife may be exposed to contaminants through ingestion of contaminated media (fish, other aquatic prey, and water) and through contaminants accumulated in the tissues of the piscivore itself. In this assessment, ingestion of food was the only pathway considered. Exposure through ingestion of water will be included in a future revision. Contaminant exposure through ingestion was estimated for mink, otter, belted kingfisher, great blue heron, and osprey. This assessment focused only on the two contaminants, mercury and PCBs, for which there is ORR-scale data. Data on mercury and PCB concentrations in fish were available from the four watersheds on the ORR. Exposure estimates were calculated for 37 locations on the ORR: 5 locations in Bear Creek, 7 locations in East Fork Poplar Creek, 17 locations in the vicinity of the K-25 Site, and 8 locations in the White Oak Creek basin. Exposure through contaminants accumulated in tissues was measured for nestling great blue herons and among adult kingfishers. Locations of sampling locations within Bear Creek, East Fork Poplar Creek, the K-25 Site, and White Oak Creek are presented in Figs. C.1 through C.4.

4.2.1 Exposure Through Oral Ingestion of Fish

For exposure estimates to be useful in the assessment of risk to wildlife, they must be expressed in terms of a body weight–normalized daily dose or milligram contaminant per kilogram body weight per day (mg/kg/d). Exposure estimates expressed in this manner may then be compared with toxicological benchmarks for wildlife, such as those derived by Sample et al. (1996a), or to doses reported in the toxicological literature. Estimation of the daily contaminant dose an individual may receive from a particular medium for a particular contaminant may be calculated by using the following equation:

$$E_j = \sum_{i=1}^{m} \left(\frac{IR_i \; x \; C_{ij}}{BW} \right) \qquad (1)$$

where:

E_j = total exposure to contaminant (j) (mg/kg/d)
m = total number of ingested media (e.g., food, water, soil)
IR_i = consumption rate for medium (I) (kg/d or L/d)
C_{ij} = concentration of contaminant (j) in medium (I) (mg/kg or mg/L)
BW = body weight of endpoint species (kg).

Exposure estimates were calculated for all contaminants detected at all ORR sampling locations. Because wildlife are mobile, their exposure is best represented by the mean contaminant concentration

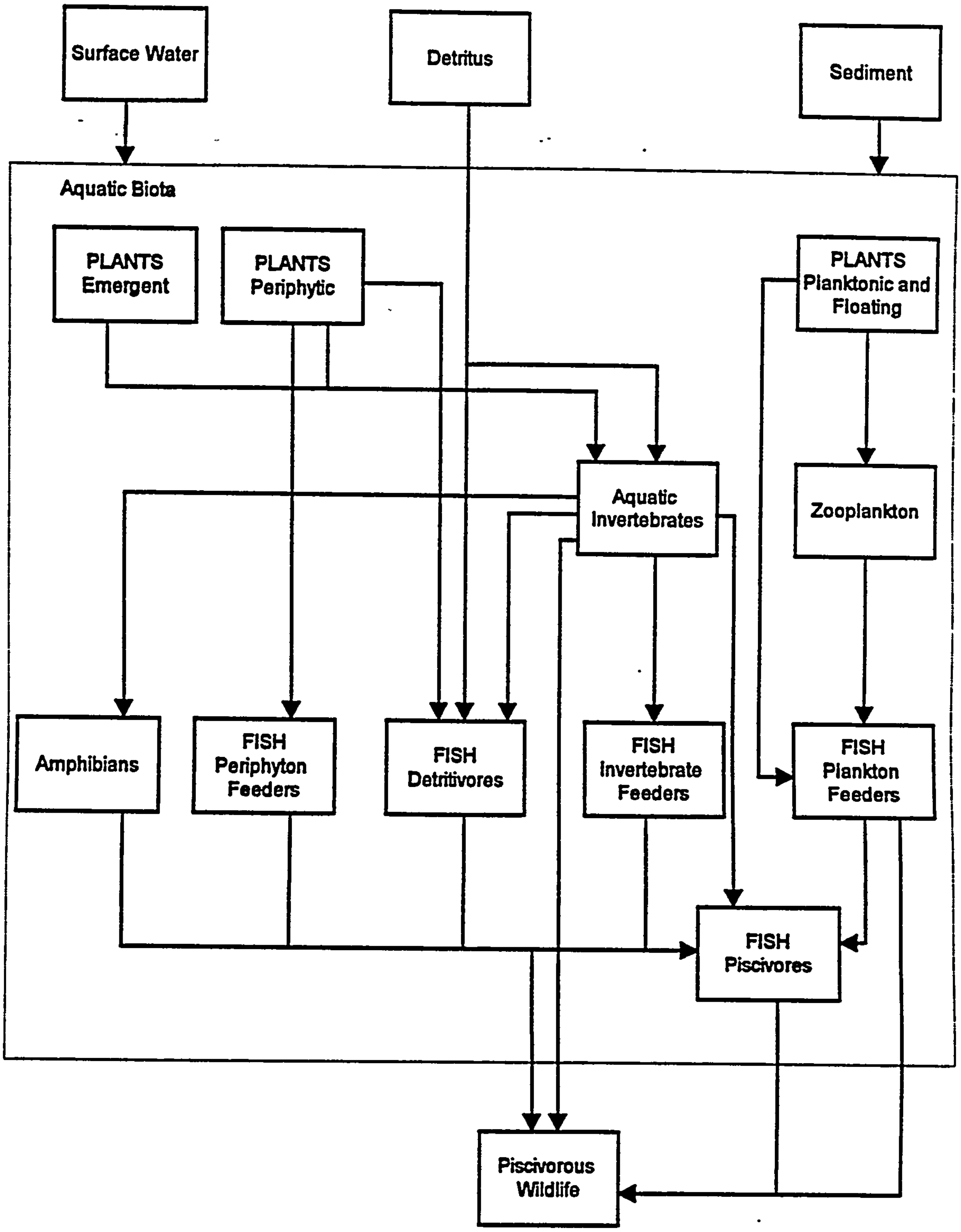


Fig. 4.1. Conceptual model for the exposure of piscivorous wildlife to contaminants.

in media. To be conservative, the 95% upper confidence limit (UCL) is used in exposure estimates. To prevent bias that may result from calculating 95% UCLs using data that contains values below the detection limit, product limit estimator (PLE) was used to calculate the 95% UCLs for contaminants observed in fish and water These data were used in the initial exposure estimates. Exposure estimates for contaminants that may potentially present a risk to piscivorous wildlife [based upon comparisons to no observed adverse effects levels (NOAELs) and LOAELs] were recalculated using Monte Carlo simulations. [**Note: Because the purpose of the initial exposure estimate is to be conservative and to identify contaminants of potential ecological concern (COPECs), the 95% UCL was used regardless of whether or not the value exceeded the maximum observed value. Overestimates of exposure that may occur at the screening level are addressed through the use of Monte Carlo simulation.]**

4.2.1.1 Estimation of whole fish contaminant concentrations from fillet data

Fish data from the ORR consisted of analyses of both whole body concentrations (generally in stonerollers, shiners, and shad) and concentrations in fillets (in sunfish, largemouth bass, and carp). Because piscivores consume whole fish (not fillets) and fillet concentrations do not accurately represent whole body concentrations, it was necessary to estimate concentrations in whole fish for those sample for which only fillet analyses were performed. Whole-fish concentrations were estimated by using the following equations:

for mercury:

$$C_{WB} = e^{[-0.8 + 0.76 * \ln(C_F)]} \qquad (2)$$

for PCBs in catfish:

$$C_{WB} = e^{[0.16 + 0.54 * \ln(C_F)]} \qquad (3)$$

for PCBs in bass or other fish:

$$C_{WB} = e^{[0.81 + 0.95 * \ln(C_F)]} \qquad (4)$$

where:

C_{WB} = whole body contaminant concentration
C_F = fillet contaminant concentration

A detailed discussion of the development of these equations is presented in Bevelheimer et al. (1996).

4.2.1.2 Contaminant concentrations in fish

Contaminant concentrations in fish are needed to estimate exposure. The 95% UCLs (calculated by using the PLE) for contaminants detected in fish from the ORR are presented in Table C.6. Note that data were aggregated into two size classes: <30 cm and >30 cm in length. This is because piscivore species forage on different size fish and contaminant body burdens are related to size (larger, older fish generally have higher contaminant concentrations). Although mink, belted kingfisher, and great blue heron generally consume fish <30 cm in size, osprey and otter forage equally on small and large fish (see Tables C.1 to C.5). To more accurately reflect exposure, data were segregated according to size and exposure was estimated by using data from the size of fish most likely to be consumed by that endpoint species. Because it was assumed that piscivores would select fish according to size and not by species, all species were pooled within each size class.

Although data concerning fish size were included in the BMAP, Bear Creek OU4, and Clinch River RI, fish sizes were not included in the K-901 data set. On the basis of the size data in the first three data sets, all sunfish, stonerollers and shad were assumed to be <30 cm in size and largemouth bass and carp were assumed to be >30 cm for the K-901 data sets.

4.2.1.3 Exposure modeling using point-estimates

Initial estimates of exposure of piscivorous wildlife to contaminants were performed for each sampling point using point estimates of parameters in the exposure model (Equation 1). Species-specific parameters necessary to estimate exposure using Equation 1 are listed in Tables C.1–C.5.

To estimate contaminant exposure experienced by mink, the following assumptions were made:

- Body weight = 1 kg.
- Food consumption = 0.137 kg/d (fresh weight).
- Diet consists 54.6% of fish or other aquatic prey.
- Contaminant concentration in fish is representative of that in other aquatic prey.
- Fish sizes consumed = 100% <30 cm.

To estimate contaminant exposure experienced by otter, the following assumptions were made:

- Body weight = 8 kg.
- Food consumption = 0.9 kg/d (fresh weight).
- Diet consists 100% of fish or other aquatic prey.
- Contaminant concentration in fish is representative of that in other aquatic prey.
- Fish sizes consumed = 50% <30 cm and 50% >30 cm.

To estimate contaminant exposure experienced by kingfisher, the following assumptions were made:

- Body weight = 0.148 kg.
- Food consumption = 0.075 kg/d (fresh weight).
- Diet consists 100% of fish.
- Fish sizes consumed = 100% <30 cm.

To estimate contaminant exposure experienced by great blue heron, the following assumptions were made:

- Body weight = 2.39 kg.
- Food consumption = 0.42 kg/d (fresh weight).
- Diet consists 100% of fish or other aquatic prey.
- Contaminant concentration in fish is representative of that in other aquatic prey.
- Fish sizes consumed = 100% <30 cm.

To estimate contaminant exposure experienced by osprey, the following assumptions were made:

- Body weight = 1.5 kg.
- Food consumption = 0.3 kg/d (fresh weight).
- Diet consists 100% of fish or other aquatic prey.
- Contaminant concentration in fish is representative of that in other aquatic prey.
- Fish sizes consumed = 92.1% <30 cm and 7.9% >30 cm.

Using Equation 1 and the assumptions and data described above, exposure to contaminants was estimated for mink (Table C.7), otter (Table C.8), kingfisher (Table C.9), and great blue heron (Table C.10) for each location on the ORR. Because osprey use only large bodies of water, exposure estimates were generated for only for those areas where suitable habitat was availabale (the K-25 Site and White Oak Lake and embayment; Table C.11).

4.2.1.4 Exposure modeling using Monte Carlo simulations

Employing point estimates for the input parameters in the exposure model does not take into account the variation and uncertainty associated with the parameters and therefore may over or under estimate the contaminant exposure that endpoints may receive in any given reach. In addition, calculating the model using point estimates produces a point estimate of exposure. This estimate provides no information concerning the distribution of exposures or the likelihood that individuals within a watershed will actually experience potentially hazardous exposures. To incorporate the variation in exposure parameters and to provide a better estimate of the potential exposure experienced by piscivores on the ORR, the exposure model was recalculated with the Monte Carlo simulations.

Monte Carlo simulation is a resampling technique frequently used in uncertainty analysis in risk assessment (Hammonds et al. 1994). In practice, distributions are assigned to input parameters in a model, and the model is recalculated many times to produce a distribution of output parameters (e.g., estimates of contaminant exposure). Each time the model is recalculated, a value is selected from within the distribution assigned for each input parameter. As a result, a distribution of exposure estimates is produced that reflects the variability of the input parameters. To determine which input parameters most strongly influence the final exposure estimate, a sensitivity analysis is performed (Hammonds et al. 1994). Detailed discussions of sensitivity and uncertainty analysis, and the use of Monte Carlo simulations in risk assessment are provided by Hammonds et al. (1994).

Monte Carlo simulations were performed to estimate watershed-wide exposures. It was assumed that wildlife were more likely to forage in areas where food is most abundant. Density or biomass of fish at or near locations where fish bioaccumulation data were collected were assumed to represent measures of food abundance. (Biomass data were prefered but were unavailable for all watersheds. Where unavailable, density data were used.) The relative proportion that each location contributed to overall watershed density or biomass data was used to weight the contribution to the watershed-level exposure. The watershed level exposure was estimated to be weighted average of the exposure at each location sampled within the watershed. In this way, locations with high fish densities or greater fish biomass contribute more to exposure than do locations with lower density or biomass. Fish density or biomass data used to weight exposure for the Bear Creek, East Fork Poplar Creek, and White Oak Creek watersheds are presented in Tables C.12 through C.14, respectively.

No data were available with which to weight exposures in the K-25 area. Therefore watershed-level exposures for this watershed represent the average exposure at each sampled location. Each location contributes equally to the total, with no preferential weighting applied.

The percentiles of the resulting exposure distributions represent the likelihood that an individual piscivore within a watershed will experience a given exposure level. Watershed-wide simulations were performed for mercury and PCBs because these contaminants are among the most important on the ORR and data for these contaminants were available at all sampling locations.

Distributions were used for the contaminant concentrations in fish and for the proportion of fish in the diet of mink. All contaminant distributions were assumed to be lognormal. Lognormal means and standard deviations for contaminants in fish are presented in Table C.6.

The proportion of aquatic prey in the diets of otter, kingfisher, and herons were assumed to be 100%. No data suggest that nonaquatic prey constitute a significant portion of their diet (see endpoint discussion, above). In contrast, mink have a very variable diet. Aquatic prey (fish, amphibians, crayfish, etc.) may make up from 16% to 92%. Nine observations from five studies indicate the proportion of aquatic prey to be 0.546 ± 0.21 (mean ± standard deviation; Table C.1). The proportion of aquatic prey in the diet of mink was assumed to be normally distributed.

Monte Carlo simulations were performed using the @Risk software. Samples from each distribution were selected with Latin hypercube sampling. The number of iterations, or recalculations, of each exposure simulation was determined by the convergence criteria set in the software. Under these criteria, iterations are performed until the between-iteration percent change in the percentiles, mean, and standard deviation are below 1.5% (i.e., the percentile, mean, and standard deviation for the latest iteration is <1.5% different than the those from the previous iteration). Using this convergence criteria, from 600 to 1000 model iterations were performed for each exposure estimate. Monte Carlo estimates of contaminant exposures are presented in Table C.16.

4.2.2 Internal Exposure of Great Blue Herons to Contaminants

To determine if contaminants from the ORR are being bioaccumulated by piscivorous wildlife, great blue heron eggs and chicks were collected from two colonies located within 3 km of the ORR and two colonies located >10 km from the site (Halbrook, unpubl. data; see Appendix F). Analyses were performed to determine the concentrations of arsenic, chromium, mercury, and PCBs in eggs, and feathers, liver, fat, and muscle of chicks. Elevated levels of Cr, Hg, and PCBs were observed in eggs from the ORR colonies (Tables F.2 and F.4). Mercury concentrations in feathers and liver (Table D.3, Appendix D) and PCB concentrations in fat (Table F.5), liver (Table F.6), and muscle (Table F.7) were significantly elevated in samples from the ORR as compared to data from the off-site locations. A detailed discussion of these data is presented in Appendix F.

4.3 EFFECTS ASSESSMENT FOR PISCIVOROUS WILDLIFE

4.3.1 Single Chemical Toxicity Data

Single-chemical toxicity data consist of NOAELs and LOAELs of toxicity studies reported in the literature.

In cases where an NOAEL for a specific chemical was not available, but a LOAEL had been determined experimentally or where the NOAEL was from a subchronic study, the chronic NOAEL was estimated. EPA (1993c) suggests the use of uncertainty factors of 1 to 10 for subchronic to chronic NOAEL and LOAEL to NOAEL estimation. Because no data were available to suggest the use of lower values, uncertainty factors of 10 were used in all instances in which they were required.

Smaller animals have higher metabolic rates and are usually more resistant to toxic chemicals because of more rapid rates of detoxification. In mammals, it has been shown that metabolism is best expressed in terms of body weight (bw) raised to the 3/4 power ($bw^{3/4}$) (EPA 1995). If the dose (d) itself has been calculated in terms of unit body weight (i.e., mg/kg), then the metabolic rate-based dose (D) equates to

$$D = \frac{d \ x \ bw}{bw^{3/4}} = d \ x \ bw^{1/4}. \tag{5}$$

Mineau (1996) reports that the mean allometric scaling factor for chemical toxicity to birds is 1.15 and may range as high as 1.55. Because the allometric scaling factors for the majority of the chemicals evaluated were not significantly different from 1, 1 was used as the best estimate of the allometric scaling factor for birds. If the dose (d) itself has been calculated in terms of unit body weight (i.e., mg/kg), then the dose per unit body surface area (D) equates to

$$D = \frac{d \ x \ bw}{bw^{1}} = d \ x \ bw^{0}. \tag{6}$$

The assumption is that the effective dose per body surface area for species "a" and "b" would be equivalent. Therefore, knowing the body weights of two species and the dose (d_b) producing a given effect in species "b," the dose (d_a) producing the same effect in species "a" can be determined. Using this approach, if a NOAEL was available for a mammalian test species ($NOAEL_t$), the equivalent NOAEL for a mammalian wildlife species ($NOAEL_w$) was calculated by using the adjustment factor for differences in body size:

$$NOAEL_w = NOAEL_t \left(\frac{bw_t}{bw_w} \right)^{1/4}. \tag{7}$$

For birds, if a NOAEL was available for an avian test species ($NOAEL_t$), the equivalent NOAEL for an avian wildlife species ($NOAEL_w$) would be calculated by using the adjustment factor for differences in body size:

$$NOAEL_w = NOAEL_t \left(\frac{bw_t}{bw_w} \right)^{0} = NOAEL_t \ (1) = NOAEL_t. \tag{8}$$

This methodology for toxicity extrapolation is equivalent to that EPA uses in their carcinogenicity assessments and Reportable Quantity documents for adjusting from animal data to an equivalent human dose.

NOAELs and LOAELs were derived for mink, river otter, belted kingfisher, great blue heron, and osprey. Mammalian and avian NOAELs and experimental information used to estimate wildlife NOAELs and LOAELs (e.g., test species, test endpoints, citation) are listed in Tables C.16 and C.17. Ecotoxicological profiles of the effects of mercury and PCBs to wildlife are presented in Appendix D.

4.3.2 Effects of Contaminants on the Reproductive Performance of Mink

At the Michigan State University Experimental Fur Farm, Halbrook (unpubl. data; see Appendix E) evaluated bioaccumulation of contaminants and reproductive effects in mink fed fish collected from Poplar Creek, the Clinch River (upstream of Melton Hill Dam), and the ocean. Mink were fed five diets consisting of 75% fish and 25% commercial mink diet. The diet composition and contaminant concentrations for each diet are described in the following table:

		Contaminant concentration (mg/kg)	
Diet	**Fish composition**	**Mercury**	**PCB 1260**
A	75% ocean	0.02 ± 0.00	0.169 ± 0.002
B	75% Clinch River	0.05 ± 0.00	11.44 ± 0.327
C	25% Poplar Creek 50% ocean	0.09 ± 0.00	4.69 ± 0.174
D	50% Poplar Creek 25% ocean	0.15 ± 0.01	10.41 ± 0.250
E	75% Poplar Creek	0.22 ± 0.01	20.67 ± 0.458

Twenty-three PCB congeners were also present in varying amounts. Concentrations of most congeners increased progressively from diets A through E (Table E.5).

Ten mink (eight females and two males) were fed each diet for ~7 months (3 months before breeding—6 weeks postpartum). Reproductive indices measured included number of females mated; number of females whelping; length of gestation; number of kits whelped (alive, dead); kit sex ratio; average kit body weight at birth, 3, and 6 weeks of age; and kit survival to 3 to 6 weeks of age. At 6 weeks of age, 3 kits from dietary groups A, B, C, and E were euthanized, organs (liver, spleen, and kidneys) were weighed, and tissue samples (liver, kidney, and remaining carcass) were analyzed for contaminant accumulation. (Note: kits from diet D were not sampled). At the termination of the study, all adult mink were necropsied. Organs (brain, liver, kidneys, heart, lungs, gonads, and adrenal glands) were weighed and examined for histopathologies. Adipose tissue, liver, kidney, and hair were analyzed for contaminant accumulation. Liver tissue also was analyzed for ethoxyresorufin-o-deethylase (EROD) activity.

The bioaccumulation of mercury in liver, kidney, and hair (Table E.3) and of Aroclor 1260 (and other PCB congeners) in liver and fat (Tables E.6 and E.7) substantially increased in adult female mink from groups fed diet A up to diet E. Mink offspring also bioaccumulated mercury in kidney tissue and carcasses and many other PCB congeners in the liver and carcasses (Tables E.8 and E.9), increasing progressively from mink fed diets A through E. The lowest levels were observed for mink fed diet A and increased to a maximum observed among mink fed diet E.

Significant effects were observed only among mink fed diet E; no adverse effects were observed for any other diet. Adverse effects from diet E included weight reduction in adult mink and their offspring, reduction in litter size, and increase in liver EROD activity in adult females. Weight reduction was observed at the end of the experimental period, increasing magnitude from diet groups A to E. At the end of the experiment, the mean whole body weights of female mink in diet group E were significantly less ($p = 0.03$) than mean weights of females in diet group A (percent reduction = 20%). Mean female relative organ weights (organ weights/body weight) were not significantly different among diet groups. At 6 weeks of age, mean whole body weights were also significantly lower ($p = 0.004$) in male kits from diet group E compared with those from diet group A (percent reduction = 17%). Similar trends were observed for female kits, although differences were not statistically significant. No histological lesions were attributed to any diet. Mean litter size was significantly reduced ($p = 0.01$) in diet group E compared with diet groups A, B, and C (percent reduction relative to diet A = 38%) but not with diet group D. Liver EROD activity was significantly increased in adult female mink from diet groups D and E compared with those from diet group A.

4.3.3 Biological Surveys

4.3.3.1 Great blue heron reproduction survey

To determine if contaminants from the ORR are adversely affecting great blue heron, Halbrook (unpubl. data; see Appendix F) monitored the reproductive success at two heron colonies located adjacent to the ORR and two colonies located >10 km from the reservation. Data were collected from each nest colony between 1992 and 1994. The mean number of eggs/nest, number of chicks/nest, egg weight, and eggshell thickness did not differ between colonies within 3 km of the ORR and those >10 km away (Table F.8). A detailed discussion of these data are presented in Appendix F.

4.3.3.2 Mink survey

Stevens (1995) investigated bioaccumulation of mercury in mink on the ORR in 1993 through 1995. The methods used in the mink survey, although indicating that mink are present on the reservation, cannot be used to estimate abundance or density on mink on the ORR. A total of 4 male mink were live-trapped over the course of 6073 trapnights (trapnight = 1 trap set for 24 h). One juvenile was captured along East Fork Poplar Creek, two adults were captured along Bear Creek, and one adult was captured along White Oak Creek. Captured mink were fitted with an intraperitoneal radio transmitter (to monitor movements and home range) and released. Before release samples of hair were collected and metals analysis were run. An additional eight roadkill mink (five male and three female) were collected from the ORR and surrounding areas of Roane and Anderson counties. One roadkill sample (a male) was collected on a bridge over Bear Creek and was assumed to be a resident of Bear Creek; all others were collected off the ORR and were used as references. The results of metals analysis are presented in the following table:

Metal concentrations in hair of mink from the ORR and from off-site reference samples
(mean ± standard deviation mg/kg dry weight)

Site	N	Hg	Se	As	Cd	Pb
East Fork Poplar Creek	1	104	0.69	not detected	not detected	0.33
Bear Creek	3	10.97 ± 3.42	1.88 ± .1.41	0.15 ± 0.09	0.04 ± .0.02	0.97 ± 1.28
White Oak Creek	1	8.8	1	not detected	not detected	0.37
Off site	7	5.15 ± 3.43	1.11 ± 0.25	0.22 ± 0.31	0.04 ± 0.02	0.7 ± 0.31

Radiotelemetry data on home ranges and movements were obtained for 3 mink—one each from the East Fork Poplar Creek, Bear Creek, and White Oak Creek watersheds. Mean (± standard deviation) home range for these three individuals was found to be 7.5 ± 3 km of stream. The entire home range of the East Fork Poplar Creek mink was in a highly urbanized area; it included all of upper East Fork inside the Y-12 Plant and all areas of East Fork upstream of the Oak Ridge Turnpike–Illinois Avenue intersection. The home range of the White Oak Creek mink included all of White Oak Creek from the headwater tributaries to the Clinch River, including ORNL. This individual was observed to use dens within ORNL and moved through the facility on several occasions.

4.3.3.3 Belted kingfisher survey

A field monitoring effort (Baron et al. 1996) was initiated in 1994 to evaluate population parameters and contaminant bioaccumulation by belted kingfisher on the ORR. Areas surveyed included White Oak Creek (WOC), White Oak Lake (WOL), White Oak Lake embayment, Melton Branch, Poplar Creek, portions of East Fork Poplar Creek (EFPC) (within Y-12 Plant to downstream of Lake Reality and approximately 1 mile east of the confluence of Poplar Creek), and portions of Bear Creek.

Methods. Nest burrows were monitored for nesting activity. If activity was observed, samples of feathers and eggshells were collected. In addition to specimens collected from the burrows, three carcasses of adult kingfisher were found on the ORR (two from East Fork Poplar Creek and one from White Oak Creek). These carcasses were necropsied; organs were extracted and analyzed for metals and radionuclides. Additional detail concerning methods are reported in Baron et al. (1996).

Results. During April–July of 1994, a total of 27 potential kingfisher burrows were identified on the ORR, 11 of which contained swallow nests. Twenty-five of these burrows were found on the Clinch River. One kingfisher burrow, containing a single unhatched kingfisher egg, was found on White Oak Creek [downstream of White Oak Creek Kilometer (WCK) 3.5].

One active burrow, containing a clutch of 6–7 eggs, was found on the Clinch River. This burrow was later abandoned with no sign of the eggs or the parents. Another burrow, containing 6 nestlings was located on the Clinch River approximately 12 miles upstream of all DOE contaminant outfalls. It was, therefore, considered uncontaminated. Three weeks following the initial observation of this burrow, three nestlings had fledged and three had died. Feathers were collected and analyzed.

Results of residue analysis for eggshells and feathers from nestlings are presented in Table C.18; results for adult carcasses are presented in Table C.19.

Nestling feathers collected from the burrow on the Clinch River, upstream of ORR outfalls (Table C.18), contained relatively low levels of metal and radioactive contaminants. Feathers from the carcasses of three fledglings accumulated similar concentrations of As, Cd, Pb, Se, and Hg. Mercury concentrations in feathers were approximately 1 mg/kg. Mercury concentrations found in fish downstream of the nesting site are approximately 0.04 ± 0.01mg/kg (Peterson et al. 1994). Thus, biomagnification is occurring in kingfishers foraging in up gradient areas of the ORR. However, these feather concentrations are much lower than those found in adult kingfishers on the ORR. Although selenium concentrations in nestling feathers appear high, they are similar to selenium levels in adult kingfishers (Table C.19) and mink and raccoons collected at reference locations (Ashwood et al. 1994). The fourth feather sample presented in Table C.18 represents a mixture of feathers retrieved from the three nestlings. This sample was analyzed to provide additional information on the variability of chemical concentrations within the feathers.

A burrow on the Clinch River contained fragments of egg shells and fish vertebrae from regurgitant. Analysis of the egg shells indicated that minimal metal contamination was present (Clinch River downstream, Table C.18). Another burrow on White Oak Creek contained an unhatched kingfisher egg (WOC, Table C.18). Metal concentrations in this egg were similar to that for the Clinch River egg, except for ^{137}Cs. The presence of this radionuclide in the egg indicates that the parent kingfisher bioaccumulated ^{137}Cs from foraging within White Oak Creek or a nearby surface impoundment (^{137}Cs is a typical contaminant of this stream and the impoundments).

Cesium-137, Cd, Pb, Se, and Hg were each detected in at least one kingfisher from the ORR (Table C.19). Arsenic was analyzed for but was not detected. Feathers of adult kingfishers contained elevated levles of mercury (Table C.19) relative to feathers from the nestlings (Table C.19). The greatest burdens of Hg, Se, Pb, and ^{137}Cs were observed in the bird from the White Oak Creek watershed (Bird 3; Table C.19). In contrast, cadmium levels were higher in the birds from East Fork Poplar Creek (Birds 1 and 2) than in the White Oak Creek bird (Table C.19).

4.3.3.4 Osprey reproduction

Although osprey monitoring studies are not performed by ORNL, an ongoing osprey reintroduction program is being conducted by TWRA in the Clinch/Tennessee River system. Osprey are currently nesting at three locations adjacent to the ORR: Gallaher and Solway bends (both located in subreach 1) and in Poplar Creek kilometer 1.6 (Fig. C.3). Mean reproductive success at these three osprey nests was 3 young/nest (B. Anderson, pers. comm). For comparison, mean reproductive success of osprey in North America ranges from 1.7 to 2.14 young/nest (EPA 1993b).

4.4 RISK CHARACTERIZATION FOR PISCIVOROUS WILDLIFE

Risk characterization integrates the results of the exposure assessment (Sect. 4.2) and effects assessment (Sect. 4.3) to estimate risks (the likelihood of effects given the exposure) based on each line of evidence and then applies a weight of evidence inference logic to determine the best estimate of risk to each assessment endpoint. In an ideal risk assessment there are three lines of evidence: literature-derived single chemical toxicity data (which indicate the toxic effects of the concentrations measured in site media), biological surveys of the affected system (these indicate the actual state of the receiving environment), and toxicity tests with ambient media (these indicate the toxic effects of the concentrations measured in site media). Although three lines of evidence are available to assess risks to piscivorous wildlife, all are not available for each endpoint or for all watersheds on the ORR. Single chemical toxicity data are available for all four endpoints within all four watersheds. Toxicity tests and a field survey/bioaccumulation study were performed for mink along Poplar Creek and in the Bear Creek, East Fork Poplar Creek, and White Oak Creek watersheds, respectively. Lastly, a field survey/bioaccumulation data were available for great blue heron and osprey along Poplar Creek and Melton Hill Lake and for kingfisher in the East Fork Poplar Creek and White Oak Creek watersheds.

Procedurally, the risk characterization is performed for each assessment endpoint by (1) screening all measured contaminants against toxicological benchmarks and background concentrations (if available), (2) estimating the effects of the contaminants retained by the screening analysis, (3) estimating the toxicity of the ambient media based on the media toxicity test results, (4) estimating the effects of exposure on the endpoint biota based on the results of the biological survey data, (5) logically integrating the lines of evidence to characterize risks to the endpoint, and (6) listing and discussing the uncertainties in the assessment. A detailed discussion of methods and the approach to risk characterization on the ORR is presented in Suter et al. (1995).

4.4.1 Single Chemical Toxicity Data

Exposure estimates generated by the exposure model (see Sect. 4.2.1.) produced by both point estimates of parameter values and Monte Carlo simulation represent exposure at the individual level. The exposure estimates using point estimates of parameter values at each individual sampling point are used to identify COPECs and locations that contribute significantly to risk. In contrast, the watershed-level exposure distributions generated by Monte Carlo simulation represent the likelihood that an individual within the area for which exposure is modeled will experience a particular exposure.

Two types of single chemical toxicity data are available with which to evaluate piscivore contaminant exposure: NOAELs and LOAELs. NOAELs are used to screen exposure estimates generated from point-estimates of exposure parameters; if the estimate is greater than the NOAEL, adverse effects are possible and additional evaluation is necessary (i.e., exposure modeling using Monte Carlo simulation). LOAELs are compared with the exposure distribution generated by the Monte Carlo simulation. If the LOAEL is lower than the 80th percentile of the exposure distribution, there is a >20% likelihood that individuals within the modeled location are experiencing contaminant exposures that are likely to produce adverse effects. By combining literature-derived population density data with the likelihood or probability of exceeding the LOAEL, population-level impacts may be estimated.

4.4.1.1 Screening point estimates of exposure

To determine if the contaminant exposures experienced by mink, river otter, belted kingfisher, great blue heron, and osprey on the ORR are potentially hazardous, the dietary contaminant exposure estimates (generated by using point estimates of parameter values; Tables C.7 through C.11) were compared with estimated NOAELs and LOAELs for these species (Tables C.16 and C.17). To quantify the magnitude of hazard, a hazard quotient (HQ) was calculated where HQ = exposure/NOAEL or LOAEL. Hazard quotients >1 indicate that individuals may be experiencing exposures that are in excess of NOAELs or LOAELs. Exceeding the NOAEL suggests that adverse effects are possible; exceeding the LOAEL suggests that adverse effects are likely. Hazard quotients for mink, river otter, belted kingfisher, and great blue heron on the ORR are presented along with the point estimates of exposure in Tables C.7 through C.11. It should be noted that because few data are available for specific PCB (Aroclor) mixtures, all PCBs were summed and the total was compared with Aroclor-1254 toxicity data.

A summary of the number of locations within each watershed where HQs>1 were observed is presented in Table C.20. NOAELs for mercury and PCBs were exceeded at at least one location for all endpoints in all watersheds. LOAELs for mercury and PCBs were exceeded at at least one location within each watershed for both otter and belted kingfisher (Table C.20). LOAELs for both contaminants were exceeded for all endpoints in East Fork Poplar Creek. LOAELs for osprey were exceeded only in the K-25 Site area.

The spatial distribution of contamination and potential risks to piscivores in Bear Creek, East Fork Poplar Creek, the K-25 Site, and White Oak Creek are illustrated in Figs. C.5, C.6, C.7, and C.8, respectively. These figures display the sum of the LOAEL-based HQs (e.g., sum of toxic units) for total PCBs and mercury. Sampling locations were arranged upstream to downstream (right to left); side tributaries or ponds are included in the order in which they enter the main stream.

In Bear Creek, no clear spatial pattern of risk is evident. Cumulative risk is greatest at Bear Creek kilometer (BCK) 4.5 and 0.6, respectively (Figs. C.5a–d). This lack of a distinct pattern is likely a result of differences in data from each location and not related to a source. Although data from BCK 12.4, 9.4, and 3.3 consisted of bodyburdens in stonerollers (a grazing species), data from BCK 4.5 and 0.6 consisted of bodyburdens in rock bass and red-breast sunfish (both invertebrate feeders). Mercury bodyburdens were substantially higher at BCK 4.5 and 0.6 (rock bass and red-breast sunfish) than at BCK 12.4, 9.4, and 3.3 (stonerollers; see Table C.6). The differences in bodyburdens are likely related to food habits of the fish and species-specific mercury uptake kinetics and not to a particular contaminant source.

In East Fork Poplar Creek, the pattern of cumulative risk is similar for all endpoint species; hazard declines with increasing distance from the Y-12 Plant (Fig. C.6a–d). As would be expected, mercury accounts for the majority of risk, with PCBs contributing 1/3 or less to the total. Risk is greatest near the Y-12 Plant East Fork kilometer (EFK) 24.5, plateaus from EFK 24.0 through EFK 6.3, with an additional decline observed at EFK 2.1 (Fig C.6)

At K-25, in Poplar Creek, mercury accounted for most risk (highest in the vicinity of the K-25 Site), and PCBs were the primary risk agent in Mitchell Branch at Mitchell Branck kilometer (MIK) 0.2 and at the K-901 and K-1007 ponds (Fig C.7). The pattern of cumulative risk was similar for mink (Fig. C.7a), kingfisher (Fig. C.7c), and herons (Fig. C.7d), with osprey (Fig. C.7e) and otter (Fig. C.7b) differing from the other three. The difference between the pattern of cumulative risk for osprey and otter and that for other piscivores can be attributed to dietary differences and variation in contaminant concentration according to fish size. Osprey and otter were assumed to consume both large (> 30 cm) and small (< 30 cm) fish; all other piscivores were assumed to consume only fish <30 cm in size. The generally greater contaminant concentrations in the larger fish acount for the inter-species differences in estimated exposures.

Similar to the K-25 Site, the pattern of cumulative risk in the White Oak Creek watershed was similar for mink (Fig. C.8a), kingfisher (Fig. C.8c), and herons (C.8d) but different for otters (C.8b). The pattern for osprey differed from all other species because only suitable habitat (large bodies of water; White Oak Lake and the embayment) were considered. In general, cumulative risk was greater in White Oak Creek than in its tributaries (the Northwest Tributary and Melton Branch). Mercury was the primary risk agent throughout the watershed, except at WCK 0.3 where PCBs dominated. A peak for risk to otters from PCBs was observed at White Oak Lake (WCK 1.5). This peak can be attributed to the presence of data for large fish (>30 cm); PCBs in large fish were 3 to 5 times higher than that in small fish (Table C.6).

4.4.1.2 Screening Monte Carlo simulation estimates of exposure

To incorporate the variation present in the parameters employed in the exposure model, Monte Carlo simulations were performed for exposure of each species to mercury and PCBs in each watershed. Simulations were performed on the average exposure within each watershed, weighted by the density or biomass of fish observed at each sampling location (see Sect. 4.2.1.4). The mean, standard deviation, and 80th percentile of the simulated exposures are presented in Table C.15. By superimposing NOAEL and LOAEL values on these distributions, the likelihood of an individual experiencing potentially hazardous exposures can be estimated and the magnitude of risk may be determined. Interpretation of the comparison of exposure distributions to NOAELs and LOAELs is described in the following table:

Comparison	Meaning	Risk-based interpretation
NOAEL>80th percentile of exposure distribution	Less than 20% of exposures are greater than NOAEL	Individual- and population-level adverse effects are highly unlikely
NOAEL<80th percentile<LOAEL	More than 20% of exposures are greater than NOAEL, but less than 20% of exposures are greater than LOAEL	Individuals experiencing exposures at the high end of the distribution may experience adverse effects, but those effects are unlikely to significantly contribute to effects on the ORR population
LOAEL<80th percentile of exposure distribution	More than 20% of exposures are greater than LOAEL	Effects on some individuals are likely and they may contribute significantly to effects on the ORR population

To evaluate the likelihood and magnitude of population-level effects on piscivores, literature-derived population density data (expressed as number of individuals/km of stream or pond shoreline) were combined with lengths of streams or pond shorelines for which risks were assessed to estimate the number of individuals of each endpoint species expected to be present in each watershed. Literature-derived population densities used for each endpoint species were mink: 0.6/km; river otter: 0.37/km; belted kingfisher: 0.4/km; and great blue heron: 2.3/km. It should be noted that density values for all endpoint species except the great blue heron represent the maximum values obtained from the literature (see Tables C.1, C.2, and C.3). The values for herons (see Table C.4) appear inflated and are not believed to accurately represent densities on the ORR. For this reason, the minimum value was used. Population estimates based on these densities are listed in the following table.

	Watershed length (km)			Estimated number of individuals by watershed			
Watershed	Stream length	Pond shoreline length	Total length	Mink	River otter	Belted kingfisher	Great blue heron
Bear Creek	12.4	0	12.4	7	5	5	29
East Fork Poplar Creek	24.8	0	24.8	15	9	10	57
K-25 Site	18.4	5.2	23.6	14	9	9	54
White Oak Creek	3.9	2.5	6.4	4	2	3	15
ORR total				40	25	27	155

Population risk estimates were not performed for osprey because as a T&E species, adverse effects to any individual are significant and because suitable density data were not available. Population risk estimates however were performed for otter, another T&E species. Although otter are not currently known to reside on the ORR, population estimates indicate the numbers that could reside on the ORR given available habitat and the risks that contaminant exposure could present.

The number of individuals within a given watershed likely to experience exposures greater than LOAELs can be estimated by using cumulative binomial probability functions (Dowdy and Wearden 1983). Binomial probability functions are estimated with the following equation:

$$b(y;n;p) = \binom{n}{y} p^{y} (1-p)^{n-y} \tag{9}$$

where:

y = the number of individuals experiencing exposures greater than LOAEL
n = total number of individuals within the watershed
p = probability of experiencing an exposure in excess of the LOAEL
b (y; n; p) = probability of y individuals out of a total of n, experiencing an exposure greater than LOAEL, given the probability of exceeding the LOAEL = p.

By solving Equation 4 for y = 0 to y = n, a cumulative binomial probability distribution may be generated that can be used to estimate the number of individuals within a watershed that are likely to experience adverse effects. Summing the number within each watershed across all watersheds and dividing by the total estimated ORR-wide population, the proportion of the total ORR population potentially at risk may be estimated.

Binomial probability distributions were generated only for contaminant-endpoint-watershed combinations where the percent of the exposure distribution exceeding the LOAEL was 20% to 80% (these values are reported in Table C.15). If the percent of the exposure distribution exceeding the LOAEL was <20%, it was assumed that no individuals within the area of interest were experiencing adverse effects. Conversely, if the percent of the exposure distribution exceeding the LOAEL was >80%, it was assumed that all individuals within the area of interest were experiencing adverse effects. Exposure estimates for 6 contaminant-endpoint-watershed combinations met the 20% to 80% exceedance criterion: mercury exposure to mink in East Fork Poplar Creek, mercury exposure to otter and kingfisher in Bear Creek, mercury exposure to otter in White Oak Creek, PCB exposure to otter in East Fork Poplar Creek and White Oak Creek. Figures C.9–C.14 graphically display the cumulative binomial probability distributions for each contaminant-endpoint-watershed combination. The total numbers of individuals for each endpoint species estimated to be experiencing adverse effects within each watershed and with the ORR as a whole are summarized in Table C.21.

On the basis of the Monte Carlo and binomial distribution analyses (Table C.21), the following conclusions may be made:

- Because >20% of the ORR mink population is estimated to be experiencing exposures greater than LOAEL, mercury presents a significant risk to mink. The ORR-scale risk is attributable solely to mercury risk in the East Fork Poplar Creek watershed.

- Because >1 individual is estimated to be experiencing exposures greater than LOAEL, mercury presents a significant risk to otter in the East Fork Poplar Creek, Bear Creek, and K-25 watersheds.

- Because >20% of the ORR kingfisher population is estimated to be experiencing exposures greater than LOAEL, mercury presents a significant risk to kingfisher. The ORR-scale risk is attributable to mercury exposure in all watersheds considered, except the White Oak Creek watershed.

- Because >20% of the ORR heron population is estimated to be experiencing exposures greater than LOAEL, mercury presents a significant risk to heron. The ORR-scale risk is attributable solely to mercury risk in the East Fork Poplar Creek watershed.

- Because <1individual is estimated to be experiencing exposures greater than LOAEL, neither mercury nor PCBs presents a significant risk to osprey in the White Oak Creek or K-25 watersheds.

- Because <20% of the ORR populations of mink, kingfisher, or herons are estimated to be experiencing exposures greater than LOAEL, PCBs do not present a significant risk to these populations.

- Because 1 individual is estimated to be experiencing exposures greater than LOAEL, PCBs present a significant risk to otter in the East Fork Poplar Creek and White Oak Creek watersheds.

4.4.1.3 Effects of retained contaminants

Mercury. For the purposes of this assessment, it is assumed that 100% of the mercury to which wildlife are exposed consists of methyl mercury.

Both the avian NOAEL and LOAEL are based upon a study of mallard ducks fed methyl mercury for three generations (Heinz 1979). The study was considered to represent a chronic exposure, and a subchronic-chronic correction factor was not employed. The only dose level administered, 0.064 mg/kg/d, caused hens to lay fewer eggs, lay more eggs outside of the nest box, and produce fewer ducklings. This dose level was considered to be an LOAEL. Because an experimental NOAEL was not established, the NOAEL was estimated by using LOAEL-NOAEL correction factor of 0.1. On the basis of the results of Heinz (1979), kingfisher experiencing exposure greater than or equal to LOAEL are likely to display impaired reproduction.

The mink and otter NOAELs and LOAELs for mercury were derived from a study of mink fed methyl mercury for 93 d (Wobeser et al. 1976). Although consumption of 0.247 mg/kg/d methyl mercury resulted in significant mortality, weight loss, and behavioral impairment, no effects were observed at the 0.15 mg/kg/d exposure level. The 0.15 mg/kg/d exposure was considered to be an NOAEL, and the 0.247 mg/kg/d exposure was considered to be an LOAEL. Because the study was subchronic in duration (<1 year), a subchronic-chronic correction factor was applied (NOAEL = 0.015, LOAEL = 0.025). Based on the results of Wobeser et al. (1976), shrews, mice, and fox experiencing exposure greater than or equal to LOAEL are likely to display increased mortality, weight loss, and behavioral impairment.

PCBs. The otter NOAEL and LOAEL for PCBs was derived from a study of mink fed Aroclor 1254 for 4.5 months (Aulerich and Ringer 1977). Although consumption of 0.69 mg/kg/d Aroclor 1254 reduced kit survivorship, no effects were observed at the 0.14 mg/kg/d exposure level. The 0.14 mg/kg/d exposure was considered to be a chronic NOAEL; the 0.69 mg/kg/d exposure was considered to be a chronic LOAEL Based on the results of Aulerich and Ringer (1977), mink experiencing exposure greater than or equal to LOAEL are likely to display reduced kit survivorship.

4.4.2 Mink Toxicity Tests

To evaluate the nature and magnitude of toxicity of contaminants in fish from the Clinch River to mink, fish were collected from the Poplar Creek embayment, formulated into mink diets, and fed to mink. Mink were fed five different diets. Ten mink (2 males, 8 females) were fed each diet for 7 months; starting approximately 3 months before breeding, extending to 6 weeks postpartum. Bioaccumulation, growth, histopathology, and reproduction were recorded. Significant effects were observed only among mink fed diet E. These effects included statistically significant reductions in body weights of adult females and male kits and in litter size. Percent reductions were 20% and 17% for adult female and male kit weights, respectively, and 37.7% for litter size. A detailed discussion of the methods and results of the mink toxicity test is presented in Appendix E.

To evaluate how the exposures experienced by mink in the toxicity test compare with those modeled for mink on the ORR, Monte Carlo simulations of mink exposure were performed using the concentrations of mercury and PCB 1260 measured in the five diets (Tables F.1 and F.5). Parameter values in the exposure model were as follows: body weight = 0.974 ± 0.202 kg; food ingestion rate = 0.137 kg/d. Results of the exposure simulation are presented in Table C.22. Estimated exposures to mercury and PCB 1260 in diet A were below both the NOAEL and LOAEL. For diets C, D, and E, mercury exposures exceeded the NOAEL (i.e., >20% of distribution exceeded the NOAEL). Diets D and E also exceeded the LOAEL for mercury, with diet D marginally exceeding and diet E significantly exceeding the LOAEL (Table C.22). Exposures to PCB 1260 in diets B, C, D, and E were greater than both the NOAEL and LOAEL (Table C.22). These data suggest that toxicity in diet E was a result of the combined effects of PCBs and mercury and that impaired reproduction should have been evident in diets B, C, D, and E, not just diet E.

The mean mercury exposure in diet D (0.022 mg/kg/d; the highest exposure at which no adverse effects were observed) was less than the LOAEL; the mean exposure in diet E was 0.033 mg/kg/d (the lowest exposure at which adverse effects were observed). This suggests that the estimated mercury LOAEL for mink (0.025 mg/kg/d) is appropriate and representative of toxicity of mercury to mink on the ORR.

Estimating that toxicity should be observed in four diets but actually observing it only in the highest concentration suggests that the LOAEL for PCBs used in this assessment is too low and is not representative of the toxicity of the PCBs present on the ORR. ORR-specific NOAEL and LOAEL for PCBs (represented by PCB 1260) of 1.7 mg/kg/d and 3 mg/kg/d can be derived from the toxicity test exposure estimate for diets B and E (Table C.22). The ORR-specific NOAEL and LOAEL for mercury would be 0.022 mg/kg/d (diet D) and 0.033 mg/kg/d (diet E), respectively.

The mercury exposure estimate for mink in the watershed where the highest exposure estimate was obtained (East Fork Poplar Creek; mean = 0.031 ± 0.006 mg/kg/d) is approximately equivolent to that observed in diet E (Table C.22), the diet where significant reproductive effects were observed. The estimated total PCB exposure in East Fork Poplar Creek (mean = 0.17 ± 0.10 mg/kg/d) is less than that in all test diets except the control diet (diet A; Table C.22).

Several conclusions may be drawn from these toxicity test data.

- Comparisons of exposure estimates to NOAELS and LOAELs suggest that effects observed in diet E are attributable to PCBs and mercury.

- Because the estimated LOAEL used in this assessment is comparable to the exposure level that resulted in adverse effects, estimated mercury LOAEL for mink is appropriate and representative of toxicity of mercury to mink on the ORR.

- Given the difference between predicted and observed toxicity from the test diets, the PCB LOAEL used in this assessment is too low and does not reflect toxicity observed among mink exposed to Poplar Creek fish.

- Consumption of a diet consisting of 75% fish from the Poplar Creek produces reproductive impairment in mink.

- An LOAEL for mink on the ORR fish of 3 mg/kg/d can be derived. Using the ORR-specific value rather than the literature value, PCBs would not be expected to cause toxic effects on survival, growth, or reproduction of mink in any ORR watershed.

Differences between the results of the toxicity tests and modeled exposures for mink on the ORR may result for several reasons.

- Differences in fish size. Exposure estimates for mink on the ORR were based solely on contaminant concentrations in fish most likely to be consumed by mink (i.e., ≤30 cm in length). Because of the large volume of fish needed to formulate the test diets and to feed mink for 7 months, the majority of fish used in the toxicity test were large (mean = 39 cm, standard deviation = 17 cm). Because body burdens of bioaccumulative contaminants like mercury and PCBs are generally greater in older, larger individuals, concentrations in the toxicity test diets were higher than that in fish expected to be consumed by mink on the ORR.

- Differences in fish species. More than 50% of the fish used in the test diets were sucker, carp, or buffalo (Table E.1). None of these species were included in the data used to estimate mink exposure on the ORR. Because fish species accumulate contaminants differently (as seen in stonerollers and sunfish in Bear Creek), variation in species included in test diets and modeled diets may have contributed to the differences in results.

- Differences in the PCB congener composition on the ORR vs. that used in the literature toxicity test. PCBs measured in environmental samples are not Aroclors. Aroclors are specific mixtures of PCB congeners as manufactured. The environmental measurements of PCBs used in the Poplar Creek toxicity test are called PCB 1254 or PCB 1260 because they have ~54% or 60% chlorine. The congener makeup of PCB 1254 or 1260 from the Poplar Creek fish is likely to be very different from the congener makeup of Aroclor 1254 or 1260. More importantly, PCB toxicity is generally correlated with individual congeners, not with Aroclors.

4.4.3 Biological Surveys

4.4.3.1 Great blue heron reproduction study

To determine if contaminants from the ORR are adversely affecting great blue heron, bioaccumulation of contaminants and reproductive success of herons at two colonies located adjacent to the ORR and two colonies located >10 km from the site was monitored. Data were collected from each nest colony between 1992 and 1994. A detailed discussion of these data are presented in Appendix F.

Analyses indicated statistically significantly elevated levels of Cr, Hg, and PCBs in eggs (Tables F.2 and F. 4), Hg in feathers and liver of chicks (Table F.3), and PCBs in fat (Table F.5), liver (Table F.6), and muscle (Table F.7) of chicks from samples from the ORR as compared with data from the off-site locations. King et al. (1991) report that 0.5 to 1.5 mg/kg mercury concentrations in bird eggs may are associated with reproductive failure; Harris et al. (1993) report a NOAEL for hatching success of Forster's Tern eggs to be 7 mg/kg. Mean concentrations of mercury (0.17 mg/kg) and PCBs (1.68 mg/kg) in great blue heron eggs from within 3 km of the ORR are substantially below both levels, suggesting that reproductive effects from mercury or PCBs in eggs are unlikely.

Despite elevated contaminant burdens, the mean number of eggs/nest, number of chicks/nest, egg weight, and eggshell thickness did not differ between colonies within 3 km of the ORR and those >10 km away (Table F.8). In addition, the number of eggs/nest observed at the colonies within 3 km of the ORR (3.5 eggs/nest) and at the colonies >10 km away (3.2 eggs/nest) are comparable to those reported in EPA (1993b) (3.16 to 4.37 eggs/nest).

The results of the great blue heron reproduction survey indicate that herons are experiencing higher contaminant exposures at the colonies adjacent to the ORR. However, this exposure is not sufficiently high to result in adverse effects to the populations at the studied colonies. [Note:five great blue heron colonies currently exist around the margins of the ORR (R. Brewer, pers. comm.). Bioaccumulation and reproductive success have only been evaluated for two of these five colonies.]

4.4.3.2 Mink survey

Results of the mink survey (see Sect. 4.3.3) indicate that mink are present on the ORR, have large home ranges, and do not avoid the industrial facilities on the ORR. The methods employed in the study do not allow numbers or density of mink to be determined. Although mercury levels in hair of mink were statistically significantly greater on the ORR than in reference samples, no statistically significant differences were observed for As, Cd, Pb, or Se.

4.4.3.3 Kingfisher survey

Results of the kingfisher survey indicate that contaminants are being accumulated by both juveniles and adult birds. Although contaminants in eggshells and nestling feathers indicate exposure, there is insufficient information to evaluate the toxicological significance of this contamination.

The toxicological significance of the tissue concentrations in adult kingfisher was evaluated by comparison of burdens and effects levels reported in other bird species. This comparison suggests that it is unlikely that cadmium or lead in kingfisher from the ORR contribute significantly to risk. Leach et al. (1979) observed a 50% reduction in egg production among chickens consuming a diet containing 48 mg/kg cadmium. Cadmium concentrations in the livers and kidneys of these birds were 100 mg/kg and 40 mg/kg, respectively. Cadmium concentrations in healthy birds from unpolluted areas ranged from 0.1 to 32 mg/kg in liver and 0.3 to 137 mg/kg in kidney (Furness 1996). In comparison, maximum cadmium concentrations in the kidney (4.04 mg/kg) and liver (0.95 mg/kg) of kingfisher collected from the ORR watershed were significantly less than concentrations associated with reproductive impairment and at the low end of the ranges observed among healthy birds from unpolluted areas. Maximum lead concentrations in the kidney (0.42 mg/kg) and liver (0.4 mg/kg) of ORR kingfisher were approximately one order of magnitude lower than the minimal level at which overt toxicity is observed in birds (3 to 6 mg/kg; Franson 1996), suggesting that lead accumulation is unlikely to be contributing to risks to kingfishers on the ORR.

In contrast to Cd and Pb, Se and Hg burdens may present a hazard to kingfishers on the ORR. The maximum concentration of selenium observed in the liver of kingfisher from the ORR (7.5 mg/kg) is less than the 10 mg/kg toxicity threshold recommend by Heinz (1996) but greater than the 3 mg/kg reproductive impairment threshold, suggesting the potential for adverse effects on reproduction. Mercury concentrations of 49 to 125 mg/kg in kidney and 4.6 to 91 mg/kg in liver have been reported for free-living birds found dead or dying (Thompson 1996). Nephrotoxicity and kidney lesions occur in birds at mercury concentrations in kidney of 5 to 13 mg/kg (Nicholson and Osborn 1983). Although the maximum observed mercury concentrations in the kidney (26.8 mg/kg) and liver (17.6 mg/kg) of ORR kingfisher were generally lower than concentrations associated with mortality, the kidney concentration exceed nephrotoxic levels, suggesting that mercury accumulation may be causing kidney damage to kingfishers on the ORR.

4.4.3.4 Osprey survey

Mean reproductive success at the three osprey nests adjacent to the ORR was 3 young/nest (B. Anderson, pers. comm). For comparison, mean reproductive success of osprey in North America ranges from 1.7 to 2.14 young/nest (EPA 1993b). These data suggest that osprey near the ORR are not being adversely affected by contaminants.

4.4.4 Weight of Evidence

4.4.4.1 Mink

Three lines of evidence—literature toxicity data, toxicity test data, and field surveys—were available to evaluate risk to mink. Comparison of exposure estimates with LOAELs indicates a significant risk from mercury in East Fork Poplar Creek and consequently to the ORR mink population (Table C.21). PCBs are not estimated to contribute to risks to mink

Toxicity test results indicate that consumption of a diet consisting primarily of fish from the Poplar Creek embayment adversely affects mink reproduction. Mercury exposure experienced by mink at the highest dose level was comparable with that estimated for mink in East Fork Poplar Creek. This dose level was associated with impaired reproduction. PCB exposures experienced by mink on the ORR were all less than exposures experienced by mink in the toxicity test.

Limited data from field surveys indicate that although mink are present on the reservation, the health and abundance of the population is unknown (the trapping methods that were employed, although suitable for capturing animals for radiotelemetry purposes, were not adequate to estimate population abundance and density). Mink on the ORR have large home ranges, make use of the creeks within the industrial facilities, and have higher mercury concentrations in hair than do mink from off-site locations. Cadmium concentrations in hair were not different between mink on the ORR and those from off-site locations.

The weight of evidence suggests that mercury presents a hazard to mink in East Fork Poplar Creek and consequently to a significant portion (30%) of the ORR-wide mink population. Risks to mink from PCBs are not significant (Table 4.1).

4.4.4.2 River otter

Two lines of evidence—literature toxicity data and the PCB and mercury NOAEL and LOAEL derived from the Poplar Creek mink toxicity test—were available to evaluate potential risk to river otter. As a T&E species, potential adverse effects to any individual are significant. Comparison of exposure estimates with literature-derived LOAELs indicates a significant risk from mercury in Bear Creek, East Fork Poplar Creek, and the K-25 Site area and from PCBs in the East Fork Poplar Creek, and White Oak Creek watersheds.

Using Equation 3 and the ORR-specific NOAELs and LOAELs for PCBs and mercury for mink (see Sect. 4.4.2), ORR-specific values for otter were estimated to be as follows:

Analyte	Estimated NOAEL (mg/kg/d)	Estimated LOAEL (mg/kg/d)
PCBs	0.92	1.8
Mercury	0.013	0.02

Comparison of the ORR-specific PCB LOAEL to the exposure distributions presented in Table C.15 indicate that there is a <1% likelihood of individuals in any watershed experiencing PCB exposure greater than ORR-specific LOAEL. Therefore, based upon the results of the Poplar Creek mink toxicity test, PCBs are unlikely to present a significant risk to the ORR-wide otter population.

The ORR-specific mercury LOAEL is somewhat higher but still comparable to the literature-derived LOAEL (0.015 mg/kg/d; Table C.16). Therefore, the results of the Poplar Creek mink toxicity test do not significantly alter the conclusions derived from evaluation of the literature-based toxicity data.

Evaluation of the potential risks to a future ORR-wide population of otter indicates that mercury presents a risk in all watersheds on the ORR (Table C.21). Because the river otter is a state threatened species, effects to any individual is significant. Therefore the weight of evidence suggests that mercury is significant risk to individual river otter that may occupy the ORR in the future (Table 4.1).

4.4.4.3 Belted kingfisher

Two lines of evidence, literature toxicity data and biomonitoring data, were available to evaluate potential risk to belted kingfisher. Comparison of exposure estimates to LOAELs indicates a significant risk from mercury in all watersheds except White Oak Creek (Table C.15). This translates into a risk to 81.5% of the ORR-wide kingfisher population (Table C.21). The limited biomonitoring data indicate that kingfisher on the ORR (particularly in the White Oak Creek area) are accumulating mercury to potentially nephrotoxicty levels. The weight of evidence suggests mercury in all

Table 4.1. Summary of risk characterization for piscivores on the ORR

Species	Evidence	Result	Explanation
Mink	Literature toxicity data	+	Comparison of exposure estimates to LOAELs indicates a significant risk from mercury in East Fork Poplar Creek and consequently to the ORR mink population . PCBs are not estimated to contribute to risks to mink
	Biological surveys	±	Mink are present on the ORR, but abundance and density are unclear but clearly not high. While Hg in hair from mink from ORR is elevated relative to references, As, Cd, Pb, and Se are not..
	Medium toxicity tests	+	Toxicity test results indicate that consumption of a diet consisting primarily of fish from the Poplar Creek embayment adversely affects mink reproduction. Mercury exposure experienced by mink at the highest dose level was comparable to that estimated for mink in East Fork Poplar Creek. This dose level was associated with impaired reproduction. PCB exposures experienced by mink on the ORR were all less than exposures experienced by mink in the toxicity test.
	Weight of evidence	+	The weight of evidence suggests that mercury presents a hazard to mink in East Fork Poplar Creek and consequently to the ORR-wide mink population. Risks from PCBs are not significant.
River otter	Literature toxicity data	+	Comparison of exposure estimates to literature-derived LOAELs indicates that individuals may be at risk from mercury in Bear Creek, East fork Poplar Creek, and the K-25 area and from PCBs in the East Fork Poplar Creek, and White Oak Creek watersheds.
	Biological surveys	NA	
	Medium toxicity tests	+	Use of the ORR-specific PCB LOAEL generated from the mink toxicity test indicates that PCBs on the ORR are unlikely to adversely affect otter. The ORR-specific mercury LOAEL was comparable to the literature-based LOAEL. Conclusions concerning risk to otter from mercury are therefore unaffected by the results of the mink toxicity test.
	Weight of evidence	+	Because the river otter is a state threatened species, effects to any individual are significant. Consequently, mercury presents a significant risk to a individuals and potential ORR-wide otter population.
Belted kingfisher	Literature toxicity data	+	Comparison of exposure estimates to LOAELs indicates a significant risk from mercury in all watersheds except White Oak Creek. This translates into a risk to 81.5% of the ORR-wide kingfisher population
	Biological surveys	+	The limited biomonitoring data indicate that kingfisher on the ORR (particularly in the White Oak Creek area), are accumulating mercury to potentially nephrotoxicty levels.
	Medium toxicity tests	NA	
	Weight of evidence	+	The weight of evidence suggests mercury in all watersheds presents a significant risk to the ORR-wide belted kingfisher population. Risks from PCBs are not significant

Table 4.1 (continued)

Species	Evidence	Result	Explanation
Great blue heron	Literature toxicity data	+	Comparison of exposure estimates to LOAELs indicates a significant risk from mercury in East Fork Poplar Creek. This translates into a risk to 36.8% of the ORR-wide heron population.
	Biological surveys	-	Biomonitoring data at 2 of 5 colonies around the ORR indicate that while PCBs and mercury are being accumulated in heron eggs and chicks, the levels in eggs are lower than levels reported in the literature to produce adverse effects. Observations of the two of the five colonies adjacent to the ORR indicate that reproduction is not reduced relative to colonies > 10 km from the ORR.
	Medium toxicity tests	NA	
	Weight of evidence	±	Contaminant bioaccumulation and reproductive success are unknown at the three additional colonies adjacent to the ORR; the primary foraging locations for herons at the two studied colonies is unknown. Because herons can travel long distances in search of food, they are likely to forage at offsite as well as on-site locations, reducing both the exposure they receive and the risk they experience. If birds from the unstudied colonies forage more extensively on the ORR, they may experience greater risk. Due to the high risk estimated for mercury exposure on the ORR, the lack of data for three of five heron colonies adjacent to the ORR, and uncertainty as to where birds from the five ORR colonies forage, a conclusion concerning whether or not great blue heron on the ORR are at risk cannot be made
Osprey	Literature toxicity data	-	Comparison of exposure estimates to LOAELs indicates a no significant risk from mercury or PCBs in any area on the ORR that provides suitable habitat (i.e., White Oak Lake and embayment and the K-25 area)
	Biological surveys	-	Biomonitoring data indicates that the reproductive success at osprey nests adjacent to the ORR (along Melton Hill Lake and in Poplar Creek) is greater than the average observed in the U.S).
	Medium toxicity tests	NA	
	Weight of evidence	-	The weight of evidence suggests mercury and PCB do not present a significant risks to osprey on or near the ORR

+ indicates that the evidence is consistent with the occurrence of the endpoint effect.
- indicates that the evidence is inconsistent with the occurrence of the endpoint effect.
± indicates that the evidence is too ambiguous to interpret.
NA indicates that the information is not available.

watersheds presents a significant risk to the ORR-wide belted kingfisher population. Risks from PCBs are not significant (Table 4.1).

4.4.4.4 Great blue heron

Two lines of evidence—literature toxicity data and biomonitoring data—were available to evaluate ecological risk to great blue heron. Comparison of exposure estimates with LOAELs indicates a significant risk from mercury in East Fork Poplar Creek (Table C.15). This translates into a risk to 36.8% of the ORR-wide heron population (Table C.21). Biomonitoring data at 2 of 5 colonies around the ORR indicate that although PCBs and mercury are being accumulated in heron eggs and chicks, the levels in eggs are lower than levels reported in the literature to produce adverse effects. Observations of the 2 of the 5 colonies adjacent to the ORR indicate that reproduction is not reduced relative to colonies >10 km from the ORR. Contaminant bioaccumulation and reproductive success are unknown at the three additional colonies adjacent to the ORR. Additionally, the primary foraging locations for herons at the two studied colonies is unknown. Because herons can travel long distances in search of food (>15 km), they are likely to forage at off-site as well as on-site locations, reducing both the exposure they receive and the risk they experience. If birds from the unstudied colonies forage more extensively on the ORR, they may experience greater risk. Because of the high risk estimated for mercury exposure on the ORR, the lack of data for three of five heron colonies adjacent to the ORR, and uncertainty as to where birds from the five ORR colonies forage, a conclusion concerning whether or not great blue heron on the ORR are at risk cannot be made (Table 4.1).

4.4.4.5 Osprey

Two lines of evidence—literature toxicity data and biomonitoring data—were available to evaluate ecological risk to osprey. As a T&E species, any adverse impact to individual osprey is significant. Comparison of exposure estimates with LOAELs indicates no significant risk from mercury or PCBs in any area on the ORR that provides suitable habitat (i.e., White Oak Lake and embayment and the K-25 Site area; Table C.15). Biomonitoring data indicates that the reproductive success at osprey nests adjacent to the ORR (along Melton Hill Lake and in Poplar Creek) is greater than the average observed in the United States. The weight of evidence suggests mercury and PCB do not present a significant risks to osprey on or near the ORR (Table 4.1).

4.4.5 Quality and Completeness of Data

The fish bioaccumulation data used in the piscivore assessment was considered to be of high quality. All data were obtained directly from the principal investigators, who collected the data. Because these persons were available to answer questions concerning interpretation of their data, few assumptions concerning sampling methods, measurements, sampling locations, and so forth were necessary.

The most severe limitation of the data used in this assessment relates to contaminants analyzed for in fish tissue. Although data for PCBs and mercury were available at all locations, data for other contaminants were not. Consequently, reservation-wide scale risks that these contaminants may present cannot be evaluated.

4.4.6 Uncertainties Concerning Risks to Piscivorous Wildlife

4.4.6.1 Bioavailability of contaminants

Bioavailability of contaminants was assumed to be comparable between fish collected from the ORR and the diets used in the literature toxicity tests. Because bioavailability may not be comparable, exposure estimates based on the contaminant concentrations in ORR fish may either under- or overestimate the actual contaminant exposure experienced.

4.4.6.2 Extrapolation from published toxicity data

Although published toxicity studies are available for mink, no published data exists for otter, kingfisher, or great blue heron. To estimate toxicity of contaminants at the site, it was necessary to extrapolate from studies performed on test species (i.e., mallard ducks, ring-necked pheasant, rats). Although it was assumed that toxicity could be estimated as a function of body size, the accuracy of the estimate is not known. For example, osprey or herons may be more or less sensitive to contaminants than ducks or pheasants as a result of factors other than metabolic rate.

Additional extrapolation uncertainty exists for those contaminants for which data consisted of only LOAELs or tests were subchronic in duration. For either case, an uncertainty factor of 10 was employed to estimate NOAELs or chronic data. The uncertainty factor of 10 may either over- or underestimate the actual LOAEL-NOAEL or subchronic-chronic relationship.

Toxicity of PCBs to piscivorous wildlife was evaluated by using toxicity data from studies on Aroclor 1254. Because toxicity of PCB congeners can vary dramatically, the applicability of data for Aroclor 1254 is unknown. Comparison of the results of the mink toxicity test results and the estimated LOAELs for mink suggests the Aroclor 1254 data do not accurately reflect (i.e., overestimate) the toxicity of the PCB mixture present in Clinch River fish.

4.4.6.3 Variable food consumption

Although food consumption by piscivorous wildlife was assumed to be similar to that reported for the same or related species in other locations, the validity of this assumption cannot be determined. Food consumption by wildlife on the ORR may be greater or less than that reported in the literature, resulting in either an increase or decrease in contaminant exposure.

4.4.6.4 Single contaminant tests vs exposure to multiple contaminants in the field

Although piscivores on the ORR are exposed to multiple contaminants concurrently, published toxicological values only consider effects experienced by exposures to single contaminants. Because some contaminants to which wildlife are exposed can interact antagonistically, single contaminant studies may overestimate their toxic potential. Similarly, for those contaminants that interact additively or synergistically, single contaminant studies may underestimate their toxic potential.

4.4.6.5 Inorganic forms or species present in the environment

Toxicity of metal species varies dramatically depending upon the valence state or form (organic or inorganic) of the metal. For example, arsenic (III) and methyl mercury are more toxic than arsenic (V) and inorganic mercury, respectively. The available data on the contaminant concentrations in media do not report which species or form of contaminant was observed. Because benchmarks used for comparison represented the more toxic species/forms of the metals (particularly for arsenic and mercury), if the less toxic species/form of the metal was actually present in fish from the Clinch River or Poplar Creek, potential toxicity at the sites may be overestimated.

4.4.6.6 Contaminant concentrations in aquatic prey

Although fish are the primary prey of piscivores, other aquatic prey are also consumed. It was assumed that the contaminant concentration in fish was representative of that in other aquatic prey. Because of the different life histories of other aquatic prey (i.e., amphibians, crayfish, benthic invertebrates), their contaminant burdens are likely to differ from that in fish. Therefore, assuming comparability to fish may either over- or underestimate exposure.

4.4.6.7 Fish size selection

Data concerning the sizes of fish consumed by piscivores were obtained from the literature. Because fish sizes consumed by piscivores on the ORR may differ from that reported in the literature, exposure may be overestimated or underestimated.

4.4.6.8 Monte Carlo simulation

To perform Monte Carlo simulations, distributions must be assigned to parameters. Because wildlife are mobile, the mean of the contaminant concentration is likely to best represent their exposure. For this report, the contaminant concentrations in fish were assumed to be normally distributed. In future revisions of this report, goodness-of-fit analyses will be performed to determine which distribution best fists the data.

The literature values used for body weights of each endpoint are nationwide values, which may overestimate or underestimate the body weight of species found at the site. Similarly the proportion of fish and aquatic prey in mink diet were derived from data from northern locations (e.g., Michigan, Canada). The applicability of these data to the percentage of fish and aquatic prey consumed by mink in Tennessee is unknown.

4.4.6.9 Estimated whole fish concentrations

Contaminant concentrations in whole fish were estimated by using contaminant-specific fillet-to-whole fish ratios. Data to generate ratios were available only for PCBs in largemouth bass and channel catfish from the Clinch River. Ratios for metals were obtained from spotted bass samples from near the Portsmouth Gaseous Diffusion Plant in Ohio. Applicability of these ratios to species other than those from which they were developed is unknown. Similarly, applicability of metal ratios from Ohio spotted bass to fish on the ORR is unknown.

5. ASSESSMENT OF RISKS TO VERMIVORES, HERBIVORES, AND PREDATORS ON THE OAK RIDGE RESERVATION

Numerous, significant changes have been made throughout this section. To facilitate the flow of the document, they are summarized below but are not specifically identified in the text. The major changes in this section include the following:

- use of ORR-specific soil-plant, soil-earthworm, and soil–small mammal uptake factors,
- inclusion in assessment of predators red fox and red-tailed hawks, and
- use of updated benchmarks that reflect regulator comments concerning scaling factors.

5.1 PROBLEM FORMULATION

On the ORR, although most wide-ranging wildlife species reside primarily in the uncontaminated terrestrial habitats outside of source OUs (the terrestrial integrator OU; Suter et al.1995), they may also use those source OUs on which suitable habitat is present. As discussed in Chap. 3, the degree to which a source OU is used (and therefore the risk that it may present) is dependant upon the availability of suitable habitat on the OU. OUs with little or no habitat will experience little use (and will present minimal risk); those with considerable habitat are likely to experience considerable use (and depending upon the degree of contamination, may present significant risks).

Although *individuals* may experience adverse effects through exposures received at source OUs, the primary concern for ecological risk assessment is for effects at the population-level (except for T&E species, for which effects to individuals are a critical concern). To evaluate effects to the reservation-wide wildlife populations, habitat suitability and population density on the ORR and within OUs must be considered. A general, six-step, habitat-based approach was developed that is applicable to all wildlife species on the ORR. The approach is outlined here.

1. Individual-based contaminant exposure estimates are generated for each OU by using the generalized exposure model outlined in Sample and Suter (1994). Data used for the exposure estimate may consist of modeled data or actual measured concentrations in food, water, or soil from the OU.

2. Contaminant exposure estimates are compared with NOAELs or LOAELs to determine the magnitude and nature of effects that may result from exposure at the OU. If the exposure estimate is greater than LOAEL, then individuals at the OU may experience adverse effects.

3. Availability and distribution of habitat on the ORR and within each OU is determined by using the ORR habitat map presented in Washington-Allen et al. (1995; see Table B.2).

4. Habitat requirements for the endpoint species of interest (from Table B.1) are compared with the ORR habitat map to determine the area of suitable habitat on the ORR and within OUs (Tables B.4, B.5, and B.6).

5. The area of suitable habitat on the ORR and within OUs is multiplied by population density values for the selected endpoints to generate estimates of the reservation-wide population and the numbers of individuals expected to reside within each OU. Population density values may be derived from the literature or may consist of site-specific data.

6. The number of individuals for a given endpoint species expected to be receiving exposures greater than LOAELs for each measured contaminant is totaled. This is performed by using the OU-specific population estimate from step 5 and the results from step 2. This number is then compared with the reservation-wide population to determine the proportion of the reservation-wide population that is receiving hazardous exposures. By using the 20% criterion outlined in Suter et al. (1995), if the proportion of the reservation-wide population receiving hazardous exposures ≥20%, then an adverse population-level effect is assumed to be present.

In this assessment, exposure estimates were calculated and risks considered for 9 OUs on the ORR: the Bear Creek OU 2, Lower and Upper East Fork Poplar Creek, 3 OUs at K-25 (K-1407, K-1420, K-1414), WAGs 1 and 6, and the South Campus Facility (SCF). In addition, results from completed risk assessments on the Bear Creek Valley OU, Chestnut Ridge OU 2, and WAGs 2 and 5 were included. Locations of these OUs on the ORR are presented in Fig. G.1 (Appendix G).

5.1.1 Ecological Assessment Endpoints

5.1.1.1 Assessment endpoints

The following assessment endpoints were selected for the assessment of risks to herbivorous, vermivorous (e.g., worm-consuming), and predatory wildlife: toxicity to white-tailed deer (*Odocoileus virginianus*) or wild turkey (*Meleagris gallopavo*) (as representative herbivores), American woodcock (*Scolopax minor*) or short-tailed shrew (*Blarina brevicauda*) (as representative vermivores), red fox (*Vulpes fulva*) or red-tailed hawk (*Buteo jamaicensis*) resulting in a reduction in population abundance or production. Deer, turkey, woodcock, red fox, and red-tailed hawk are assessment endpoints agreed to be appropriate for the ORR by the FFA parties (Suter et al. 1995). The shrew is identified as a measurement endpoint in Suter et al. (1995). It is selected here as a surrogate for the several T&E shrew species listed in Suter et al. (1995). The criteria for selection of the entities are those recommended by the EPA (Risk Assessment Forum 1992), plus considerations of scale and practical considerations.

The appropriate properties of the entities selected by these criteria depend on the level of organization of the entity and the criteria that led to their selection. Although the primary concern for wildlife is effects at the population level, due to limited population sizes, effects to individuals are critical for T&E species. Because none of the selected endpoint species is a T&E species, the appropriate endpoint properties for populations of endpoint species are abundance and production.

Finally, the level of effects on these properties of the endpoint entities that is considered to be potentially significant is 20% as agreed by the FFA parties (Suter et al. 1995). This level is consistent with current regulatory practice.

5.1.1.2 Measurement endpoints

Three basic types of effects data are potentially available to serve as measurement endpoints: results of biological surveys, toxicity tests performed with fish from the ORR, and literature-derived toxicity test results for chemicals found on the ORR. Measurement endpoints for each assessment endpoint are presented here.

- **White-tailed deer**
  - Biological Survey Data—None.
  - Media Toxicity Data—None.

- — Single Chemical Toxicity Data—These data consist of chronic toxicity thresholds for contaminants of concern in mammals with greater weight given to data from long-term feeding studies with wildlife species. Preference was also given to tests that included reproductive endpoints. These test endpoints are assumed to correspond to the assessment endpoint after allometric scaling.

- **Wild turkey**
  - — Biological survey data—None.
  - — Media toxicity data—None.
  - — Single chemical toxicity data—These data consist of chronic toxicity thresholds for contaminants of concern in birds with greater weight given to data from long-term feeding studies with wildlife species. Preference was also given to tests that included reproductive endpoints. These test endpoints are assumed to correspond to the assessment endpoint after allometric scaling.

- **American woodcock**
  - — Biological survey data—None.
  - — Media toxicity data—None.
  - — Single chemical toxicity data—These data consist of chronic toxicity thresholds for contaminants of concern in birds with greater weight given to data from long-term feeding studies with wildlife species. Preference was also given to tests that included reproductive endpoints. These test endpoints are assumed to correspond to the assessment endpoint after allometric scaling.

- **Short-tailed shrew**
  - — Biological survey data—None.
  - — Media toxicity data—None.
  - — Single chemical toxicity data—These data consist of chronic toxicity thresholds for contaminants of concern in mammals with greater weight given to data from long-term feeding studies with wildlife species. Preference was also given to tests that included reproductive endpoints. These test endpoints are assumed to correspond to the assessment endpoint after allometric scaling.

- **Red fox**
  - — Biological survey data—None.
  - — Media toxicity data—None.
  - — Single chemical toxicity data—These data consist of chronic toxicity thresholds for contaminants of concern in mammals with greater weight given to data from long-term feeding studies with wildlife species. Preference was also given to tests that included reproductive endpoints. These test endpoints are assumed to correspond to the assessment endpoint after allometric scaling.

- **Red-tailed hawk**
  - — Biological survey data—None.
  - — Media toxicity data—None.
  - — Single chemical toxicity data—These data consist of chronic toxicity thresholds for contaminants of concern in mammals with greater weight given to data from long-term feeding studies with wildlife species. Preference was also given to tests that included reproductive endpoints. These test endpoints are assumed to correspond to the assessment endpoint after allometric scaling.

5.1.2. Ecological Conceptual Model

The ecological conceptual model graphically represents the relationships between the contaminant sources and the endpoint receptors. It integrates the information in the other subsections of the hazard identification and presents them graphically. It is not intended to show all of the possible sources, routes of transport, modes of exposure, or effects. Rather, it includes the only identified CERCLA source, the receptors that are designated as assessment endpoint species or communities, and the major routes that result in exposure to contaminants from the ORR.

The conceptual model for exposure of herbivores, vermivores, and predators to contaminants is presented in Fig. 5.1. Components of this model include plants and soil/litter invertebrates that reside on OUs on the ORR, the herbivorous and vermivorous wildlife that feed on them, and the predators that feed on the herbivores and vermivores. Plants and soil/litter invertebrates are exposed to contaminants from surface soil. Contaminants are bioaccumulated in lower trophic levels (i.e., plants or invertebrates) and transferred to higher trophic levels (i.e., herbivores, vermivores, predators). Herbivorous and vermivorous wildlife are exposed to contaminants through consumption of plants and soil/litter invertebrates, respectively. Predators are exposed to contaminants through consumption of herbivores and vermivores. All three wildlife endpoint groups are also exposed to contaminants through incidental ingestion of contaminated soil.

5.2 EXPOSURE ASSESSMENT FOR HERBIVOROUS, VERMIVOROUS, AND PREDATORY WILDLIFE

Potential routes of exposure for wildlife inhabiting the ORR include ingestion of food (either plant or animal) and surface water. In addition, some species may ingest soil incidentally while foraging or purposefully to meet nutrient needs. The total exposure experienced by terrestrial wildlife is represented by the sum of the exposure from each individual source (e.g., vegetation, earthworms, small mammals, soil, water).

The primary pathway of contaminant exposure is through oral ingestion of food and soil. Consumption of surface water, in most cases, contributes minimal contaminant exposure. Exposure from ingestion of surface water within the OU will not be included in the total exposure estimation. The surface water contaminant concentrations available in the ORR database will be compared with the water consumption benchmarks for each endpoint in the future revision of this document. Contaminant exposures were estimated for white-tailed deer, wild turkey, short-tailed shrew, American woodcock, red fox, and red-tailed hawk.

5.2.1 Exposure Through Oral Ingestion of Food and Soil

Exposure estimates were calculated for all contaminants detected at all ORR sampling locations within an OU by using Equation 1 from Sect. 4.2.1. The 95% UCL is used in exposure estimates.

5.2.1.1 Life history parameters for endpoint species

Species-specific parameters for herbivorous and vermivorous endpoints necessary to estimate exposure through the use of the above equation are listed in Tables G.1 to G.6. Habitat requirements and densities for each endpoint will be used to determine the percentage of the population which is experiencing unacceptable levels of contaminant exposure.

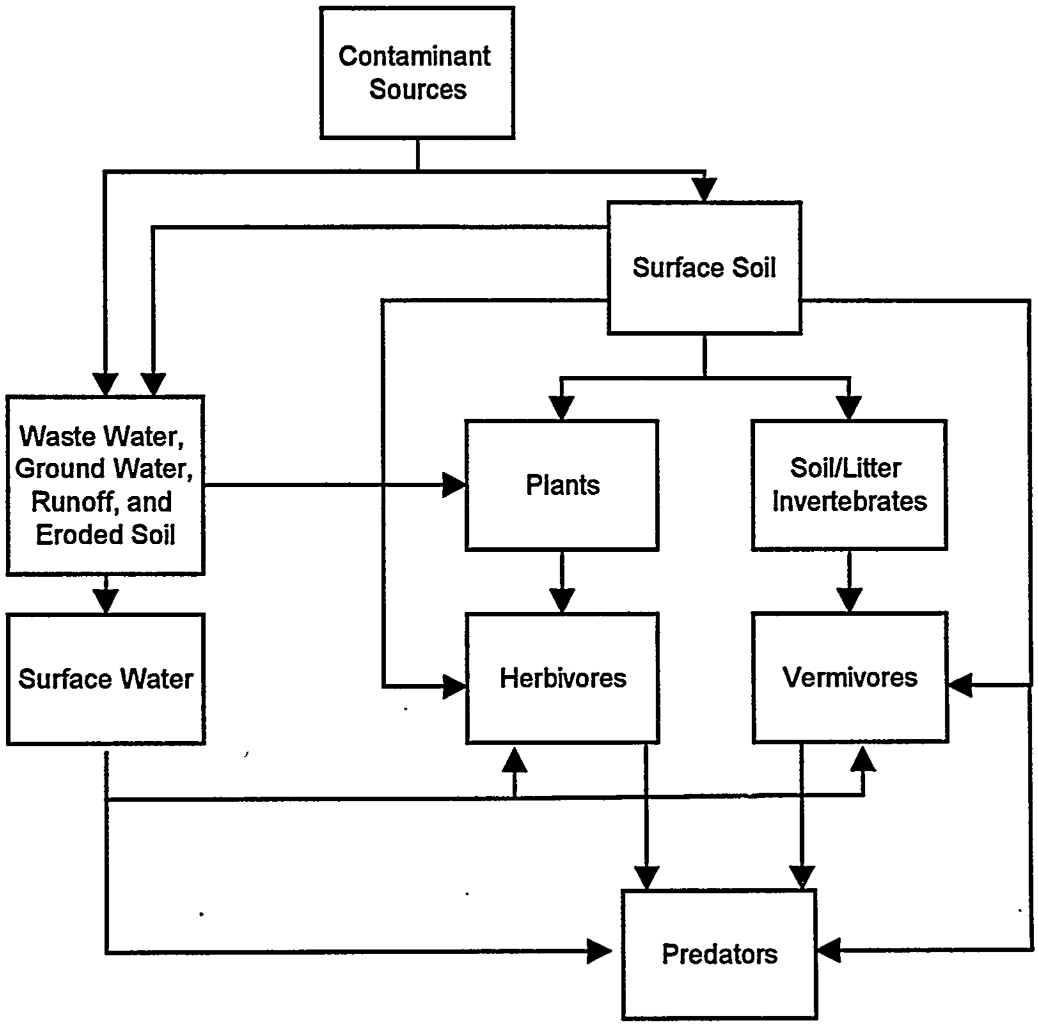


Fig. 5.1. Conceptual model for the exposure of vermivorous, herbivorous, and predatory wildlife to contaminants.

5.2.1.2 Contaminant concentrations in biotic and abiotic media

Contaminant concentrations in soil, vegetation, soil invertebrates, and small mammals are needed to estimate exposure. The surface soil 95% UCL (Table G.7) was used to calculate incidental ingestion of soil for each endpoint species. However, if the contaminant was only detected in a single sample, the single concentration was used to calculate exposure. The surface soil samples used in the calculations were collected at a depth ranging from 0 to 2 ft. Contaminants that were not detected or do not have an associated wildlife ecotoxicological benchmark were not evaluated. The 95% UCL soil concentrations were compared with background concentrations identified from the ORR Background Soils Characterization Project (Environmental Sciences Divison 1993; Table G.8). Concentrations of inorganic contaminants in vegetation were estimated by using the 90th percentile of the ORR-specific soil-plant uptake factors presented in Efroymson et al. (1996). Soil-plant uptake factors for organic contaminants were derived from the log octanol-water partition coefficient (log K_{ow}) by using the following equation (Travis and Arms 1988; Table G.9):

$$\text{Log soil-plant uptake factor} = 1.588 - 0.578\ (\log K_{ow})$$

Concentrations of inorganic contaminants and PCBs in earthworms and small mammals were estimated using the 90th percentile of the ORR-specific soil-earthworm and soil-small mammal uptake factors presented in Sample et al. (1996b).

5.2.1.3 Exposure modeling using point-estimates

To estimate contaminant exposure experienced by white-tailed deer feeding within each OU, the following assumptions were made:

- Body weight = 56.5 kg.
- Food consumption = 1.74 kg/d.
- Soil consumption = 0.0348 kg/d.
- Diet consists 100% of vegetation.

To estimate contaminant exposure experienced by wild turkey feeding within each OU, the following assumptions were made:

- Body weight = 5.8 kg.
- Food consumption = 0.174 kg/d.
- Soil consumption = 0.0162 kg/d.
- Diet consists 100% of vegetation, seeds, and fruits.
- Contaminant concentrations in seeds and fruits are similar to vegetation.

To estimate contaminant exposure experienced by short-tailed shrew feeding within each OU, the following assumptions were made:

- Body weight = 0.015 kg.
- Food consumption = 0.009 kg/d.
- Soil consumption = 0.00117 kg/d.
- Diet consists 100% of earthworms.

To estimate contaminant exposure experienced by American woodcock feeding within each OU, the following assumptions were made:

- Body weight = 0.198 kg.
- Food consumption = 0.15 kg/d.
- Soil consumption = 0.0156 kg/d.
- Diet consists 100% of earthworms.

To estimate contaminant exposure experienced by red fox feeding within each OU, the following assumptions were made:

- Body weight = 4.5 kg.
- Food consumption = 0.45 kg/d.
- Soil consumption = 0.0126 kg/d.
- Diet consists 80.8% of small mammals, 10.4% plants, and 8.8% of earthworms..

To estimate contaminant exposure experienced by red-tailed hawk feeding within each OU, the following assumptions were made:

- Body weight = 1.126 kg.
- Food consumption = 0.109 kg/d.
- Soil consumption = 0 kg/d.
- Diet consists 100% of small mammals

By using the Equation 1 from Sect. 4.2.1 and the assumptions and data described above, the total exposure to contaminants was estimated for the white-tailed deer (Table G.10) wild turkey (Table G.11), short-tailed shrew (Table G12), American woodcock (Table G.13), red fox (Table G.14), and red-tailed hawk (Table G.15) foraging within each OU.

5.3 EFFECTS ASSESSMENT FOR HERBIVOROUS, VERMIVOROUS, AND PREDATORY WILDLIFE

5.3.1 Toxicological Benchmarks

To determine if the contaminant exposures experienced by terrestrial wildlife foraging on individual OUs could produce adverse effects, exposure estimates are compared with NOAELs and LOAELs derived according to the methods outlined by Sample et al. (1996). NOAELs represent the highest exposure at which no adverse effects were observed among the animals tested. LOAELs represent the lowest exposure at which significant adverse effects are observed.

Toxicological studies of the effects of contaminants observed in the soil were obtained from the open literature. Only studies of long-term, chronic oral exposures were used to estimate the NOAEL or LOAEL. To make the NOAELs and LOAELs relevant to possible population effects, preference was given to studies that evaluated effects on reproductive parameters. In the absence of a reproduction endpoint, studies that considered effects on growth, survival, and longevity were used. Experimental data used for the development of NOAELs and LOAELs for mammalian endpoints are presented in Table G.16; estimated NOAELs and LOAELs for mammalian endpoints are listed in Table G. 17. Experimental data used for the development of NOAELs and LOAELs for avian endpoints and estimated wildlife NOAELs and LOAELs are presented in Table G.18. Specific details on development of the NOAELs and LOAELs for all wildlife endpoints are discussed in Sect. 4.3.1.

5.3.2 Ecotoxicological Profiles for Herbivorous and Vermivorous Wildlife

The ecotoxicological profiles for COPECs for herbivorous and vermivorous wildlife on the ORR may be found in Appendix D.

5.4 RISK CHARACTERIZATION FOR HERBIVOROUS, VERMIVOROUS, AND PREDATORY WILDLIFE

Risk characterization integrates the results of the exposure assessment (Sect. 5.2) and effects assessment (Sect. 5.3) to estimate risks (the likelihood of effects given the exposure) based on each line of evidence. A weight of evidence approach, as outlined in Suter et al. (1995), is applied to determine the best estimate of risk to each assessment endpoint. This risk assessment is based on only one line of evidence: literature-derived single chemical toxicity data that indicates the toxic effects of media concentrations measured within each OU.

Procedurally, the risk characterization in this assessment is performed for each assessment endpoint by

- screening all measured contaminants within each OU against background soil levels and toxicological benchmarks;
- estimating the effects of the contaminants retained by the screening analysis for individuals of each endpoint species;
- estimating the number of individuals within the ORR population;
- estimating the number of individuals within an OU that are potentially exposed based on habitat availability and population density;
- calculating the total number of individuals on the ORR that may be at risk (addition of number of animals exposed within all OUs for which data exist);
- calculating the percentage of the ORR population that may experience adverse effects from contaminant exposure;
- using the 20% exposure criteria outlined in Suter et al. (1995), determine if reservation-wide endpoint populations are significantly at risk from contaminants present within OUs for which data is available;
- prioritizing the OUs based on the contribution of risk to the entire ORR population; and
- discussing the uncertainties in the assessment.

Data for this assessment was limited to single chemical toxicity data and habitat availability for herbivores, vermivores, and predators inhabiting the ORR.

5.4.1 Contaminant Screening of Soil to Background Levels

The initial screening for COPECs in soil begins with a comparison of the 95% UCL or single detected concentration found in surface soil in each OU with appropriate ORR background soils identified in the ORR Background Soils Characterization Project (Environmental Sciences Division 1993). Table G.8 identifies the background levels (95% UCL) found for each formation indicative of each OU. In some cases, an OU may be located on multiple formations. Therefore, a range of the minimum and maximum 95% UCL background values for multiple formations were used for comparison. Data were not available for certain formations indicative of an OU; thus, the range of 95% UCLs of all formations was used.

Chemicals were rejected from further consideration if the 95% UCL concentrations in OU soil were <95% UCL background concentration for the specific formation. Aluminum was eliminated from the analysis for WAG 1 and WAG 6. Arsenic was eliminated from K-1420 OU, LEFPC, and UEFPC OU 2. Chromium, mercury, and zinc were eliminated from WAG 6. Vanadium was eliminated from K-1407, the South Campus Facility, and UEFPC OU.

5.4.2 Single Chemical Toxicity Data for Herbivorous, Vermivorous, and Predatory Wildlife (Individuals)

Exposure of endpoint species to chemicals found in concentrations greater than background was calculated. The total contaminant exposure estimates for herbivores, vermivores, and predators foraging on vegetation, earthworms, and/or small mammals within an OU were compared with estimated LOAELs. If the LOAEL was lower than the exposure, portions of the endpoint population may experience contaminant exposures that are likely to produce adverse effects. Consequently, the *individuals* living within the OU are at risk because of hazardous exposures.

5.4.2.1 Screening point estimates of exposure

To determine if the contaminant exposures experienced by herbivores, vermivores, and predators feeding on each OU are potentially hazardous, the total exposure estimates were compared with estimated LOAELs. HQs were calculated to quantify the magnitude of the hazard where

NOAEL HQ = estimated contaminant exposure (mg/kg/d)/NOAEL

LOAEL HQ = estimated contaminant exposure (mg/kg/d)/LOAEL.

HQs>1 indicate that individuals may be experiencing exposures that are in excess of LOAELs and suggest that adverse effects may be occurring. HQs for all endpoints are presented along with exposure estimates in Tables G.10 to G.15. Contaminants that may most likely adversely impact the individual endpoints foraging within OUs are discussed below. The location (operable unit) of COPECs for each endpoint species are further detailed in Table 5.1. This discussion is limited to those contaminants for which the 95% UCL was greater than background concentrations and for which the LOAEL HQ was >1.

Exposure of herbivores, vermivores, and predators to aluminum exceeded both NOAELs and LOAELs at many locations, including the background. However, it is highly unlikely that the aluminum exposures estimated within the OUs are toxic and present a hazard to wildlife. This is for several reasons. Aluminum is a common and abundant structural element in soil whose most common

Table 5.1. Location (operable units[a]) of contaminants of potential concern for each endpoint species

Contaminant	White-tailed deer	Wild Turkey	Short-tailed shrew	American Woodcock	Red Fox	Red-tailed Hawk
Acetone	SCF		SCF		SCF	
Antimony			BC OU 1 BCV OU			
Arsenic	FCAP		BC OU 2 FCAP K-1407 OU SCF WAG 1	BC OU 2 K-1407 OU SCF	BC OU 2 FCAP	
Barium	FCAP		FCAP UEFPC OU 2 WAG 5	UEFPC OU 2		
Boron				WAG 1		
Cadmium			SCF WAG 2	LEFPC SCF		
Chromium			BC OU 2 K-1407 OU K-1420 OU LEFPC SCF UEFPC OU 2 WAG 1	BC OU 2 K-1407 OU K-1420 OU UEFPC OU 2 WAG 1 WAG 5	UEFPC OU 2 FCAP	
Copper			BCV OU LEFPC	LEFPC		
DDT and metabolites		LEFPC	LEFPC	LEFPC		
Lead				BC OU 2 K-1420 OU LEFPC UEFPC OU 2		
Lithium			K-1420 OU			

Table 5.1 (continued)

Contaminant	White-tailed deer	Wild Turkey	Short-tailed shrew	American Woodcock	Red Fox	Red-tailed Hawk
Mercury	BC OU 2 LEFPC	BC OU 2 K-1407 OU LEFPC WAG 2	BC OU 1 BC OU 2 BCV OU K-1407 OU K-1420 OU LEFPC SCF WAG 1 WAG 2 WAG 5	BC OU 2 K-1407 OU K-1420 OU LEFPC SCF WAG 1 WAG 5	BC OU 2 FCAP K-1407 OU K-1420 OU LEFPC SCF WAG 1 WAG 2	BC OU 2 FCAP K-1407 OU LEFPC WAG 1
Methylene chloride	SCF					
Nickel			K-1407 OU UEFPC OU 2	BC OU 2 K-1407 OU K-1420 OU LEFPC UEFPC OU 2 WAG 6		
Selenium	FCAP		BC OU 2 FCAP K-1407 OU LEFPC SCF WAG 1 WAG 2	BC OU 2 K-1407 OU LEFPC SCF WAG 1	FCAP K-1407 OU LEFPC WAG 1	FCAP
Thallium	FCAP		FCAP WAG 1		FCAP WAG 1	

Table 5.1 (continued)

Contaminant	White-tailed deer	Wild Turkey	Short-tailed shrew	American Woodcock	Red Fox	Red-tailed Hawk
Total PCBs			BC OU 1			
			BC OU 2			
	BC OU 2		BCV OU	BC OU 2		
	K-1420 OU		K-1420 OU	K-1420 OU	K-1420 OU	
	LEFPC		LEFPC	LEFPC	LEFPC	
	WAG 1		SCF	WAG 1		
			WAG 1			
			WAG 2			
Uranium			K-1407 OU			
			K-1420 OU			
Vanadium			BC OU 1			
	FCAP		BC OU 2			
			FCAP			
			SCF			
Zinc				BC OU 2		
				K-1407 OU		
				K-1420 OU		
			UEFPC OU 2	LEFPC		
				SCF		
				UEFPC OU 2		
				WAG 1		
				WAG 5		

[a] Data from Bear Creek (BC) OU 1, Bear Creek Valley (BCV) OU, Filled Coal Ash Pond (FCAP), WAG 2, and WAG 5 were taken from the following sources:

Environmental Sciences Division. 1996. Report on the Remedial Investigation of Bear Creek Valley at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee. Volume 6. Appendix G—Baseline Ecological Risk Assessment Report. DOE/OR/01-1455/V6&D0. Oak Ridge National Laboratory. Oak Ridge, TN.

CDM Federal. 1995. Remedial Investigation Report on Chestnut Ridge Operable Unit 2 (Filled Coal Ash Pond/Upper McCoy Branch) at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee. Volume 1. Main Text. DOE/OR/01-1268/V1&D2. Y/ER-172/V1&D2. Oak Ridge, TN.

Efroymson, R. A., B. L. Jackson, D. S. Jones, B. E. Sample, G. W. Suter II, and C. J. E. Welsh. 1996. Waste Area Grouping 2 Phase I Task Data Report: Ecological Risk Assessment and White Oak Creek Watershed Screening Ecological Risk Assessment. ORNL/ER-366. Oak Ridge National Laboratory, Oak Ridge, TN.

Bechtel National, Inc./ CH2M Hill/ Ogden/PEER. 1995. Remedial Investigation Report on Waste Area Grouping 5 at Oak Ridge National Laboratory, Oak Ridge, Tennessee. Volume 4. Appendix C: Risk Assessment. DOE/OR/01-1326&D2/V4. ORNL/ER-284&D2/V4. ORNL/ER/Sub/87-99053/76/V4. Oak Ridge, TN.

forms are unlikely to be bioavailable and therefore toxic; toxicity data for aluminum are derived from soluble salts (e.g., $AlCl_3$) that do not accurately reflect the toxicity of the forms generally found in soil (e.g., oxides). Therefore, aluminum was eliminated as a COPEC from all subsequent analyses.

White-tailed deer. Deer foraging on the Filled Coal Ash Pond (FCAP) are potentially at greatest risk with five COPECs (Table 5.1). Deer foraging on SCF, Bear Creek (BC) OU 2, and LEFPC are also at risk; each OU had three COPECs with HQs>1. K-1420 OU, K-1407 OU, UEFPC OU 2, and WAG 1 had two, one, one, and one COPECs with HQs>1, respectively. COPECs for deer were PCBs (five locations), mercury (two locations), acetone (one location), and methylene chloride (one location).

Wild turkey. Mercury is the only major contaminant that poses a risk to wild turkey on BC OU 2, K-1407 OU, and LEFPC. DDT (and metabolites) is 24 times the benchmark for turkey on LEFPC. No other COPECs were identified for wild turkey on any of the other OUs.

Short-tailed shrews. Short-tailed shrews may be at significant risk foraging at all OUs except WAG 6 (Table 5.1). Each OU had from two to eight COPECs. Mercury, Cr, Se, total PCBs, and As contributed to the majority of the risk. Mercury at BC OU 2 and LEFPC were 560 and 306 times the benchmark, respectively.

American woodcock. American woodcock may be at significant risk foraging at most OUs except for BC OU 1, Bear Creek Valley (BCV) OU, FCAP, WAG 2, and WAG 6 (Table 5.1). Risk is primarily due to exposure to mercury, DDT and metabolites, and chromium. Foraging at LEFPC poses the most significant risk, with possible exposure to 10 COPECs. The remaining OUs with HQs>1 had from three to eight COPECs except for WAG 6, which had only one COPEC, nickel, at only 1.73 times the benchmark. Zinc was identified as a COPEC at eight locations. Other significant COPECs for woodcock were Hg at seven locations, Ni and Cr at six locations, Se (five), Pb and total PCBs (four), and As (three). Barium, B, Cu, DDT, and metabolites were above benchmark values at one location, and Cd was found at two locations.

Red fox. Mercury poses the most significant risk to red fox foraging on 8 of the 13 OUs. Mercury concentrations at BC OU 2 and LEFPC are 462 and 253 times the benchmark, respectively. With the exception of WAG 6, each of the OUs has between two to four COPECs found at concentrations large enough to exceed benchmark values. Other COPECs for red fox were Se (4 locations), total PCBs (2), and As, Cr, and Tl (2).

Red-tailed hawk. Mercury and selenium were the only contaminants that pose a risk to red-tailed hawks on the ORR. Mercury was identified as a COPEC at five locations. BC OU 2 and LEFPC were the primary contributors to risk from mercury, with levels that exceeded benchmarks by 86 and 47 times, respectively. Selenium was identified as a COPEC at FCAP.

5.4.3 Effects of Retained Contaminants for Herbivorous, Vermivorous, and Predatory Wildlife

5.4.3.1 Acetone

Both the NOAEL and LOAEL for mammalian endpoints are based on a study in which liver and kidney damage was observed in rats fed acetone for 90 days (EPA 1986). Three dose levels were administered (100, 500, and 2500 mg/kg/d). Significant tubular degeneration of the kidneys and increases in kidney weights were observed at the 500 mg/kg/d dose level. No adverse effects were observed at the 100 mg/kg/d level. These doses are considered subchronic values and therefore were multiplied by the subchronic-chronic uncertainty factor of 0.1. On the basis of the results of EPA (1986), white-tailed deer foraging at SCF experiencing exposure greater than or equal to LOAEL may display tubular degeneration of the kidneys.

Although acetone is highly volatile, the exposure experienced by white-tailed deer is 24.98 times the LOAEL, and the exposure to short-tailed shrews is 3.5 times the LOAEL at SCF. The presence of acetone may be a concern if it is a continuous source.

5.4.3.2 Antimony

Both the NOAEL and LOAEL for mammalian endpoints are based on a study in which lifespan and longevity was observed in mice fed antimony potassium tartrate for the lifetime of the organism (Schroeder et al. 1968b). One dose level was administered. Because median lifespan was reduced among female mice exposed to the 5 ppm dose level and because the study considered exposure throughout the entire lifespan, this dose was considered to be a chronic LOAEL. A chronic NOAEL was estimated by multiplying the chronic LOAEL by a LOAEL-NOAEL uncertainty factor of 0.1. On the basis of the results of Schroeder et al. (1968b), short-tailed shrews foraging on BCV OU and BC OU 1 may have reduced lifespans.

5.4.3.3 Arsenic

Both the NOAEL and LOAEL for mammalian endpoints are based on a study in which reproductive success and offspring survival was observed among mice fed arsenite for three generations (Schroeder and Mitchener 1971). One dose level administered (1.261 mg/kg/d), designated as the chronic LOAEL, resulted in declining litter size with each successive generation. A chronic NOAEL was estimated by multiplying the chronic LOAEL by a LOAEL-NOAEL correction factor of 0.1. Based on the results of Schroeder and Mitchener (1971), short-tailed shrews foraging within most of the OUs and red fox foraging on BC OU 2 experiencing exposures greater than or equal to LOAEL are likely to display a decline in litter size.

The NOAEL and LOAEL for American woodcock are based upon a study in which mortality was observed in mallard ducks fed sodium arsenite for 128 days (U.S. Fish and Wildlife Service 1964). Four dose levels were administered. Mallards in the 1000, 500, and 250 ppm groups experienced 92%, 60%, and 12% mortality, respectively. Because those in the 100 ppm group experienced 0% mortality, and the study considered exposure over 128 days, the 100 ppm Sodium Arsenite (51.35 mg/kg As^{+3}) dose was considered to be a chronic NOAEL. The 250 ppm Sodium Arsenite (128.375 mg/kg As^{+3}) dose was considered to be a chronic LOAEL. On the basis of the results of the U.S. Fish and Wildlife Service (1964), American woodcock foraging on BC OU 2, K-1407 OU, and SCF experiencing exposures greater than or equal to LOAEL may display increased mortality.

5.4.3.4 Barium

The NOAELs for mammals are based on a study in which growth, food and water consumption, and hypertension was observed among rats fed barium chloride for 16 months (Perry et al. 1983). Three dose levels were administered. The maximum dose (5.1 mg/kg/d) did not affect growth or food or water consumption and was therefore considered to be a chronic NOAEL. The LOAEL was based on a study which observed mortality in rats fed barium for 10 days (Borzelleca et al. 1988). Four doses were administered and exposure of rats to the highest dose (300 mg/kg/d) resulted in 30% mortality to female rats. The 300 mg/kg/d dose is considered to be a subchronic LOAEL; therefore a chronic LOAEL was estimated by multiplying the subchronic LOAEL by a subchronic to chronic uncertainty factor of 0.1. On the basis of the results of Borzelleca et al. (1988), short-tailed shrews foraging on UEFPC OU 2 and WAG 5 experiencing exposures greater than or equal to LOAEL may display increased mortality.

Both the NOAELs and LOAELs for woodcock are based on a study that observed mortality to 1-day-old chicks fed 8 doses of barium hydroxide for 4 weeks (Johnson et al. 1960). The NOAEL dosage (208.3 mg/kg/d) produced no mortality; the LOAEL dosage (416.5 mg/kg) and highest dosage (40.3 mg/kg/d) resulted in 5% to 100% mortality. The NOAEL and LOAEL were considered subchronic and was multiplied by the subchronic to chronic uncertainty factor of 0.1. On the basis of the results of Johnson et al. (1960), American woodcock foraging at UEFPC OU 2 experiencing exposures greater than or equal to LOAEL may display increased mortality.

5.4.3.5 Boron

Both the NOAELs and LOAELs for mammals are based on a study in which reproductive success was observed among rats fed boric acid for three generations (Weir and Fisher 1972). Three does levels were administered. Although consumption of 1170 ppm boron as either boric acid or borax resulted in sterility, no adverse reproductive effects were observed among rats consuming 117 or 350 ppm boron. Because the study considered exposure throughout 3 generations including critical lifestages (reproduction), the 350 ppm dose was considered to be a chronic NOAEL and the 1170 ppm dose was considered a chronic LOAEL. There are no mammalian species at risk from boron at any of the OUs.

Both NOAEL and LOAEL for avian endpoints are based on a study in which reproductive success and mortality was monitored for mallard ducks fed boric acid 3 weeks before, during, and 3 weeks after reproduction (Smith and Anders 1989). Four dose levels were administered. Although consumption of 1000 ppm boron resulted in reduced egg fertility and duckling growth and increased embryo and duckling mortality, no adverse reproductive effects were observed among the other dose levels. Because the study considered exposure throughout reproduction, the 288 ppm dose was considered to be a chronic NOAEL and the 1000 ppm dose was considered a chronic LOAEL. On the basis of the results of Smith and Anders (1989), American woodcock foraging on WAG 1 experiencing exposures greater than or equal to LOAEL may display decreased reproduction.

5.4.3.6 Cadmium

Both the NOAEL and LOAEL for mammalian endpoints are based upon a study in which reproductive success was observed among rats fed cadmium chloride for 6 weeks through mating and gestation (Sutou et al. 1980). Four dose levels were administered. Although no adverse effects were observed at the 1 mg/kg/d dose level, fetal implantations were reduced by 28%, fetal survivorship was reduced by 50%, and fetal resorptions increased by 400% among the 10 mg/kg/d group. Because the study considered oral exposure during reproduction, the 1 and 10 mg/kg/d doses were considered to be chronic NOAELs and LOAELs, respectively. On the basis of the results of Sutou et al. (1980b), short-tailed shrews foraging on SCF experiencing exposures greater than or equal to LOAEL may display decreased reproduction.

Both the NOAEL and LOAEL for avian endpoints are based on a study in which reproductive success was observed among mallard ducks fed cadmium chloride for 90 days (White and Finley 1978). Three dose levels were administered. The highest dosage (20.03 mg/kg/d), designated as the chronic LOAEL, produced significantly fewer eggs. A dosage of 1.45 mg/kg/d produced no adverse effects and was designated as the chronic NOAEL. On the basis of the results of White and Finley

(1978), American woodcock experiencing exposures greater than or equal to LOAEL at BC OU 1 may display impaired reproduction. Also on the basis of the results of White and Finely (1978), American woodcock foraging on LEFPC and SCF experiencing exposures greater than or equal to LOAEL may display decreased reproductive success.

5.4.3.7 Chromium

The LOAEL for mammalian endpoints is based upon a study in which mortality was observed in rats fed chromium (Cr^{+6}) for three months [Steven et al. 1976 (cited in Eisler 1986a)]. Two doses were administered. Because the 1000 ppm dose was identified as the toxicity threshold, this dose was considered to be a subchronic LOAEL. A chronic LOAEL was estimated by multiplying the subchronic LOAEL by a subchronic-chronic uncertainty factor of 0.1. On the basis of the studies of Steven et al. (1976), short-tailed shrews foraging on most OUs and red fox foraging on UEFPC OU 2 experiencing exposures greater than or equal to LOAEL may display increased mortality.

Both the NOAEL and LOAEL for avian endpoints are based upon a study in which reproduction in black ducks was observed fed chromium [Cr^{+3} as $CrK(SO_4)_2$] for ten months (Haseltine et al., unpubl. data). Two doses were administered. Although duckling survival was reduced at the 50 ppm dose level, no significant differences were observed at the 10 ppm Cr^{+3} dose level. Because the study considered exposure throughout a critical lifestage (reproduction), the dose 50 ppm dose was considered to be a chronic LOAEL and the dose 10 ppm dose was considered to be a chronic NOAEL. On the basis of the results of Haseltine et al., American woodcock foraging on most OUs experiencing exposures greater than or equal to LOAEL may display decreased reproductive success.

5.4.3.8 Copper

Both the NOAEL and LOAEL for mammalian endpoints are based on a study in which mink were fed copper sulfate for 357 days (including a critical life stage) (Aulerich et al. 1982). Although consumption of 15.14 mg/kg/d copper increased the percentage of mortality in mink kits, no adverse effects were observed at a 11.71 mg/kg/d exposure level. On the basis of the results of Aulerich et al. (1982), short-tailed shrews experiencing exposures greater than or equal to LOAEL within LEFPC display a reduction in offspring survival.

Both the NOAEL and LOAEL for avian endpoints are based on a study in which 1-day-old chicks were fed copper oxide for 10 weeks (Mehring et al. 1960). Eleven dose levels were administered in the study. No adverse effects were observed on the growth of chicks up to dose levels of 47 mg/kg/d. Consumption of 61.7 mg/kg/d copper in the diet, designated as the LOAEL, resulted in reduced growth by over 30% and produced 15 % mortality. On the basis of the results of Mehring et al. (1960), American woodcock experiencing exposures greater than or equal to LOAEL at LEFPC may display a reduction in growth and survivorship.

5.4.3.9 DDT and metabolites

Both the NOAEL and LOAEL for mammalian endpoints are based upon a study in which reproduction was observed in rats fed DDT for 2 years (Fitzhugh 1948). Four dose levels were administered. Although consumption of 50 ppm or more DDT in the diet reduced the number of young produced, no adverse effects were observed at the 10 ppm DDT dose level. Because the study considered exposure throughout 2 years and reproduction, the 10 and 50 ppm DDT doses were considered to be chronic NOAELs and LOAELs, respectively. On the basis of the results of Fitzhugh

(1948), short-tailed shrews experiencing exposures greater than or equal to LOAEL may display decreased reproductive success.

Both the NOAEL and LOAEL for avian endpoints are based on a study in which reproduction was observed in brown pelican for 5 years (Anderson et al. 1975). One dose level was administered. Anderson et al. (1975) studied the reproductive success of pelicans from 1969 through 1974. During this time, DDT residues in anchovies, their primary food, declined from 4.27 ppm (wet weight) to 0.15 ppm (wet weight). Although reproductive success improved from 1969 to 1974, in 1974 the fledgling rate was still 30% below that needed to maintain a stable population. Because this study was long-term and considered reproductive effects in a wildlife species, EPA (1993) judged this study to be the most appropriate to evaluate DDT effects to avian wildlife. Therefore the 0.15 ppm DDT value was considered to be a chronic LOAEL. To estimate the chronic NOAEL, the chronic NOAEL was multiplied by a LOAEL-NOAEL uncertainty factor of 0.1. On the basis of the results of Anderson et al. (1975), wild turkey and American woodcock experiencing exposures greater than or equal to LOAEL may experience long-term reproductive effects.

5.4.3.10 Lead

Both the NOAEL and LOAEL for mammalian endpoints are based on a study in which reproduction was observed in rats fed lead (lead acetate) for three generations (Azar et al. 1973). Five dose levels were administered. Although none of the lead exposure levels studied affected the number of pregnancies, the number of live births, or other reproductive indices, lead exposure of 1000 and 2000 ppm resulted in reduced offspring weights and produced kidney damage in the young. Therefore the 100 ppm lead dose was considered to be a chronic NOAEL and the 1000 ppm lead dose was considered to be a chronic LOAEL.

The NOAEL and LOAEL for avian species are based on a study in which the reproductive success of Japanese quail fed lead (acetate) was observed for 12 weeks (Edens et al. 1976). Four dose levels were administered. Although egg hatching success was reduced among birds consuming the 100 ppm lead dose, reproduction was not impaired by the 10 ppm lead dose. Because the study considered exposure over 12 weeks and throughout a critical lifestage (reproduction), these values were considered to be chronic LOAELs and NOAELs. Final NOAEL: 1.13 mg/kg/d; final LOAEL: 11.3 mg/kg/d. On the basis of the results of Edens et al. (1976), American woodcock foraging on BC OU 2, K-1420 OU, LEFPC, and UEFPC OU 2 experiencing exposures greater than or equal to LOAEL may display decreased reproductive success.

5.4.3.11 Mercury

Both the NOAEL and LOAEL for mammalian endpoints are based on a study in which reproductive success and offspring survival was observed among rats fed methyl mercury for three generations (Verschuuren et al. 1976c). The highest dose administered (0.16 mg/kg/d), designated as the LOAEL, resulted in reduction in offspring viability. This exposure also resulted in reduction in growth, increased kidney weight, and altered kidney histochemistry (Verschuuren et al. 1976b). No effects were observed at a dose of 0.032 mg/kg/d. The study was considered to represent chronic exposure; therefore, a subchronic-chronic correction factor was not employed. On the basis of the results of Verschuuren et al. (1976a–c), white-tailed deer, short-tailed shrews, and red fox experiencing exposure greater than or equal to LOAELs are likely to display impaired reproduction.

Both the wild turkey and American woodcock NOAELs and LOAELs are based on a study in which reproductive success was observed among mallard ducks that were fed methyl mercury for three generations (Heinz 1979). The study was considered to represent a chronic exposure. The only dose level administered, 0.064 mg/kg/d, caused hens to lay fewer eggs, lay more eggs outside the nest box, and produce fewer ducklings. This dose level was considered the chronic LOAEL. Because an experimental NOAEL was not established, the chronic NOAEL was estimated by multiplying the chronic LOAEL by a LOAEL-NOAEL uncertainty factor of 0.1. On the basis of the results of Heinz (1979), wild turkeys, American woodcock, and red-tailed hawk experiencing exposures greater than or equal to LOAELs may display impaired reproduction.

5.4.3.12 Methylene chloride

The NOAEL and LOAEL for the mammalian endpoints was based on a study in which rats were fed methylene chloride for 2 years (National Coffee Association 1982). Rats fed a 5.85 mg/kg/d dose level did not experience adverse effects and is considered the chronic NOAEL. Rats consuming 50 mg/kg/d or greater produced histological changes in the liver. This dose level was designated as the chronic LOAEL. On the basis of the results of the National Coffee Association (1982), white-tailed deer experiencing exposures greater than or equal to LOAELs at SCF may display changes in liver histology.

5.4.3.13 Nickel

Both the NOAEL and LOAEL for mammalian endpoints are based on a study in which reproduction was observed in rats fed nickel (nickel sulfate hexahydrate) for three generations (Ambrose et al. 1976). Three dose levels were administered. Although 1000 ppm Ni in the diet reduced offspring body weights, no adverse effects were observed in the other dose levels. Because this study considers exposures over multiple generations, the 500 ppm dose was considered to be a chronic NOAEL and the 1000 ppm dose was considered to be a chronic LOAEL. On the basis of the results of Ambrose et al. (1976), short-tailed shrew foraging on K-1407 OU and UEFPC OU 2 experiencing exposures greater than or equal to LOAEL may display reduced offspring body weight.

Both the NOAEL and LOAEL for avian species are based on a study in which mortality, growth, and behavior were observed in mallard ducklings fed nickel (nickel sulfate) for 90 days (Cain and Pafford 1981). Three doses were administered. Although consumption of up to 774 ppm nickel in diet did not increase mortality or reduce growth, the 1069 ppm nickel diet reduced growth and resulted in 70% mortality. Because the study considered exposure over 90 days, the 774 ppm dose was considered to be a chronic NOAEL and the 1069 ppm dose was considered to be a chronic LOAEL. To estimate daily nickel intake throughout the 90-day study period, food consumption of 45-day-old ducklings was calculated. Although this value will over- and underestimate food consumption by younger and older ducklings, it was assumed to approximate food consumption throughout the entire 90-day study. On the basis of the results of Cain and Pafford (1981), American woodcock foraging on most OUs experiencing exposures greater than or equal to LOAEL may have impaired growth.

5.4.3.14 PCBs

The mammalian endpoint NOAEL and LOAEL are based on a study in which old field mice were fed Aroclor 1254 for 12 months (McCoy et al. 1995). A dose level of 0.68 mg/kg/d, designated as the chronic LOAEL, caused a reduction in the number of litters, offspring weights, and offspring survival. Because an experimental NOAEL was not established, the chronic NOAEL was estimated by multiplying the chronic LOAEL by a LOAEL-NOAEL uncertainty factor of 0.1.On the basis of the results of McCoy et al. (1995), short-tailed shrews and wild turkeys at most OUs, as well as red fox at K-1420 OU and LEFPC, experiencing exposures greater than or equal to the LOAEL may display impaired reproduction and offspring viability.

The American woodcock NOAEL and LOAEL are based on a study in which ring-necked pheasants were fed Aroclor 1254 for 17 weeks (Dahlgren et al. 1972). A dose level of 1.8 mg/kg/d, designated as the chronic LOAEL, caused a significant reduction in egg hatchability. Because an experimental NOAEL was not established, the chronic NOAEL was estimated by multiplying the chronic LOAEL by a LOAEL-NOAEL uncertainty factor of 0.1. On the basis of the results of Dahlgren et al. (1972), American woodcock experiencing exposures greater than or equal to the LOAEL may display a reduction in egg hatchability.

5.4.3.15 Selenium

Both the NOAEL and LOAEL for mammalian endpoints are based on a study in which reproduction was observed in rats fed selenium (SeO_4) for 1 year (Rosenfeld and Beath 1954). Three dose levels were administered. Although no adverse effects on reproduction were observed among rats exposed to 1.5 mg Se /L in drinking water, the number of second-generation young was reduced by 50% among females in the 2.5 mg/L group. In the 7.5 mg/L group, fertility, juvenile growth and survival were all reduced. Because study considered exposure over multiple generations, the 1.5 and 2.5 mg/L doses were considered to be chronic NOAEL and LOAEL, respectively. On the basis of the results of Rosenfield and Beath (1954), short-tailed shrews at most OUs, and red fox at K-1407 OU, LEFPC, and WAG 1 experiencing exposures greater than or equal to LOAEL may display long-term reductions in reproductive viability.

The NOAEL and LOAEL for avian endpoints are based on a study in which reproductive success was observed in mallard ducks fed selenium (sodium selenite) for 78 days (Heinz et al. 1987). Five dose levels were administered. Although consumption of 1, 5, or 10 ppm selenium on the diet as Sodium Selenite had no effect on weight or survival of adults, 100 ppm selenium reduced adult survival and 25 ppm selenium reduced duckling survival. Consumption of 10 or 25 ppm selenium in the diet resulted in a significantly larger frequency of lethally deformed embryos as compared with the 1 or 5 ppm selenium exposures. Because 5 ppm selenium in the diet was the highest dose level that produced no adverse effects and the study considered exposure through reproduction, this dose was considered to be a chronic NOAEL. The lowest dose at which adverse effects were observed, 10 ppm, was considered to be a chronic LOAEL. On the basis of the results of Heinz et al. (1987), American woodcock foraging at most OUs experiencing exposures greater than or equal to LOAEL may display an increased frequency of deformed embryos.

5.4.3.16 Thallium

The mammalian endpoint NOAEL and LOAEL are based on a study in which rats were fed thallium sulfate for 60 days (Formigli et al. 1986). This study represents subchronic exposures because the duration of the study did not include a critical life stage. Rats exposed to a single dose, 0.074 mg/kg/d, displayed reduced sperm motility. Because this is a subchronic exposure, a subchronic-chronic uncertainty factor of 0.1 was applied to obtain a chronic LOAEL. To estimate the chronic NOAEL, the chronic LOAEL was multiplied by a LOAEL-NOAEL uncertainty factor of 0.1. On the basis of the results of Formigli et al. (1986), short-tailed shrews and red fox foraging on WAG 1 experiencing exposures greater than or equal to the LOAEL may display impaired reproduction from a reduction of sperm motility.

5.4.3.17 Uranium

The short-tailed shrew NOAEL and LOAEL are based on a study in which mice were fed uranyl acetate for 60 days prior to gestation, through gestation, delivery, and lactation (Paternain et al. 1989). This study represents chronic exposures because it took place during the critical life stage of the mouse. Significant effects on reproduction including increased number dead young/litter and reduction in size and weight of offspring were observed at 6.13 mg/kg/d. The lowest dose administered, 3.07 mg/kg/d, resulted in no significant differences in measured reproductive parameters. Therefore, these doses were considered the chronic LOAEL and NOAEL, respectively. On the basis of the results of Paternain et al. (1989), short-tailed shrews foraging on K-1407 or K-1420 OUs experiencing exposures greater than or equal to the LOAEL may display a reduction in reproductive success.

5.4.3.18 Vanadium

The short-tailed shrew NOAEL and LOAEL are based on a study in which rats were fed sodium metavanadate for 60 days prior to gestation, through gestation, delivery, and lactation (Domingo et al. 1986). This study represents chronic exposures because it took place during the rat's critical life stage. Significant effects on reproduction including increased number dead young/litter and reduction in size and weight of offspring were observed at the lowest dose administered, 5 mg/kg/d. Therefore, this dose was considered the chronic LOAEL. To estimate the chronic NOAEL, the chronic LOAEL was multiplied by a LOAEL-NOAEL uncertainty factor of 0.1. On the basis of the results of Domingo et al. (1986), short-tailed shrews foraging at BC OU 2 or SCF experiencing exposures greaterm than or equal to the LOAEL may display a reduction in reproductive success.

5.4.3.19 Zinc

Both the NOAEL and LOAEL for mammalian endpoints are based on a study in which reproductive success was observed in rats fed zinc oxide for days 1–16 of gestation (Schlicker and Cox 1968). Two dose levels were administered. Rats exposed to 4000 ppm zinc in the diet displayed increased rates of fetal resorption and reduced fetal growth rates. Because no effects were observed at the 2000 ppm zinc dose rate and because the exposure occurred during gestation (a critical lifestage), this dose was considered a chronic NOAEL. The 4000 ppm zinc dose was considered to be a chronic LOAEL. On the basis of the results of Schlicker and Cox (1968), short-tailed shrews foraging on UEFPC OU 2 experiencing exposures greater than or equal to LOAEL may display increased rates of fetal resorption and reduced fetal growth rates.

Both the NOAEL and LOAEL for avian endpoints are based upon a study in which reproductive success was observed for white leghorn hens fed zinc sulfate for 44 weeks (Stahl et al. 1990). Three dose levels were administered. Although no adverse effects were observed among hens consuming 48 and 228 ppm zinc, egg hatchability was <20% of controls among hens consuming 2028 ppm zinc. Because the study was greater than 10 weeks in duration and considered exposure during reproduction, the 228 ppm dose was considered a chronic NOAEL, and the 2028 ppm dose was considered a chronic LOAEL. On the basis of the studies of Stahl et al. (1990), American woodcock foraging at most OUs experiencing exposures greater than or equal to the LOAEL may display reduced egg hatchability.

5.4.4 Population Level Risks on the Oak Ridge Reservation

The COPECs within each OU, as designated by the screening process (Sect. 5.4.1), may cause adverse effects (Sect. 5.4.2) to *individuals* foraging within each OU. To consider adverse effects on the reservation-wide *population*, steps 3 through 6 within the problem formulation (Sect. 5.1) must be completed. By comparing an endpoint species habitat requirements (Table B.1), the amount of suitable habitat within each OU (Table B.3), and population densities for each endpoint (see following), the number of individuals exposed on an OU can be estimated. The densities used for each endpoint species are presented in the following table.

	White-tailed deer	Wild turkey	Short-tailed shrew	American woodcock	Red fox	Red-tailed hawk
Density	0.1704[a]	0.0426[a]	23/ha (median of 2.5 to 45/ha range)	.28/ha (based on 5.6 males /100 ha; assuming 1:1 sex ratio)	0.77/ha	0.03 pairs/ha
No. on the ORR (if known)	2000	>500				
Source	Personal communication, Jim Evans	Personal communication, Jim Evans	Getz 1989	Stewart and Robbins 1958	EPA 1993b	EPA 1993b

[a]Density calculated based on total deer and turkey habitat on ORR (11,734.8 ha) and total number of deer and turkey estimated on ORR (2000 deer and 500 turkey).

Because contaminants found on all OUs, except for K-1414, present a risk to all assessment endpoints, the number of animals present in the OU is equivalent to the number of individuals exposed at unacceptable levels. The estimated number of individuals of endpoint species exposed within each OU and the proportion of the reservation-wide population that are at risk are summarized in Tables 5.2 through 5.7.

Although specific OUs pose unacceptable risks to the individuals, the total number of exposed individuals within the entire ORR population is minimal. Approximately 8.77% and 8.8.1% of the reservation-wide populations of turkey and deer are at risk. Only 8.6% and 8.95% of short-tailed shrews and woodcock on the ORR are at risk. Approximately 8.82% of the red-tailed hawk and 8.71% of the red fox are at risk on the ORR. Therefore, using the 20% criterion outlined by Suter et al. (1995), the occurrence of population-level effects on the reservation are highly unlikely. However, because the short-tailed shrew is a measurement endpoint for four species of T&E shrews, 8.6% of the impacted population may represent a significant risk to T&E shrews on the ORR.

BCV OU and LEFPC OU contributed, by far, the highest number of deer, shrews, foxes, woodcock, and turkeys at risk on the ORR (Tables 5.2–5.7). The population of short-tailed shrews in Bear Creek Valley is estimated to be experiencing exposures greater than LOAEL from Sb, Cu, Hg, PCBs, and V; foxes are at risk from Cu and Hg (Table 5.1). Contaminants contributing to the majority of the risk at LEFPC include Hg, total PCBs, DDT and metabolites, Se, and Al. Other contaminants of concern include Cd, Cr, Cu, Ni, and Zn. WAG 2 is the third highest contributor to risk on the ORR. The short-tailed shrew population in WAG 2 is estimated to be experiencing exposures greater

Table 5.2. The number of potentially exposed white-tailed deer within each OU and the entire reservation

OU	Available habitat (ha)	Total suitable area (ha)	No. of animals present[a,b]	% of the ORR population exposed[c]
BCV OU	Evergreen plantation(20.94) Evergreen forest (37.37) Deciduous forest (192.81) Mixed forest (140.56) Pasture (14.62) Transitional (246.06)	652.36	111	5.55
LEFPC	Evergreen plantation (2.62) Evergreen forest (7.37) Deciduous forest (41.06) Mixed forest (50.87) Pasture (8.5) Transitional (133.87)	244.29	42	2.1
WAG 2	Evergreen forest (1) Deciduous forest (15.75) Mixed forest (29) Pasture (0.06) Transitional (14.81)	60.62	10	0.5
WAG 5	Deciduous forest (3.56) Mixed forest (6.44) Pasture (7.69) Transitional (9.06)	26.75	5	0.25
South Campus Facility	Pasture (13.25) Transitional (4.5)	17.75	3	0.15
WAG 6	Deciduous forest (5.06) Mixed forest (2.06) Pasture (0.5) Transitional (2.94)	10.56	2	0.10
Chestnut Ridge OU2	Deciduous forest (3.81) Mixed forest (0.38) Transitional (2.62)	6.81	1	0.05
WAG 1	Evergreen forest (0.81) Deciduous forest (1.25) Mixed forest (0.81) Pasture (0.94)	3.81	0.7	0.04
K-1407 OU	Transitional (4.19)	4.19	0.7	0.04
BC OU2	Transitional (0.62)	0.62	0.1	0.005
UEFPC OU2	0	0	0	0.00
K-1420 OU	0	0	0	0.00
K-1414 Ou[d]				

Table 5.2 (continued)

OU	Available habitat (ha)	Total suitable area (ha)	No. of animals present[a,b]	% of the ORR population exposed
Total no. exposed within 13 OUs			62[b]	
Total reservation	Evergreen plantations (323.5) Evergreen forest (704.87) Deciduous forest (4,028.62) Mixed forest (3,469) Pasture (312.44) Transitional (2,896.19)	11,734.8	2000[e]	
Percentage of the ORR population at risk				**8.8%**

[a]The number of animals present within OU was calculated by multiplying the total area of suitable habitat (ha) by 0.1704 deer/ha (calculated from 2,000 deer on reservation).

[b]All white-tailed deer present on OUs are exposed at contaminant levels >LOAELs, with the exception of animals at WAG 5 and K-1414.

[c]The percentage of the ORR population exposed = (estimated no. of animals present on the OU/the total no. of animals on the reservation) x 100.

[d]Habitat maps are not available for the K-1414 OU.

[e]The approximately 2,000 deer present on the ORR were estimated from deer hunts (personal communication, Jim Evans 1995).

Table 5.3. The number of potentially exposed wild turkey within each OU and the entire reservation

OU	Available habitat (ha)	Total suitable area (ha)	No. of animals present[ab]	% of ORR population exposed[c]
BCV OU	Evergreen plantation (20.9) Evergreen forest (37.37) Deciduous forest (192.81) Mixed forest (140.56) Pasture (14.62) Transitional (246.06)	652.32	28	5.6
LEFPC	Evergreen plantation (2.62) Evergreen forest (7.37) Deciduous forest (41.06) Mixed forest (50.87) Pasture (8.5) Transitional (133.87)	244.29	10	2.0
WAG 2	Evergreen forest (1) Deciduous forest (15.75) Mixed forest (29) Pasture (0.06) Transitional (14.81)	60.62	3	0.6
WAG 5	Deciduous forest (3.56) Mixed forest (6.44) Pasture (7.69) Transitional (9.06)	26.75	1	0.2
South Campus Facility	Pasture (13.25) Transitional (4.5)	17.75	0.8	0.16
WAG 6	Deciduous forest (5.06) Mixed forest (2.06) Pasture (0.5) Transitional (2.94)	10.56	0.5	0.10
Chestnut Ridge OU2	Deciduous forest (3.81) Mixed forest (0.38) Transitional (2.62)	6.81	0.3	0.06
K-1407 OU	Transitional (4.19)	4.19	0.2	0.04
BC OU2	Transitional (0.62)	0.62	0.03	0.006
WAG 1	Evergreen forest (0.81) Deciduous forest (1.25) Mixed forest (0.81) Pasture (0.94)	3.81	0.2	0.00
UEFPC OU2	0	0	0	0.00
K-1420 OU	0	0	0	0.00
K-1414 OU[d]				

Table 5.3 (continued)

OU	Available habitat (ha)	Total suitable area (ha)	No. of animals present[ab]	% of ORR population exposed[c]
Total no. exposed within 13 OUs			15[b]	
Total reservation	Evergreen plantations (323.5) Evergreen forest (704.87) Deciduous forest (4,028.62) Mixed forest (3,469) Pasture (312.44) Transitional (2,896.19)	11,734.8	500[e]	
Percentage of ORR population at risk				8.77%

[a]The number of animals present within the OU was calculated by multiplying the total area of suitable habitat (ha) by 0.0426 wild turkey/ha (calculated from 500 turkey observed on the reservation).

[b]All wild turkey present on OUs are exposed at contaminant levels >LOAELs, with the exception of animals at WAG 1, WAG 5, and K-1414.

[c]The percentage of the ORR population exposed = (estimated no. of animals present on the OU/total no. of animals on the reservation) x 100.

[d]Habitat maps are not available for the K-1414 OU.

[e]Approximately 500 wild turkey are present on the ORR (personal communication, Jim Evans 1995).

Table 5.4. The number of potentially exposed short-tailed shrews within each OU and the entire reservation

OU	Available habitat (ha)	Total suitable area (ha)	No. of animals present [a,b]	% of the ORR population exposed[c]
BCV OU	Evergreen plantation (20.9) Evergreen forest (37.37) Deciduous forest (192.81) Mixed forest (140.56) Transitional (246.06)	637.7	14,667	5.58
LEFPC	Evergreen plantation (2.62) Evergreen forest (7.37) Deciduous forest (41.06) Mixed forest (50.87) Transitional (133.87)	235.79	5,423	2.06
WAG 2	Evergreen forest (1) Deciduous forest (15.75) Mixed forest (29) Transitional (14.81)	59.85	1377	0.52
WAG 5	Deciduous forest (3.56) Mixed forest (6.44) Transitional (9.06)	19.06	438	0.17
WAG 6	Deciduous forest (5.06) Mixed forest (2.06) Transitional (2.94)	10.06	231	0.09
Chestnut Ridge OU2	Deciduous forest (3.81) Mixed forest (0.38) Transitional (2.62)	6.81	157	0.06
K-1407 OU	Transitional (4.19)	4.19	96	0.04
South Campus Facility	Transitional (4.5)	4.5	104	0.04
WAG 1	Evergreen forest (0.81) Deciduous forest (1.25) Mixed forest (0.81)	2.87	66	0.03
BC OU2	Transitional (0.62)	0.62	14	0.005
UEFPC OU2	0	0	0	0.00
K-1420 OU	0	0	0	0.00
K-1414 OU[d]				

Table 5.4 (continued)

OU	Available habitat (ha)	Total suitable area (ha)	No. of animals present [a][b]	% of the ORR population exposed[c]
Total no. exposed within 13 OUs			7,274[b]	
Total reservation	Evergreen plantations (323.5) Evergreen forest (704.87) Deciduous forest (4,028.62) Mixed forest (3,469) Transitional (2,896.19)	11,422.36	262,714	
Percentage of ORR population at Risk				8.6%

[a]The number of animals present within the OU was calculated by multiplying the total area of suitable habitat (ha) by 23 short-tailed shrews/ha (Getz 1989, as cited in EPA 1987).

[b]All animals present within OUs are exposed at levels exceeding LOAELs, with the exception of animals at K-1414.

[c]The percentage of the ORR population exposed = (estimated no. of animals present on the OU/total no. of animals on the reservation) x 100.

[d]Habitat maps are not available for the K-1414 OU.

Table 5.5. The number of potentially exposed American woodcock within each OU and the entire reservation

OU	Available habitat (ha)	Total suitable area (ha)	No. of animals present[a,b]	% of the ORR population exposed[c]
BCV OU	Deciduous forest (192.81) Mixed forest (140.56) Pasture (14.62) Transitional (246.06)	594.05	166	5.5
LEFPC	Deciduous forest (41.06) Mixed forest (50.87) Pasture (8.5) Transitional (133.87)	234.3	66	2.2
WAG 2	Deciduous forest (15.75) Mixed forest (29) Pasture (0.06) Transitional (14.81)	59.62	17	0.57
WAG 5	Deciduous forest (3.56) Mixed forest (6.44) Pasture (7.69) Transitional (9.06)	26.75	8	0.27
South Campus Facility	Pasture (13.25) Transitional (4.5)	17.75	5	0.17
WAG 6	Deciduous forest (5.06) Mixed forest (2.06) Pasture (0.5) Transitional (2.94)	10.56	3	0.10
Chestnut Ridge OU2	Deciduous forest (3.81) Mixed forest (0.38) Transitional (2.62)	6.81	2	0.07
WAG 1	Deciduous forest (1.25) Mixed forest (0.81) Pasture (0.94)	3	0.8	0.03
K-1407 OU	Transitional (4.19)	4.19	1	0.03
BC OU2	Transitional (0.62)	0.62	0.2	0.007
UEFPC OU2	0	0	0	0.00
K-1420 OU	0	0	0	0.00
K-1414 OU[d]				

Table 5.5 (continued)

OU	Available habitat (ha)	Total suitable area (ha)	No. of animals present[a,b]	% of the ORR population exposed[c]
Total no. exposed within 13 OUs			98	
Total reservation	Deciduous Forest (4,028.62) Mixed Forest (3,469) Pasture (312.44) Transitional (2,896.19)	10,706.25	2,998	
Percentage of the ORR population at risk				8.95%

[a]The number of animals present within the OU was calculated by multiplying the total area of suitable habitat (ha) by 0.28 American woodcock/ha (derived from Stewart and Robbins 1958).

[b]All woodcock present within OUs are exposed at levels exceeding the LOAEL, with the exception of animals at K-1414.

[c]The percentage of the ORR population exposed = (estimated no. of animals present on the OU/total no. of animals on the reservation) x 100.

[d]Habitat maps are not available for the K-1414 OU.

Table 5.6 The number of potentially exposed red-tailed hawk within each OU and the entire reservation

OU	Available habitat (ha)	Total suitable area (ha)	No. of animals present[a]	% of the ORR population exposed[b]
BCV OU	Evergreen plantation (20.9) Evergreen forest (37.37) Deciduous forest (192.81) Mixed forest (140.56) Pasture (14.62) Transitional (246.06)	652.32	39	5.5
LEFPC	Evergreen plantation (2.62) Evergreen forest (7.37) Deciduous forest (41.06) Mixed forest (50.87) Pasture (8.5) Transitional (133.87)	244.29	15	2.1
WAG 2	Evergreen forest (1) Deciduous forest (15.75) Mixed forest (29) Pasture (0.06) Transitional (14.81)	606.2	4	0.57
WAG 5	Deciduous forest (3.56) Mixed forest (6.44) Pasture (7.69) Transitional (9.06)	26.75	2	0.28
South Campus Facility	Pasture (13.25) Transitional (4.5)	17.75	1	0.14
WAG 6	Deciduous forest (5.06) Mixed forest (2.06) Pasture (0.5) Transitional (2.94)	10.56	0.63	0.09
Chestnut Ridge OU2	Deciduous forest (3.81) Mixed forest (0.38) Transitional (2.62)	6.81	0.41	0.06
K-1407 OU	Transitional (4.19)	4.19	0.25	0.04
WAG 1	Evergreen forest (0.81) Deciduous forest (1.25) Mixed forest (0.81) Pasture (0.94)	3.81	0.23	0.03
BC OU2	Transitional (0.62)	0.62	0.04	0.006
UEFPC OU2	0	0	0	0.00
K-1420 OU	0	0	0	0.00

Table 5.6 (continued)

OU	Available habitat (ha)	Total suitable area (ha)	No. of animals present[a]	% of the ORR population exposed
K-1414 OU[c]				
Total no. exposed within 13 OUs			8	
Total reservation	Evergreen plantations (323.5) Evergreen forest (704.87) Deciduous forest (4,028.62) Mixed forest (3,469) Pasture (312.44) Transitional (2,896.19)	11,734.8	704	
Percentage of the ORR population at risk				**8.82%**

[a]The number of animals present within OU was calculated by multiplying the total area of suitable habitat (ha) by 0.06 red tailed hawks/ha (calculated from 0.03 pairs/ha, EPA 1993).

[b]The percentage of the ORR population exposed = (estimated no. of animals present on the OU/the total no. of animals on the reservation) x 100.

[c]Habitat maps are not available for the K-1414 OU.

Table 5.7. The number of potentially exposed red fox within each OU and the entire reservation

OU	Available habitat (ha)	Total suitable area (ha)	No. of animals present[ab]	% of the ORR population exposed[c]
BCV OU	Evergreen plantation (20.9) Evergreen forest (37.37) Deciduous forest (192.81) Mixed forest (140.56) Pasture (14.62) Transitional (246.06)	652.32	50	5.5
LEFPC	Evergreen plantation (2.62) Evergreen forest (7.37) Deciduous forest (41.06) Mixed forest (50.87) Pasture (8.5) Transitional (133.87)	244.29	19	2.1
WAG 2	Evergreen forest (1) Deciduous forest (15.75) Mixed forest (29) Pasture (0.06) Transitional (14.81)	60.62	5	0.55
WAG 5	Deciduous forest (3.56) Mixed forest (6.44) Pasture (7.69) Transitional (9.06)	26.75	2	0.22
South Campus Facility	Pasture (13.25) Transitional (4.5)	17.75	1	0.11
WAG 6	Deciduous forest (5.06) Mixed forest (2.06) Pasture (0.5) Transitional (2.94)	10.56	0.81	0.09
Chestnut Ridge OU2	Deciduous forest (3.81) Mixed forest (0.38) Transitional (2.62)	6.81	0.52	0.05
K-1407 OU	Transitional (4.19)	4.19	0.32	0.04
WAG 1	Evergreen forest (0.81) Deciduous forest (1.25) Mixed forest (0.81) Pasture (0.94)	3.81	0.29	0.03
BC OU2	Transitional (0.62)	0.62	0.05	0.006
UEFPC OU2	0	0	0	0.00
K-1420 OU	0	0	0	0.00

Table 5.7 (continued)

OU	Available habitat (ha)	Total suitable area (ha)	No. of animals present[a,b]	% of the ORR population exposed
K-1414 OU[d]				
Total no. exposed within 13 OUs			79[b]	
Total reservation	Evergreen plantations (323.5) Evergreen forest (704.87) Deciduous forest (4,028.62) Mixed forest (3,469) Pasture (312.44) Transitional (2,896.19)	11,734.8	904	
Percentage of the ORR population at risk				**8.71%**

[a]The number of animals present within OU was calculated by multiplying the total area of suitable habitat (ha) by 0.077 foxes/ha (EPA 1993).

[b]All red fox present on OUs are exposed at contaminant levels >LOAELs, with the exception of animals at WAG 5 and K-1414.

[c]The percentage of theORR population exposed = (estimated no. of animals present on the OU/the total no. of animals on the reservation) x 100.

[d]Habitat maps are not available for the K-1414 OU.

than LOAEL from Aroclor 1260, Cd, Cr, Hg, and Se (Efroymson et al. 1996). WAG 5, the fourth ranked contributor, only poses a risk to the short-tailed shrew and woodcock populations from Cr, Hg, and Zn exposure.

5.4.5 Quality and Completeness of Data

Although the data used in this portion of the assessment were generally considered to be of high quality, spatial coverage of the ORR was incomplete. Soil data were available for only 12 of 37 OUs on the ORR. Consequently, the magnitude of risk to reservation-wide populations is underestimated. The actual magnitude cannot be determined without incorporating data from additional OUs.

Another limitation, discussed in Chap. 4, concerns the level of detail in the ORR habitat map. There is a need for the habitat maps to identify specific characteristics of the habitat categories. For example, identification of floodplain forests, dense forests, etc. is necessary to better determine suitable habitat for many endpoint species. Furthermore, a better estimate of the number of individuals of each endpoint species within each OU may be predicted.

Additionally, the lack of site specific vegetation and earthworm concentrations on many OUs result in the use of average calculated soil-plant or soil-earthworm uptake factors. The uptake factors have a high degree of uncertainty associated with them and may over or underestimate the risk to herbivorous or vermivorous wildlife.

5.4.6 Uncertainties Concerning Risks to Herbivorous, Vermivorous, and Predatory Wildlife

5.4.6.1 Limitations of habitat maps

The level of precision differs between the habitat maps and the habitat requirements data. For example, habitat type such as open forest, dense forest, or floodplain forest cannot be identified. More detailed information is necessary because the actual habitat that is used may be only portions of the habitat categories (e.g., woodcock prefer moist floodplain soils in forested areas). This may overestimate or underestimate the number of individuals present within an OU.

5.4.6.2 Soil to vegetation and earthworm uptake factors

There is a large degree of uncertainty when using soil to vegetation and earthworm uptake factors to model contaminant concentrations found in vegetation and earthworms. Uptake factors of inorganics will vary by soil condition (e.g., pH, water availability, organic matter content, texture, aeration, elemental concentrations) and plant/earthworm conditions (species and age) (Sommers et al. 1987; Chaney et al. 1984). The use of plant uptake factors assumes that all species and all soil conditions will result in the same uptake rate. Also, the use of uptake factors assumes that the uptake rate is best estimated by taking the average of all observed values. These site specific factors within the OUs are not taken into consideration for the uptake factors that were used. Therefore, the predicted contaminant concentrations in vegetation and earthworms may be overestimated or underestimated; thus overestimating or underestimating contaminant exposure for each endpoint species.

5.4.6.3 Relative quality of habitats

It was assumed that the quality of habitat found within each land cover type was equivalent. Although specific landcover types were designated as providing suitable habitat, the usability of the areas will vary and certain habitat types may be used preferentially. This will either overestimate or underestimate the number of animals found within each OU based on the lower or higher quality of certain habitat types.

5.4.6.4 Distribution of contamination within habitats on operable units

It was assumed that contamination was equally distributed throughout the OU. Therefore, all available habitat that is used by the specific endpoint was assumed to be equally contaminated throughout the entire OU. Because most contamination is likely to be in less suitable habitats (urban areas, lawns, etc.), on-OU contaminant exposure is likely to be overestimated.

5.4.6.5 Literature density values

The use of literature density values of endpoint species, with the exception of deer and turkey, obtained from other areas of the United States, are considered representative of the ORR. This may overestimate or underestimate the number of exposed individuals.

5.4.6.6 Bioavailability of contaminants

It was assumed that 100% of the contaminant concentrations reported in soil and modeled vegetation and earthworms were bioavailable. The double acid extraction method used to determine soil concentrations reflect the total potential pool of contaminants. The future bioavailability of these contaminants, which is dependent upon the chemical (e.g., pH, organic carbon) and physical (e.g., clay, moisture content) nature of the soil, cannot be addressed for this assessment. Therefore, exposure estimates based on the contaminant concentrations in media are highly conservative and are likely to overestimate the actual contaminant exposure experienced.

5.4.6.7 Extrapolation from published toxicity data

To estimate toxicity of contaminants at the site, it was necessary to extrapolate from NOAELs observed for test species (i.e., rats, mice). Although it was assumed that toxicity could be estimated as a function of body size, the accuracy of the estimate is not known. For example, white-tailed deer may be more or less sensitive than rats or mice.

Additional extrapolation uncertainty exists for those contaminants for which data consisted of either LOAELs or was subchronic in duration. For either case, an uncertainty factor of 10 was employed to estimate NOAELs or chronic data. The uncertainty factor of 10 may either over- or underestimate the actual LOAEL-NOAEL or subchronic-chronic relationship.

5.4.6.8 Variable food and water consumption

Although food consumption by wildlife was assumed to be similar to that reported for the same species in other locations, the validity of this assumption cannot be determined. Food consumption at the Clinch River and Poplar Creek may be greater or less than that reported in the literature, resulting in either an increase or decrease in contaminant exposure. Similarly, water consumption was estimated according to the allometric equations of Calder and Braun (1983). The accuracy with which the estimated water consumption represents actual water consumption is unknown.

5.4.6.9 Single contaminant tests vs exposure to multiple contaminants in the field

Although plants and mammals are exposed to multiple contaminants concurrently, published toxicological values only consider effects experienced by exposures to single contaminants. Because some contaminants can interact antagonistically, single contaminant studies may overestimate their toxic potential. Similarly, for those contaminants that interact additively or synergistically, single contaminant studies may underestimate their toxic potential.

5.4.6.10 Inorganic constituents or species present in the environment

Toxicity of metal species varies dramatically depending upon the valence state or form (organic or inorganic) of the metal. For example, arsenic (III) and methyl mercury are more toxic than arsenic (V) and inorganic mercury, respectively. The available data on the contaminant concentrations in media do not report which species or form of contaminant was observed. Because benchmarks used for comparison represented the more toxic species/forms of the metals (particularly for arsenic and mercury), if the less toxic species/form of the metal was actually present in modeled vegetation or sediment from the Clinch River or Poplar Creek, potential toxicity at the sites may be overestimated.

6. CONCLUSIONS

Based upon a preliminary evaluation of the currently available data, the following conclusions may be made concerning risks to selected wide-ranging wildlife species on the ORR:

- The largest OUs on the ORR generally have the most diverse habitat and consequently can support the greatest number of potential endpoint species (Chap. 3).
- Species that can use urban habitats or that have broad habitat requirements have the highest potential to experience exposure because of the large numbers of OUs that provide suitable habitat (Chap. 3).
- Mercury presents a hazard to mink in East Fork Poplar Creek and consequently to a significant portion (30%) of the ORR-wide mink population. Risks to mink from PCBs are not significant (Chap. 4).
- Evaluation of the potential risks to a future ORR-wide population of otter indicates that mercury presents a risk in all watersheds on the ORR. Because the river otter is a state threatened species, effects to any individual is significant. Therefore, the weight of evidence suggests that mercury is significant risk to individual river otter that may occupy the ORR in the future (Chap. 4)
- Comparison of exposure estimates to LOAELs indicates a significant risk from mercury in all watersheds except White Oak Creek. This translates into a risk to 81.5% of the ORR-wide kingfisher population. The limited biomonitoring data indicate that kingfisher on the ORR (particularly in the White Oak Creek area) are accumulating mercury to potentially nephrotoxicty levels. The weight of evidence suggests mercury in all watersheds presents a significant risk to the ORR-wide belted kingfisher population. Risks from PCBs are not significant (Chap. 4).
- Although mercury in fish is estimated to represent a significant risk to great blue heron within the EFPC watershed and, consequently, to an estimated 37% of the heron population on the ORR, studies on two of five colonies adjacent to the ORR indicate that reproduction at these locations is not impaired. Contaminant bioaccumulation and reproductive success are unknown at the three additional colonies adjacent to the ORR. Additionally, the primary foraging locations for herons at the two studied colonies is unknown. Because herons can travel long distances in search of food (>15 km), they are likely to forage at off-site as well as on-site locations, reducing both the exposure they receive and the risk they experience. If birds from the unstudied colonies forage more extensively on the ORR, they may experience greater risk. Because of the high risk estimated for mercury exposure on the ORR, the lack of data for three of five heron colonies adjacent to the ORR, and uncertainty as to where birds from the five ORR colonies forage, a conclusion concerning whether or not great blue heron on the ORR are at risk cannot be made (Chap. 4).
- Comparison of exposure estimates to LOAELs for osprey indicates no significant risk from mercury or PCBs in any area on the ORR that provides suitable habitat (i.e., White Oak Lake and embayment and the K-25 Site area). Biomonitoring data indicates that the reproductive success at osprey nests adjacent to the ORR, along Melton Hill Lake and in Poplar Creek, is greater than the average observed in the United States. The weight of evidence suggests mercury and PCB do not present significant risks to osprey on or near the ORR (Chap. 4).

- On the basis of a habitat-based evaluation of risk, although significant risks exist to individuals of selected herbivore, vermivore, and predator endpoint species resident on OUs, the reservation-wide populations of these endpoints are unlikely to be significantly affected (<20% of the ORR population is affected). This conclusion must be viewed with caution, however, because data were evaluated for only 13 of 37 OUs. Inclusion of additional OUs is likely to increase the proportion of the ORR populations exposed and at risk. (Chap. 5).

7. RECOMMENDED REVISION SCHEDULE

This assessment is based on only a small portion of the data available on the ORR. To accurately evaluate the nature and magnitude of risks on the ORR, all available data should be incorporated and considered. This report should be revised and updated annually until all existing data have been incorporated. Following this, revisions should be produced on a 5-year schedule to incorporate new data that become available.

8. REFERENCES

Abiola, F. A. 1992. "Ecotoxicity of Organochloride Insecticides: Effects of Endosulfan on Birds' Reproduction and Evaluation of Its Induction Effects in Partridge, *Perdix perdix* L." *Rev. Vet. Med.* 143, pp. 443–450.

Ables, E.D. 1969. Home range studies of red foxes (Vulpes vulpes). J. Mamm. 50: 108-120.

ACGIH (American Conference of Governmental Industrial Hygienists). 1986. "Copper," in *Documentation of the Threshold Limit Values and Biological Exposure Indices, 5th Ed.* ACGIH, Cincinnati, Ohio, p. 146.

Alexander, G. R. 1977. "Food of Vertebrate Predators on Trout Waters in North Central Lower Michigan." *Mich. Acad.* 10, pp. 181–195.

Allen, J. G., et al. 1983. "Zinc Toxicity in Ruminants." *J. Comp. Pathol.* 93, pp. 363–377 (as cited in ATSDR 1989, Eisler 1993).

Alumot, E. (Olomucki), E. Nachtomi, E. Mandel, and P. Holstein. 1976a. "Tolerance and acceptable daily intake of chlorinated fumigants in the rat diet." Fd. Cosmet. Toxicol. 14: 105-110.

Alumot, E., M. Meidler, and P. Holstein. 1976. "Tolerance and Acceptable Daily Intake of Ethylene Dichloride in the Chicken Diet." *Fd. Cosmet. Toxicol.* 14, pp. 111–114.

Ambrose, A.M., P.S. Larson, J.R. Borzelleca and G.R. Hennigar, Jr. 1976. Long term toxicologic assessment of nickel in rats and dogs. J. Food. Sci. Technol. 13: 181-187.

Amur, M., J. McCarthy, M. Gill. 1982. "Respiratory Response of Guinea Pigs to Zinc Oxide Fume." *Am. Ind. Hyg. Assoc. J.* 43, pp. 887–889.

Anders, E. D., et al. 1982. "Morphological, Phamacokinetic, and Hematological Studies of Lead Exposed Pigeons." *Environ. Res.* 28, pp. 344–363.

Andersen, D.E. and O.J. Rongstad. 1989. Home-range estimates of Red-tailed hawks based on random and systematic relocations. J. Wildl. Manage. 53: 802-807.

Anderson, D. W., et al. 1975. "Brown Pelicans: Improved Reproduction off the Southern California Coast." *Science* 190, pp. 806–808.

Anderson, D.W., R.W. Risebrough, L.A. Woods, Jr., L.R. DeWeese, and W.G. Edgecomb. 1975. "Brown pelicans: improved reproduction off the southern California coast." Science 190: 806-808.

Arnold, T. W., and E. K. Fritzell. 1987. "Food Habits of Prairie Mink During the Waterfowl Breeding Season." *Can. J. Zool.* 65, pp. 2322–2234.

Arthur, E., I. Motzok, and H. D. Branion. 1958. "Interaction of Dietary Copper and Molybdenum in Rations Fed to Poultry." *Poult. Sci.* 37, pp. 1181.

Ashwood,T.L. et al. 1994. Eighth annual report on the ORNL Biological Monitoring and Abatement Program. Oak Ridge National Laboratory, Oak Ridge, TN. ORNL/TM-12767.

Ashwood, T. L. , C. R. Olsen, L. L Larsen, and D.D. Lowry, 1986. Sediment contamination in streams surrounding the Oak Ridge Gaseous Diffusion Plant. Environmental Sciences Division Pub. 2597, ORNL/TM-9791.

ATSDR (Agency for Toxic Substances and Disease Registry). 1988. Toxicological Profile for Nickel. ATSDR/U.S. Public Health Service, ATSDR/TP-88/19.

ATSDR (Agency for Toxic Substances and Disease Registry). 1989a. *Toxicological Profile for Selected PCBs (Aroclor-1260, -1254, -1248, -1242, -1232, -1221, and -1016).* ATSDR/TP-88/21, Syracuse Research Corporation for ATSDR, U.S. Public Health Service.

ATSDR (Agency for Toxic Substances and Disease Registry). 1989b. *Toxicological Profile for Zinc.* ATSDR/TP-89-25, Agency for Toxic Substances and Disease Registry, U.S. Public Health Service, Atlanta, Georgia.

ATSDR (Agency for Toxic Substances and Disease Registry). 1990. *Toxicological Profile for Copper.* ATSDR/TP-90-08, prepared by Syracuse Research Corporation for ATSDR, U.S. Public Health Service under Contract 88-0608-2.

ATSDR (Agency for Toxic Substances and Disease Registry). 1993. "Toxicological profile for 4,4'-DDT, 4,4'-DDE, and 4,4'-DDD)." ATSDR/TP-92/53.

Aughey, E., L. Grant, B. L. Furman, and W. F. Dryden. 1977. "The Effects of Oral Zinc Supplementation in the Mouse." *J. Comp. Pathol.* 87, pp. 1–14.

Aulerich, R. J., and R. K. Ringer. 1977. "Current Status of PCB Toxicity to Mink, and Effect on Their Reproduction." *Arch. Environ. Contam. Toxicol.* 6, pp. 279–292.

Aulerich, R. J. and R. K. Ringer, 1979. Toxic effects of dietary polybrominated biphenyls on mink. Arch. Environ. Contam. Toxicol. 8:487-498.

Aulerich, R. J., R. K. Ringer, H. L. Seagran, and W. G. Youatt, 1971. Effects of feeding Coho salmon and other Great Lakes fish on mink reproduction. Canad. J. Zool. 49:611-616.

Aulerich, R. J., R. K. Ringer, and S. Iwamoto, 1973. Reproduetive failure and mortality in mink fed on Great Lakes fish. J. Reprod, Fertil. Suppl. 19:365-376.

Aulerich, R. J., R. K. Ringer, and S. Iwamoto, 1974. Effects of dietary mercury on mink. Arch. Environ. Contam. Toxicol. 2:43-51.

Aulerich, R. J., R. K. Ringer, M. R. Bleavins, and A. Napolitano. 1982. "Effects of Supplemental Dietary Copper on Growth, Reproductive Performance and Kit Survival of Standard Dark Mink and the Acute Toxicity of Copper to Mink." *J. Animal Sci.* 55, pp. 337–343 (as ciited in ATSDR 1990).

Aulerich, R.J., A.C. Napolitano, S.J. Bursian, B.A. Olson, and J.R. Hochstein. 1987. "Chronic toxicity of dietary fluorine in mink." J. Anim. Sci. 65: 1759-1767.

Azar, A., H. J. Trochimowicz, and M. E. Maxwell. 1973. "Review of Lead Studies in Animals Carried out at Haskell Laboratory: Two-year Feeding Study and Response to Hemorrhage Study," in *Environmental Health Aspects of Lead: Proceedings, International Symposium,* D. Barth et al., eds. Commission of European Communities, pp. 199–210.

Baron, L. A., T. L. Ashwood, B.E. Sample, and C. Welsh. 1996. Monitoring bioaccumulation of contaminants in the belted kingfisher (*Ceryle alcyon*). Environmental Monitoring and Assessment. In Review.

Bean, J. R., and R. H. Hudson. 1976. "Acute Oral Toxicity and Tissue Residues of Thallium Sulfate in Golden Eagles, *Aquila chrysaetos*." *Bull. Environ. Contam. Toxicol.* 15, pp. 118–121.

Bent, A. C. 1940. *Life Histories of North American Cuckoos, Goat Suckers, Hummingbirds, and Their Allies.* U.S. Government Printing Office, Washington, D.C. *Smithsonian Inst. U.S. Nat. Mus., Bull.* 176.

Berlin, M. 1979. "Mercury" in *Handbook on the Toxicology of Metals,* L. Fribourg, ed. Elsevier Press, New York, pp. 503–530.

Bevelheimer, M.S., B.E. Sample, G.R. Southworth, J.J. Beauchamp, and M.J. Peterson. 1996. Estimation of whole-fish contaminant concentrations from fish fillet data. ES/ER/TM-???. Oak Ridge National Laboratory, Oak Ridge, TN

Beyer, W.N., E. Conner, and S. Gerould. 1994. "Survey of soil ingestion by wildlife." J. Wildl. Mgmt. 58: 375-382.

Blamberg, D. L., U. B. Blackwood, W. C. Supplee, and G. F. Combs. 1960. "Effect of Zinc Deficiency in Hens on Hatchability and Embryonic Development " in *Proc. Soc. Exp. Biol. Med.* 104, pp. 217–220.

Bleavins, M. R., R. J. Aulerich, and R. K. Ringer. 1980. "Polychlorinated Biphenyls (Aroclors 1016 and 1242): Effects on Survival and Reproduction in Mink and Ferrets." *Arch. Environ. Contam. Toxicol.* 9(5), pp. 627-635.

Bleavins, M. R., and R. J. Aulerich. 1981. "Feed Consumption and Food Passage Time in Mink (*Mustela vison*) and European Ferrets (*Mustela putorius furo*)." *Lab. Anim. Sci.* 31, pp. 268–269.

Bleavins, M. R., R. J. Aulerich, and R. K. Ringer. 1984. "Effects of Chronic Dietary Hexachlorobenzene Exposure on the Reproductive Performance and Survivability of Mink and European Ferrets." *Arch. Environ. Contam. Toxicol.* 13, pp. 357–365.

Borzelleca, J. F., L. W. Condie, Jr., and J. L. Egle, Jr. 1988. "Short-term Toxicity (One-and Ten-day Gavage) of Barium Chloride in Male and Female Rats." *J. American College of Toxicology* 7, pp. 675–685.

Boyden, R., V. R. Potter, and C. A. Elvehjem. 1938. "Effect of Feeding High Levels of Copper to Albino Rats." *J. Nutr.* 15(4), pp. 397–402.

Branica, M., and Z. Konrad, eds. 1980. *Lead in the Marine Environment.* Pergamon Press, Oxford, England.

Braune, B.M., and R.J. Norstrom. 1989. "Dynamics of organochlorine compounds in herring gulls: III Tissue distribution and bioaccumulation in Lake Ontario gulls." *Environ. Toxicol. Chem.* 8: 957-968.

Brink, M. F., D. E. Becker, S. W. Terril., and A. H. Jensen. 1959. "Zinc Toxicity in the Weanling Pig." *J. Anim. Sci.* 18, pp. 836–842.

Brooks, R. P, and W. J. Davis. 1987. "Habitat Selection by Breeding Belted Kingfishers (Ceryle *alcyon*)." *Am. Midl. Nat.* 117, pp. 63–70.

Brown, L. and D. Amadon. 1968. Eagles, hawks, and falcons of the world: v. 1. New York, NY: McGraw-Hill.

Buben, J.A. and E.J. O'Flaherty. 1985. "Delineation of the role of metabolism in the hepatotoxicity of trichloroethylene and perchloroethylene: a dose-effect study." Toxicol. Appl. Pharmacol. 78: 105-122.

Burgess, S. A., and J. R. Bider. 1980. "Effects of Stream Habitat Improvements on Invertebrates, Trout Populations, and Mink Activity." *J. Wildl. Manage.* 44, pp. 871–880.

Burkart, W. 1991. Uranium, thorium, and decay products. In: Merian, E., Ed. Metals and their compounds in the environment: Occurrence, analysis, and biological relevance. VCH, Weinheim, Germany. pp. 1275-1287.

Burt, W.H. and R.P. Grossenheider. 1976. A field guide to the mammals of America north of Mexico. Third Edition. Houghton Mifflin Co., Boston

Cain, B.W., and E.A. Pafford. 1981. Effects of dietary nickel on survival and growth of mallard ducklings. Arch. Environ. Contam. Toxicol. 10:737-745.

Cain, B.W., L. Sileo, J. C. Franson, and J. Moore. 1983. "Effects of Dietary Cadmium on Mallard Ducklings." *Environ. Res.* 32, pp. 286–297.

Calabrese, E. J., R J Aulerich, and G. A. Padgett. 1992. Mink as a predictive model in toxicology. Drug Metab. Rev.

Calder, W. A. and E. J. Braun. 1983. "Scaling of osmotic regulation in mammals and birds." *Am. J. Physiol.* 224, pp. R601–R606.

Callazo, J. A. 1985. "Food Habits of Nesting Great Blue Herons at Heyburn State Park, Idaho." *Northwest Science* 59, pp. 144–146.

Campbell, P.G.C., and P.M. Stokes. 1985. "Acidification and Toxicity of Metals to Aquatic Biota." *Can. J. Fish. Aquatic Sci.* 42, pp. 2034–2049.

Carriere, D., K. Fischer, D. Peakall, and P. Angehrn. 1986. "Effects of Dietary Aluminum in Combination with Reduced Calcium and Phosphorus on the Ring Dove (*Streptopelia risoria*)." *Water, Air, and Soil Poll.* 30, pp. 757–764.

Chakravarty, S., and P. Lahiri. 1986. "Effect of Lindane on Eggshell Characteristics and Calcium Level in the Domestic Duck." *Toxicology* 42, pp. 245–258.

Chaney, L. R, S. B. Sterret, and H. W. Mielke. 1984. "The Potential for Heavy Metal Exposure from Urban Gardens and Soils," in *Proceedings of the Symposium on Heavy Metals in Urban Gardens.* University of the District of Columbia Extension Service, Washington, D.C.

Chen, P.S., R. Terepka, and H.C. Hodge. 1961. The pharmacology and toxicology of the bone seekers. Annu. Rev. Pharmacol. 1:369-393.

Clark, D. R. 1979. "Lead Concentrations: Bats Vs. Terrestrial Mammals Collected Near a Major Highway." *Environ. Sci. Technol.* 3, pp. 338–341.

Clark, D. R., Jr., P. A. Ogasawara, G. J. Smith, and H. M. Ohlendorf. 1989. "Selenium Accumulation by Raccoons Exposed to Irrigation Drain Water at Kesterson National Wildlife Refuge, California, 1986." *Arch. Environ. Contam. Toxicol.* 18, pp. 787–794.

Conant, R. 1986. *A Field Guide to the Reptiles and Amphibians of Eastern and Central North America.* Houghton Mifflin Co., Boston.

Craighead, J.J., and F.C. Craighead. 1969, "Hawks, owls, and wildlife". Dover Publ. Co. New York. 443 pp.

Crum, J. A., et al. 1993. "The Reproductive Effects of Dietary Heptachlor in Mink (*Mustela Vison*)." *Arch. Environ. Contam. Toxicol.* 24, pp. 156–164.

Custer, T. W., and G. H. Heinz. 1980. "Reproductive Success and Nest Attentiveness of Mallard Ducks Fed Aroclor 1254." *Environmental Pollution (Series A)* 21, pp. 313–318.

Dahlgren, R. B., R. L. Linder, and C. W. Carlson. 1972. "Polychlorinated Biphenyls: Their Effects on Penned Pheasants." *Environmental Health Perspectives* 1, pp. 89–101.

Davis, W. J. 1982. "Territory Size in *Megaceryle alcyon* Along a Stream Habitat." *The Auk.* 99, pp. 353–362.

Davis, A., R. Barale, G. Brun, et al. 1987. "Evaluation of the genetic and embryotoxic effects of bis(tri-*n*-butyltin)oxide (TBTO), a broad-spectrum pesticide, in multiple in vivo and in vitro short-term tests." *Muta. Res.* 188: 65-95.

DeGraaf, R.M., G.M. Witman, J.W. Lanier, B.J. Hill, and J.M. Keniston. 1981. Forest habitat for birds of the northeast. U.S.D.A. Forest Service. Northeast Forest Experiment Station and Eastern Region. 598 pp.

DeGraaf, R. M., and D. D. Rudis. 1986. *New England Wildlife: Habitat, Natural History, and Distribution.* General Technical Report NE-108, U.S.D.A. Forest Service, Northeastern Forest Experiment Station.

Dikshith, T. S. S., R. B. Raizada, M. K. Srivastava, and B. S. Kaphalia. 1984. "Response of Rats to Repeated Oral Administration of Endosulfan." *Ind. Health* 22, pp. 295–304.

Domingo, J.L., J.M. Llobet and J. Corbella. 1985. Protection of mice against the lethaleffects of sodium metavanadate: a quantitative comparison of a number of chelating agents. Toxicol. Lett. 26: 95-99.

Domingo, J. L., J. L. Paternain, J. M. Llobet, and J. Corbella. 1986. "Effects of Vanadium on Reproduction, Gestation, Parturition and Lactation in Rats upon Oral Administration." *Life Sci.* 39, pp. 819–824.

Domingo, J. L., J. L. Paternain, J. M. Llobet, and J. Corbella. 1987. "The Effects of Aluminum Ingestion on Reproduction and Survival in Rats." *Life Sci.* 41, pp. 1127–1131.

Dounce, A. L. 1951. The mechanism of action of Uranium compounds in the animal body. Pages 951-991 *in* C. Voegtlin and H. C. Hodge, eds. The Pharmacology and Toxicology of Uranium Compounds. National Nuclear Energy Series, Div. IV, Vol. 1 and Div. VI, Vol. 1. McGraw-Hill Book Co., Inc., New York.

Dounce, A. L., E. Roberts, and J. H. Wills. 1951. Catalasuria as a sensitive test for Uranium poisoning. Pages 889-950 *in* C. Voegtlin and H. C. Hodge, eds. The Pharmacology and Toxicology of Uranium Compounds. National Nuclear Energy Series, Div. IV, Vol. 1 and Div. VI, Vol. 1. McGraw-Hill Book Co., Inc., New York.

Dowdy, S., and S. Wearden. 1983. *Statistics for Research.* John Wiley and Sons, New York.

Drinker, K. R., P. K. Thompson, and M. Marsh. 1927. "An Investigation of the Effect of Long Continued Ingestion of Zinc, in the Form of Zinc Oxide, by Cats and Dogs, Together with Observations upon the Excretion and Storage of Zinc." *Am. J. Physiol.* 80, pp. 31–64.

Drinker, K., and P. Drinker. 1928. "Metal Fume Fever: V. Results of the Inhalation by Animals of Zinc and Magnesium Oxide Fumes." *J. Ind. Hyg.* 10, pp. 56–70.

Dunning, J. B. 1984. *Body Weights of 686 Species of North American Birds.* Western Bird Banding Association Monograph 1. Eldon Publishing Co., Cave Creek, Arizona.

Dunstone, N. 1993. The mink. T&AD Poyser, London. 232pp.

Durbin, P. W., and M. E. Wrenn. 1975. Metabolism and effects of Uranium in animals. Pages 68-129 *in* Conference on occupational health experience with Uranium. U.S. Energy Research and Development Administration, Washington, D.C. ERDA 93/UC41.

Edens, F. W., E. Benton, S. J. Bursian, and G. W. Morgan. 1976. "Effect of Dietary Lead on Reproductive Performance in Japanese Quail, *Coturnix coturnix japonica.*" *Toxicol. Appl. Pharmacol.* 38, pp. 307–314.

Efroymson, R., B.E. Sample, G.W. Suter II and T.L. Ashwood. 1996. Soil-plant contaminant uptake factors: review and recommendations for the Oak Ridge Reservation. ES/ER/TM-198. Oak Ridge National Laboratory, Oak Ridge, TN

Ehrlich, P. R., D. S. Dobkin, and D. Wheye. 1988. *The Birder's Handbook: A Field Guide to the Natural History of North American Birds.* Simon and Schuster, Inc., New York.

Eisler, R. 1985a. *Cadmium Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review.* U.S. Fish Wildlife Service Biology Report 85(1.2).

Eisler, R. 1985b. *Selenium Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review.* U.S. Fish and Wildlife Service Biology Report 85(1.5).

Eisler, R. 1986(a). Chromium hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish Wildl. Serv. Biol. Rep. 85(1.6). 60pp.

Eisler, R. 1986(b). *Polychlorinated Biphenyl Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review.* U.S. Fish and Wildlife Service Biology Report 85(1.7).

Eisler, R. 1987. *Mercury Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review.*U.S. Fish and Wildife Service Biology Report 85(1.10).

Eisler, R. 1988a. *Arsenic Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review.*U.S. Fish and Wildlife Service Biology Report 85(1.12).

Eisler, R. 1988b. *Lead Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review.* U.S. Fish Wildife Service Biology Report 85(1.14).

Eisler, R. 1993. *Zinc Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review.* U.S. Fish and Wildlife Service Biology Report 85(1.26).

Environmental Sciences Division (ESD). 1993. Final report on the background soil characterization project at the Oak Ridge Reservation, Oak Ridge, Tennessee. DOE/OR/01-1175/V1-V3. Oak Ridge National Laboratory, Oak Ridge, Tenn.

EPA (Environmental Protection Agency). 1980. *Ambient Water Quality Criteria for Polychlorinated Biphenyls.* U.S. Environ. Protection Agency Rep. 440/5-80-068.

EPA. 1980a. "Guidelines and Methodology Used in the Preparation of Health Effects Assessment Chapters of the Consent Decree Water Quality Criteria Documents." *Federal Register* 45(**231**), pp. 79347–79356.

EPA. 1984. *Health Effects Assessment for Zinc (and Compounds).* EPA/540/1-86-048, U.S Environmental Protection Agency, Office of Research and Development, Washington, D.C.

EPA (U. S. Environmental Protection Agency). 1986. 90-day gavage study in albino rats using acetone. Office of Solid Waste, Washington, D.C.

EPA. 1987. *Drinking Water Criteria Document for Copper.* ECAO-CIN-417, prepared by the Office of Health and Environmental Assessment, Environmental Criteria and Assessment Office, Cincinnati, Ohio, for the Office of Drinking Water, Washington, D.C.

EPA. 1992. *Framework for Ecological Risk Assessment.* EPA/630/R-92/001, Risk Assessment Forum, U.S. Environmental Protection Agency, Washington, D.C.

EPA (U. S. Environmental Protection Agency). 1993. "Great Lakes water quality initiative criteria documents for the protection of wildlife (proposed): DDT, Mercury, 2,3,7,8-TCDD, PCBs." EPA/822/R-93-007. Office Science and Technology Washington, D.C.

EPA. 1993a. *Integrated Risk Information System (IRIS)—Carcinogenicity Assessment for Zinc and Compounds, and Oral RFD Assessment for Zinc phosphide.* Office of Health and Environmental Assessment, Cincinnati, Ohio.

EPA. 1993b. *Wildlife Exposure Factors Handbook, Volume II.* EPA/600/R93/187b, Office of Research and Development, Washington, D.C.

EPA. 1993c. *Wildlife Criteria Portions of the Proposed Water Quality Guidance for the Great Lakes System.* EPA/822/R-93/006, Office of Science and Technology, Washington, D.C.

EPA. 1995. Great Lakes Water Quality Initiative Technical Support Document for Wildlife Criteria. U.S. Environmental Protection Agency, Washington D.C. EPA-820-B-95-009.

Ferm, V. H., and D. P. Hanlon. 1974. "Toxicity of Copper Salts in Hamster Embryonic Development." *Biol. Reprod.* 11, pp. 97–101.

Ferm, V. H., and W. M. Layton, Jr. 1981. "Teratogenic and Mutagenic Effects of Cadmium," in *Cadmium in the Environment, Part 2: Health Effects,* J.O. Nriagu, ed. John Wiley, New York, pp. 743–756.

Feron, V.J., C.F.M. Hendriksen, A.J. Speek, et al. 1981. "Lifespan oral toxicity study of vinyl chloride in rats." Food Cosmet. Toxicol. 13: 633-638.

Fimreite, N. 1970. "Effects of Methyl Mercury Treated Feed on the Mortality and Growth of Leghorn Cockerels." *Can. J. Anim. Sci.* 50, pp. 387–389.

Fimreite, N. 1971. *Effects of Dietary Methylmercury on Ringnecked Pheasants.* Occasional Paper No. 9, Canadian Wildlife Service.

Fleming, W. J., M. A. Ross Mclane, and E. Cromartie. 1982. "Endrin Decreases Screech Owl Productivity." *J. Wildl. Manage.* 46, pp. 462–468.

Fitzhugh, O.G. 1948. "Use of DDT insecticides on food products." Ind. Eng. Chem. 40: 704-705.

Food & Drug Research Laboratory, Inc. 1984. Acute oral toxicity of seventeen nickel/cobalt samples in Sprague-Dawley rats. Report submitted to Nickel Producers Environ. Res. Assoc.

Formigli, L., et al. 1986. "Thallium-induced Testicular Toxicity in the Rat." *Environ. Res.* 40, pp. 531–539.

Fox, M. R. S., and R. M. Jacobs. 1986. "Zinc: Essentiality, Function, Effects of Deficiency, and Requirements," in *Metal Ions in Biological Systems,* H. Sigel, ed. Marcel Dekker, Inc., New York. pp. 214–248.

Furness, R. W. 1996. Cadmium in birds. p.389-404. In: W. N. Beyer, G. H. Heinz and A. W. Redmon-Norwood (eds.), Environmental contaminants in wildlife. Lewis Publishers, NY.

Gale, T.F. 1978. Embryotoxic effects of chromium trioxide in hamsters. Environ. Res. 16: 101-109.

Ganrot, P. O. 1986. "Metabolism and Possible Health Effects of Aluminum." *Environ. Health Persp.* 65, pp. 363–441.

Gasaway, W. C., and I. O. Buss. 1972. "Zinc Toxicity in the Mallard Duck." *J. Wildl. Manage.* 36, pp. 1107-1117.

Gerell, R. 1970. "Home Ranges and Movements of the Mink Mustela Vison Schreber in Southern Sweden." *Oikos* 21, pp. 160–173.

Getz, L. L. 1989. "A 14-year Study of *Blarina brevicauda* Populations in East-central Illinois." *J. Mamm.* 70, pp. 8–66.

Giavini, E., C. Vismara, and L. Broccia. 1985. "Teratogenesis study of dioxane in rats." Toxicol Lett. 26: 85-88.

Gilani, S.H., and M. Marano. 1979. Chromium poisoning and chick embryogenesis. Environ. Res.19: 427-431.

Golub, M. S., et al. 1987. "Maternal and Developmental Toxicity of Chronic Aluminum Exposure in Mice." *Fund. Appl. Toxicol.* 8, pp. 346–357.

Good, E. E., and G. W. Ware. 1969. "Effects of Insecticides on Reproduction in the Laboratory Mouse, Iv. Endrin and Dieldrin." *Toxicol. Appl. Pharmacol.* 14, pp. 201–203.

Gopinath, C., G. A. Hall, and J. M. C. Howell. 1974. [Title not given.] *Res. Vet. Sci.* 16, pp. 57–69.

Gosselin, R.E. R.P. Smith, H.C. Hodge, et al. 1984. Clinical Toxicology of Commercial Products, 5th ed. Williams and Wilkins, Baltimore, MD. pp. II-148-149.

Goyer, R.A. 1991. Toxic effects of metals. In: Amdur, M.O., J. Doull, and C.D. Klaassen, Eds. Casarett and Doull's toxicology: The basic science of poisons. 4th ed. Pergamon Press, New York. pp. 623-680.

Grandjean, P. 1976. "Possible Effect of Lead on Eggshell Thickness in Kestrels 1874-1974." *Bull. Environ. Contam. Toxicol.* 16, p. 101

Grant, D.L., W.E.J. Phillips, and G.V. Hatina. 1977. "Effects of hexachlorobenzene on reproduction in the rat." Arch. Environ. Contam. Toxicol. 5: 207-216.

Gray, L.E., Jr., J. Ostby, R. Sigmon, J. Ferrell, G. Rehnberg, R. Linder, R. Cooper, J. Goldman, and J. Laskey. 1988. "The development of a protocol to assess reproductive effects of toxicants in the rat." Reprod. Toxicol. 2: 281-287.

Hamilton, W. J., Jr. 1940. "The Summer Food of Minks and Raccoons on the Montezuma Marsh, New York." *J. Wildl. Manage.* 4, pp. 80–84.

Hammonds, J. S., F. O. Hoffman, and S. M. Bartell.1994. *An Introductory Guide to Uncertainty Analysis in Environmental and Health Risk Assessment.* ES/ER/TM-35/R1, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Harr, J. R. 1978. "Biological Effects of Selenium" in *Toxicity of Heavy Metals in the Environment: Part I,* F.W. Oehme, ed. Marcel Dekker, Inc., New York, pp. 393–426.

Harris, H. J., T. C. Erdman, G. T. Ankley, and K. B. Lodgel. 1993. "Measures of Reproductive Success and Polychlorinate Biphenyl Residues in Eggs and Chicks of Forster's Terns on Green Bay, Lake Michigan, Wisconsin—1988." *Arch. Environ. Contam. Toxicol.* 25, pp. 304–314.

Harvey, M. J. 1992. *Bats of the Eastern United States.* Arkansas Game and Fish Commission, Little Rock, Arkansas.

Haseltine, S.D. and L. Sileo. 1983. Response of American Black Ducks to dietary uranium: a proposed substitute for lead shot. J. Wildl. Manage. 47(4): 1124-1129.

Haseltine, S.D., L. Sileo, D.J. Hoffman, and B.D. Mulhern. 1985. "Effects of chromium on reproduction and growth in black ducks."

Haywood, S. 1985."Copper Toxicosis and Tolerance in the Rat—I. Changes in Copper Content of the Liver and Kidney." *J. Pathol.* 145, pp. 149–158.

Heaton S. N., 1992. Effects on reproduction of ranch mink fed carp from Saginaw Bay, Michigan . M. S. Thesis, Department of Animal Science, Michigan State University, East Lansing, MI. 152 pp.

Heinz, G. H. 1979. "Methyl Mercury: Reproduction and Behavioral Effects on Three Generations of Mallard Ducks." *J. Wildl. Mgmt.* 43, pp. 394-401.

Heinz, G. H. 1996. Selenium in birds. p. 447-458. In: W. N. Beyer, G. H. Heinz and A. W. Redmon-Norwood (eds.), Environmental contaminants in wildlife. Lewis Publishers, NY, NY.

Heinz, G.H., and S.D. Haseltine. 1981. Avoidance behavior of young black ducks treated with chromium. Toxicol. Lett. 8: 307-310..

Heinz, G. H., and S. D. Haseltine. 1983. "Altered Avoidance Behavior of Young Black Ducks Fed Cadmium." *Environ. Toxicol. Chem.* 2, pp. 419–421.

Heinz, G. H., D. J. Hoffman, A. J. Krynitsky, and D. M. G. Weller. 1987. "Reproduction in Mallards Fed Selenium." *Environ. Toxicol. Chem.* 6, pp. 423–433.

Heinz, G. H., D. J. Hoffman, and L. G. Gold. 1989. "Impaired Reproduction of Mallards Fed an Organic Form of Selenium." *J. Wildl. Mgmt.* 53, pp. 418–428.

Hill, E.F., and M.B. Camardese. 1986. "Lethal dietary toxicities of environmental contaminants and pesticides to *Coturnix*" U.S. Fish and Wildlife Service, Fish and Wildlife Tech. Rept. 2. 147 pp.

Hinzman, R. L., et al. 1995. Report on the biological monitorining and abatement program for Bear Creek at the Oak Ridge Y-12 Plant, Oak Ridge, Tennessee (1989-1994). ORNL/TM-12884. Oak Ridge National Laboratory, Oak Ridge, Tenn.

Hockman, J. G., and J. A. Chapman. 1983. Comparative feeding habits of red foxes (*Vulpes vulpes*) and gray foxes (*Urocyon cinereoargenteus*) in Maryland. Amer. Midl. Natur. 110 (2): 276-285.

Hoffman, R. D. 1978. *The Diets of Herons and Egrets in Southwestern Lake Erie.* National Audubon Society Research Report 7, pp. 365–369.

Hoffman, D. J., and G. H. Heinz. 1988. "Embryotoxic and Teratogenic Effects of Selenium in the Diet of Mallards." *J. Toxicol. Environ. Health* 24, pp. 477–490.

Hornshaw, T. C., R. J. Aulerich, and H. E. Johnson. 1983. "Feeding Great Lakes Fish to Mink: Effects on Mink and Accumulation and Elimination of Pcbs by Mink." *J. Toxicology and Environ. Health* 11, pp. 933–946.

Hudson, R. H., R. K. Tucker, and M. A. Haegele. 1984. "Handbook of toxicity of pesticides to wildlife." 2nd ed. U.S. Fish and Wildl. Serv. Resour. Publ. 153. 90 pp.

Hussein, A. S., A. H. Cantor, and T. H. Johnson. 1988. "Use of High Levels of Dietary Aluminum and Zinc for Inducing Pauses in Egg Production of Japanese Quail." *Poultry Sci.* 67, pp. 1157–1165.

International Commission on Radiological Protection (ICRP). 1959. Report of committee II on permissible dose for internal radiation. Health Physics 3:1-380.

Janes, S.W. 1984. Influences of territory compostion and interspecific competition on Red-tailed hawk reproductive success. Ecology. 65: 862-870.

Johnson, D., Jr., A. L. Mehring, Jr., and H. W. Titus. 1960. "Tolerance of Chickens for Barium." *Proc. Soc. Exp. Biol. Med.* 104, pp. 436–438.

Kazantzis, G. 1979. "Thallium," in *Handbook on the Toxicology of Metals,* L. Fribourg , ed. Elsevier Press, New York, pp. 599–612.

Kendall, R. J., and P. F. Scanlon. 1981. "Effects of Chronic Lead Ingestion on Reproductive Characteristics of Ringed Turtle Doves *Streptopelia risoria* and on Tissue Lead Concentrations of Adults and Progeny." *Environ. Poll.* Series A, 26, pp. 203–213.

Ketcheson, M. R., G. P. Barron, and D. H. Cox. 1969. "Relationship of Maternal Dietary Zinc During Gestation and Lactation to Development and Zinc, Iron, and Copper Content of the Postnatal Rat." *J. Nutr.* 98, pp. 303–311.

Kimmel, C. A., L. D. Grant, C. S. Sloan, and B. C. Gladen. 1980. "Chronic Low-level Lead Toxicity in the Rat—I. Maternal Toxicity and Perinatal Effects." *Toxicol. Appl. Pharmacol.* 56, pp. 28–41.

King, K. A., T. W. Custer, and J. S. Quinn. 1991. "Effects of Mercury, Selenium, and Organochlorine Contaminants on Reproduction of Forster's Terns and Black Skimmers Nesting in a Contaminated Texas Bay." *Arch. Environ. Contam. Toxicol.* 20, pp. 32–40.

Kinnamon, K. E. 1963. "Some Independent and Combined Effects of Copper, Molybdenum, and Zinc on the Placental Transfer of Zinc-65 in the Rat." *J. Nutrition* 81, pp. 312–320.

Kline, R. D., V. W. Hays and G. L. Cromwell. 1971. "Effects of Copper, Molybdenum and Sulfate on Performance, Hematology and Copper Stores of Pigs and Lambs." *J. Animal Sci.* 33, pp. 771–779.

Korschgen, L. J. 1958. "December Food Habits of Mink in Missouri." *J. Mamm.* 39, pp. 521–527.

Krueger, G. L., T. K. Morris, R. R. Suskind, and E. M. Widner. 1984. "The Health Effects of Aluminum Compounds in Mammals." *Crit. Rev. Toxicol.* 13, pp. 1–24.

Kushlan, J. A. 1978. "Feeding Ecology of Wading Birds" in *Wading Birds.* National Audubon Society, pp. 249–297.

Lam, H. F., et al. 1985. "Functional and Morphological Changes in the Lungs of Guinea Pigs Exposed to Freshly Generated Ultrafine Zinc Oxide." *Toxicol. Appl. Pharmacol.* 78, pp. 29–38.

Lamb, J.C., IV, R.E. Chapin, J. Teague, A.D. Lawton, and J.R. Reel. 1987. "Reproductive effects of four phthalic acid esters in the mouse." Toxicol. Appl. Pharmacol. 88: 255-269.

Landrum, C. L., T. L. Ashwood, and D. K. Cox. 1993. *Belted Kingfishers as Ecological Monitors of Contaminations: A Review.* ORNL/M-2533, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Lane, R. W., B. L. Riddle, and J. F. Borzelleca. 1982. " Effects of 1,2-dichloroethane and 1,1,1-trichloroethane in drinking water on reproduction and development in mice." Toxicol. Appl. Pharmacol. 63: 409-421.

Larngard, S., and T. Norseth. 1979. Chromium. pp. 383-397. in L. Friberg (ed). Handbook on the toxicology of metals. Elsevier Press, NY. 709 pp.

Laskey, J.W., G.L. Rehnberg, J.F. Hein, and S.D. Carter. 1982. Effects of chronic manganese (Mn_3O_4) exposure on selected reproductive parameters in rats. J. Toxicol. Environ. Health. 9:677-687.

Laskey, J.W., and F.W. Edens. 1985. "Effects of chronic high-level manganese exposure on male behavior in the Japanese Quail (*Cotirnix coturnix japonica*)." *Poult. Sci.* 64: 579-584.

Leach, L.J., E.A. Maynard, H.C. Hodge, Scott J.K., C.L. Yuile, G.E. Sylvester, and H.B. Wilson. 1970. A five year inhalation study with uranium dioxide (UO^2) dust. I. Retention and biologic effect in the monkey, dog, and rat. Health Phys. 18:559-612.

Leach, R. M., K. W.-L. Wang, and D. E. Baker. 1979. Cadmium and the food chain: the effect of dietary cadmium on tissue composition in chicks and laying hens. J. Nutr. 109: 437-443.

Lecyk, M. 1980. "Toxicity of Cupric Sulfate in Mice Embryonic Development." *Zool. Pol.* 28, pp. 101–105.

Leonards, P.E.G., M. D. Smit, A. W. J. J. de Jongh, B. van Hattum. 1994. Evaluation of dose-response relationships for the effects of PCBs on the reproduction of mink (Mustela vison). Institute for Environmental Studies, Amsterdam. 50pp.

Lepore, P.D., and R.F. Miller, 1965. "Embryonic viability as influenced by excess molybdenum in chicken breeder diets." *Proc. Soc. Exp. Biol. Med.* 118: 155-157

Lewis, R. J. and D. V. Sweet, eds. 1984. *Registry of Toxic Effects of Chemical Substances,* Vol. 1. U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, Cincinnati, Ohio.

Linder, R. E., T. B. Gaines, and R. D. Kimbrough. 1974. "The Effect of PCB on Rat Reproduction." *Food Cosmet. Toxicol.* 12, p. 63.

Linzey, A. V. 1987. "Effects of Chronic Polychlorinated Biphenyls Exposure on Reproductive Success of White-footed Mice (*Peromyscus leucopus*)." *Arch. Environ. Contam. Toxicol.* 16, pp. 455–460.

Lloyd, T. B. 1984. "Zinc Compounds" in *Kirk-Othmer Encyclopedia of Chemical Technology,* 3rd ed., H. F. Mark, D. F. Othmer, C. G. Overberger, G. T. Seaborg, eds. John Wiley & Sons, New York, pp. 851–863.

Lo, M. T., and E. Sandi. 1980. Selenium: "Occurrence in Foods and its Toxicological Significance. A Review." *J. Environ. Pathol. Toxicol.* 4, pp. 193–218.

Loar, J. M. 1990. Fourth annual report on the ORNL biological monitonng and abatement program. Environmental Sciences Division, Oak Ridge National Laboratory, ORNL/TM-Draft.

Loar, J.M., et al. 1992. Second report on the Oak Ridge National Laboratory Biological Monitoring and Abatement Program for White Oak Creek Watershed and the Clinch River. Oak Ridge National Laboratory, Oak Ridge, TN. ORNL/TM-10804.

Ma, W., W. Denneman, and J. Faber. 1991. "Hazardous Exposure of Ground-living Small Mammals to Cadmium and Lead in Contaminated Terrestrial Ecosystems." *Arch. Environ. Contam. Toxicol.* 20, pp. 266–270.

Mackenzie, K. M., and D. M. Angevine. 1981. "Infertility in Mice Exposed in Utero to Benzo[a]pyrene." *Biol. Reprod.* 24, pp. 183–191.

Mackenzie, R.D., R.U. Byerrum, C.F. Decker, et al. 1958. Chronic toxicity studies, II.Hexavalent and trivalent chromium administered in drinking water to rats. Am. Med.Assoc. Arch. Ind. Health. 18:232-234.

Maita, K., et al. 1981. "Subacute Toxicity with Zinc Sulfate in Mice and Rats." *J. Pest. Sci.* 6, pp. 327–336.

Marathe, M.R., and G.P. Thomas. 1986. "Embryotoxicity and Teratogenicity of Lithium Carbonate in Wistar Rat." *Toxicol. Lett.* 34, pp. 115–120.

Massie, H.R. and V.R. Aiello. 1984. "Excessive Intake of Copper: Influence on Longevity and Cadmium Accumulation in Mice." *Mech. Ageing Dev.* 26, pp. 195–203.

Mastromatteo, E. 1986. Nickel. Am. Ind. Hyg. Assoc. J. 47(10):589-601.

Maynard, E.A. and H.C. Hodge. 1949. Studies of the toxicity of various uranium compounds when fed to experimental animals. In: The Pharmacology and Toxicology of Uranium Compounds. C. Voegtlin and H.C. Hodge, eds. McGraw-Hill, New York, pp. 309-376.

Mayo, R.H., et al. 1956. "Copper Tolerance of Young Chickens." *Poult. Sci.* 35, pp. 1156–1157.

McCoy, G., et al. 1995. "Chronic Polychlorinated Biphenyls Exposure on Three Generations of Oldfield Mice (*Permyscus polionotus*): Effects on Reproduction, Growth, and Body Residues." *Arch. Environ. Contam. Toxicol.* 28, pp. 431–435

McLane, M. A. R., and D. L. Hughes. 1980. "Reproductive Success of Screech Owls Fed Aroclor 1248." *Arch. Environm. Contam. Toxicol.* 9, pp. 661–665.

Mehring, A. L., Jr., J. H. Brumbaugh, A. J. Sutherland, and H. W. Titus. 1960. "The Tolerance of Growing Chickens for Dietary Copper." *Poult. Sci.* 39, pp. 713–719.

Melquist, W. E., and M. G. Hornocker. 1983. "Ecology of River Otters in West Central Idaho." *Wildl. Monogr.* 83, pp. 1–60.

Mendenhall, V. M., E. E. Klaas, and M. A. R. McLane. 1983. "Breeding Success of Barn Owls (*Tyto alba*) Fed Low Levels of Dde and Dieldrin." *Arch. Environ. Contam. Toxicol.* 12, pp. 235–240.

Merritt, R.C. 1971. The extractive metallurgy of uranium. Colorado School of Mines Research Institute. Atomic Energy Commission.

Meyers-Schone, L. M., and B. T. Walton. 1994. "Turtles as Monitors of Chemical Contaminants in the Environment." *Rev. Environ. Contam. Toxicol.* 135, pp. 93–153.

Miller, W. J., et al. 1989. "Long-term Feeding of High Zinc Sulfate Diets to Lactating and Gestating Dairy Cows." *J. Dairy Sci.* 72, pp. 1499–1508.

Mineau, P., B.T. Collins, and A. Baril. 1996. On the use of scaling factors to improve interspecies extrapolation of acute toxicity in birds. Reg. Toxicol. and Pharmacol. In Press.

Mitchell, J. L. 1961. "Mink Movements and Population on a Montana River." *J. Wildl. Manage.* 25, pp. 48–54.

Mumford, R. E., and J. O. Whitaker, Jr. 1982. *Mammals of Indiana.* Indiana University Press, Bloomington, Indiana.

National Academy of Sciences (NAS) 1977. *Arsenic.* U.S. National Academy of Sciences, Washington, D.C.

National Academy of Sciences (NAS). 1979. *Zinc.* U.S. National Academy of Sciences, National Research Council, Subcommittee on Zinc, University Park Press, Baltimore, Maryland.

National Academy of Sciences (NAS). 1980. Mineral Tolerance of Domestic Animals. National Academy Press, Washington, DC.

National Academy of Sciences (NAS). 1980. Uranium. In: Mineral tolerance of domestic animals. National Academy Press, Washington, DC.

National Coffe Association. 1982. "24-month Chronic Toxicity and Oncogenicity Study of Methylene Chloride in Rats." Final Report, Hazelton Laboratories, Inc., Vienna, Virginia.

NCI (National Cancer Institute). 1978. "Bioassay of Aroclor 1254 for Possible Carcinogenicity." NCI Carcinogenesis Technical Report, Series No. 38, NCI-CG-TR-38, DHEW Pub. No. (NIH) 78-838.

National Geographic Society. 1987. *Field Guide to the Birds of North America,* 2nd ed.

Nawrot, P.S. and R.E. Staples. 1979. "Embryofetal toxicity and teratogenicity of benzene and toluene in the mouse." Teratology. 19: 41A

Nicholson, J. K., and D. Osborn. 1983. Kidney lesions in pelagic seabirds with high tissue levels of cadmium and mercury. J. Zool. (Lond.) 200: 99-118.

NRC (National Reseach Council), 1982. Nutrient Requirements of Mink and Foxes, No. 7. National Academy of Sciences, Washington, D.C. 72 pp.

NRCC. 1978. *Effects of Arsenic in the Canadian Environment.* National Research Council of Canada Publication No. NRCC 15391.

Nyholm, N. E. I. 1981. "Evidence of Involvement of Aluminum in Causation of Defective Formation of Eggshells and of Impaired Breeding in Wild Passerine Birds." *Environ. Res.* 26, pp. 363–371.

Oh, S. H., et al. 1979. "Accumulation and Depletion of Zinc in Chick Tissue Metallothioneins." *J. Nutr.* 109, pp. 1720–1729.

Ohlendorf, H. M., et al. 1986. "Relationships Between Selenium Concentrations and Avian Reproduction." *Trans. N. Am. Wildl. Nat. Res. Conf.* 51, pp. 330–342.

Ondreicka, R., E. Ginter, and J. Kortus. 1966. "Chronic Toxicity of Aluminum in Rats and Mice and its Effects on Phosphorus Metabolism." *Brit. J. Indust. Med.* 23, pp. 305–313.

Palafox, A. L., and E. Ho-A. 1980. "Effect of Zinc Toxicity in Laying White Leghorn Pullets and Hens." *Poultry Sci.* 59, pp. 2024–2028.

Palmer, A. K., D. D. Cozens, E. J. F. Spicer, and A. N. Worden. 1978. "Effects of Lindane upon Reproductive Functions in a 3-generation Study in Rats." *Toxicology* 10, pp. 45–54.

Palmer, A.K., A.E. Street, F.J.C. Roe, A.N. Worden, and N.J. Van Abbe. 1979. "Safety evaluation of toothpaste containing chloroform, II. Long term studies in rats." J. Environ. Pathol. Toxicol. 2: 821-833.

Paternain, J. L., J. L. Domingo, J. M. Llobet, and J. Corbella. 1988. "Embryotoxic and Teratogenic Effects of Aluminum Nitrate in Rats upon Oral Administration." *Teratology* 38, pp. 253–257.

Paternain, J. L., J. L. Domingo, A. Ortega, and J. M. Llobet. 1989. "The Effects of Uranium on Reproduction, Gestation, and Postnatal Survival in Mice." *Ecotoxicol. Environ. Saf.* 17, pp. 291–296.

Pattee, O. H. 1984. "Eggshell Thickness and Reproduction in American Kestrels Exposed to Chronic Dietary Lead." *Arch Environ. Contam. Toxicol.* 13, pp. 29–34.

Pattee, O.H., S.N. Wiemeyer, and D.M. Swineford. 1988. "Effects of dietary fluoride on reproduction in eastern Screech-Owls." Arch. Environ. Contam. Toxicol. 17: 213-218.

Peakall, D.B. 1974. "Effects of di-N-buylphthalate and di-2-ethylhexylphthalate on the eggs of ring doves." Bull. Environ. Contam. Toxicol. 12: 698-702.

Perry, H. M., E. F. Perry, M. N. Erlanger, and S. J. Kopp. 1983. "Cardiovascular Effects of Chronic Barium Ingestion," in *Proceedings of the 17th Annual Conference on Trace Substances in Environmental Health,* vol. 17. University of Missouri Press, Columbia, Missouri.

Peterson, M.A., R.R. Petri, and G.R. Southworth. 1994. Bioaccumulation Studies. In T.L. Ashwood (ed.) Eighth Annual Report on the ORNL Biological Monitoring and Abatement Program. Draft ORNL/TM-12767. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Phatak, S.S., and V.N. Patwardhan. 1952. Toxicity of nickel -- accumulation of nickel in rats fed on nickel-containing diets and its elimination. J. Sci. Industr. Res. 11b:173-176.

Platonow, N. S., and B. S. Reinhart. 1973. "The Effects of Polychlorinated Biphenyls (Aroclor 1254) on Chicken Egg Production, Fertility and Hatchability." *Can. J. Comp. Med.* 37, pp. 341–346.

Platonow, N. S., and L. H. Karstad. 1973. "Dietary Effects of Polychlorinated Biphenyls on Mink." *Can. J. Comp. Med.* 37, pp. 391–400.

Prasad, A. S. 1979. "Clinical, Biochemical, and Pharmacological Role of Zinc." *Ann. Rev. Pharmacol. Toxicol.* 20, pp. 393–426.

Preston, A.M., R.P. Dowdy, M.A. Preston, and J.N. Freeman. 1976. Effect of dietary chromium on glucose tolerance and serum cholesterol in guinea pigs. J. Nutr. 106: 1391-1397.

Pullar, E. M. 1940. "The Toxicity of Various Copper Compounds and Mixtures for Domesticated Birds. 2." *Australian Vet. J.* 16, pp. 203–213.

Pullin, B. P. 1990. Size and trends of wading bird populations in Tennessee during 1977-1988. Migrant 61:95-104.

Quast, J.F., C.G. Humiston, C.E. Wade, et al. 1983. "A chronic toxicity and oncogenicity study in rats and subchronic toxicity in dogs on ingested vinylidene chloride." Fund. Appl. Toxicol. 3: 55-62.

Rana, S. V. S., and A. Kumar. 1978. "Simultaneous Effects of Dietary Molybdenum and Copper on the Accumulation of Copper in the Liver and Kidney of Copper Poisoned Rats—A Histochemical Study." *Ind. Health* 18, pp. 9–17.

Ratcliffe, D.A. 1967. "Decease in eggshell weight in certain birds of prey" *Nature* 215: 208-210.

Reece, R. L., D. B. Dickson, and P. J. Bunowes. 1986."Zinc Toxicity (New Wire Disease) in Aviary Birds." *Australian Vet. J.* 63, p. 199.

Ringer, R. K., R. J. Aulerich, and M. R. Bleavins. 1981. "Biological Effects of PCBs and PBBs on Mink and Ferrets—A Review" in *Halogenated Hydrocarbons: Health and Ecological Effects,* M. A. Q. Khan, ed. Permagon Press, Elmsford, New York, pp. 329–343.

Roberson, R. H., and P.J . Schaible. 1960. "The Tolerance of Growing Chicks for High Levels of Different Forms of Zinc." *Poult. Sci.* 39, pp. 893–896.

Romoser, G.L., W.A. Dudley, L.J. Machlin, and L. Loveless. 1961. Toxicity of vanadium and chromium for the growing chick. Poultry Sci. 40: 1171-1173.

Rosenfeld, I. and O.A. Beath. 1954. Effect of selenium on reproduction in rats. Proc. Soc. Exp. Biol. Med. 87: 295-297.

Roshchin, I.V. 1967. Toxicity of vanadium compounds used in modern industry. Gig. Sanit. 32: 26-32.

SAIC. 1994. East Fork Poplar Creek - Sewer Line Beltway Remedial Investigation Report. U.S. Department of Energy,, Oak Ridge, TN. DOE/OR/02-1119&D2&V2.

Sample, B. E., and G. W. Suter, II. 1994. *Estimating Exposure of Terrestrial Wildlife to Contaminants.* ES/ER/TM-125, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Sample, B.E., D.M. Opresko and G.W. Suter II. 1996(a). Toxicological Benchmarks for Wildlife: 1996 Revision. ES/ER/TM-86/R3. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Sample, B.E., R. Efroymson, G.W. Suter II and T.L. Ashwood. 1996(b). Soil-earthworm and soil-small mammmal contaminant uptake factors: review and recommendations for the Oak Ridge Reservation. ES/ER/TM-197. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Sanders, O. T., R. L. Zepp, and R. L. Kirkpatrick. 1974. "Effect of PCB Ingestion on Sleeping Times, Organ Weights, Food Consumption, Serum Corticosterone and Survival of Albino Mice." *Bull. Environ. Contam. Toxicol.* 12 (4), pp. 394–399.

Sargeant, A.B. 1972. Red fox spatial characteristics in relation to waterfowl predation. J. Wildl. Manage. 36: 225-236.

Sargeant, A.B. 1978. "Red fox prey demands and implications to prairie duck production." J. Wildl. Manage. 42(3): 520-527.

Schlatterer, B., T.M.M. Coenen, E. Ebert, R. Grau, V. Hilbig, and R. Munk. 1993. "Effects of Bis(tri-*n*-butyltin)oxide in Japanese Quail exposed during egg laying period: an interlaboratory comparison study." *Arch. Environ. Contam. Toxicol.* 24: 440-448.

Schlicker, S.A., and D.H. Cox. 1967. "Maternal Dietary Zn in Excess, Fetal Development, and Fe and Cu Metabolism." Abstract, *Fed. Amer. Proc.* 26, p. 520.

Schlicker, S.A., and D.H. Cox. 1968. "Maternal Dietary Zinc and Development; Zinc, Iron, and Copper Content of the Rat Fetus." *J. Nutr.* 95, pp. 287–294.

Schroeder, H. A., J. J. Balassa, and W. H. Vinton, Jr. 1965. Chromium, Cadmium and Lead in Rats: Effects on Life Span, Tumors and Tissue Levels. *J. Nutr.* 86, pp. 51–66.

Schroeder, H. A., and J. J. Balassa. 1967. Arsenic, germanium, tin and vanadium in mice: effects on growth, survival and tissue levels. J. Nutr. 92:245-251.

Schroeder, H.A., M. Kanisawa, D.V. Frost, and M. Mitchener. 1968a. "Germanium, Tin, and Arsenic in Rats: Effects on Growth, Survival and Tissue Levels." *J. Nutr.* 96, pp. 37–45.

Schroeder, H.A., et al.. 1968b. "Zirconium, Niobium, Antimony, and Fluorine in Mice: Effects on Growth, Survival and Tissue Levels." *J. Nutr.* 95, pp. 95–101.

Schroeder, H. A., and M. Mitchener. 1971. Toxic Effects on the Reproduction of Mice and Rats. *Arch. Environ. Health.* 23, pp. 102–106.

Schroeder, H. A., and M. Mitchener. 1972. "Selenium and Tellurium in Mice." *Arch. Environ. Health.* 24, pp. 66–71.

Schroeder, H. A., and M. Mitchener. 1975a. "Life-term Studies in Rats: Effects of Aluminum, Barium, Beryllium, and Tungsten." *J. Nutr.* 105, pp. 421–427.

Schroeder, H. and M. Mitchener. 1975b. Life-term effects of mercury, methyl mercury and nine other trace metals on mice. J. Nutr. 105: 452-458.

Schroeder, H.A., and M. Mitchener. 1975b. "Life-term Effects of Mercury, Methyl Mercury and Nine Other Trace Metals on Mice." *J. Nutr.* 105, pp. 452–458.

Schroeder, H., M. Mitchener and A.P. Nason. 1970. Zirconium, niobium, antimony, vanadium and lead in rats: life term studies. J. Nutrit. 100: 59-68.

Schwetz, B.A., J.F. Quast, P.A. Keeler, C.G. Humiston, and R.J. Kociba. 1978. "Results of two-year toxicity and reproduction studies on pentachlorophenol in rats." pp 301-309 in K.R. Rao, ed., *Pentachlorophenol: Chemistry, Pharmacology, and Environmental Toxicology.* Plenum Press, New York. 401 pp.

Scientifur, 1987. Scientifur Index. I. G. Joergensen (ed.). Scientifur, Hillerod Denmark, 196 pp.

Sealander, J.A. 1943. "Winter Food Habits of Mink in Southern Michigan." *J. Wildl. Manage.* 7, pp. 411–417.

Shaw, P.A. 1933. "Toxicity and Deposition of Thallium in Certain Game Birds." *J. Pharmacol. Exp. Ther.* 48, pp. 478–487.

Short, H.L. and R.J. Cooper. 1985. *Habitat Suitability Index Models: Great Blue Heron.* Biological Report 82(10.99), Fish and Wildlife Service, U.S. Department of the Interior.

Skoryna, S.C. 1981. "Effects of oral supplementation with stable strontium." Can. Med. Assoc. J. 125: 703-712.

Sleight, S.D. and O.A. Atallah. 1968. "Reproduction in the guinea pig as affected by chronic administration of potassium nitrate and potassium nitrite." Toxicol. Appl. Pharmacol. 12: 179-185.

Smith, G.J., and V.P. Anders. 1989. "Toxic effects of boron on mallard reproduction." *Environ. Toxicol. Chem.* 8: 943-950.

Smith, H.M. 1967. *Handbook of lizards: Lizards of the United States and Canada.* Comstock Publ. Assoc., Cornell University Press, Ithaca, New York.

Sommers, L., et al. 1987. "Effects of Soil Properties on Accumulation of Trace Elements by Crops," in *Land Application of Sludge,* A. L. Page, T. J. Logan, J. A. Ryan, eds., pp. 5–24.

Sorensen, J. R. R., I. R. Campbell, L. B. Tepper, and R. D. Lingg. 1974. "Aluminum in the Environment and Human Health." *Environm. Health. Persp.* 8, pp. 3–95.

Stahl, J. L., M. E. Cook, M. L. Sunde, and J. L. Greger. 1989."Enhanced Humoral Immunity in Progeny Chicks Fed Practical Diets Supplemented with Zinc," *Appl. Agric. Res.* 4, pp. 86–89.

Stahl, J. L., J. L. Greger, and M. E. Cook. 1990. "Breeding-hen and Progeny Performance When Hens Are Fed Excessive Dietary Zinc," *Poultry Sci.* 69, Pp. 259–263.

Steven, J. D., et al. 1976. *Effects of Chromium in the Canadian Environment.* NRCC No. 151017.

Steven, J.D., L.J. Davies, E.K. Stanley, R.A. Abbott, M. Ihnat, L. Bidstrup, and J.F. Jaworski. 1976. Effects of chromium in the Canadian environment. NRCC No. 151017. 168 pp.

Stevens, R. T., 1995. *Heavy Metals and PCBs in Mink (Mustela vison) and Muskrat (Ondatra zibethcus) from the U.S. Department of Energy's Oak Ridge Reservation.* Unpublished master's thesis, Tennessee Technological University, Cookeville, Tennessee.

Stickel, L. F., W. H. Stickel, R. A. Dyrland, and D. L. Hughes. 1983. "Oxychlordane, HCS-3260, and Nonachlor in Birds: Lethal Residues and Loss Rates," *J. Toxicol. Environ. Health* 12, pp. 611–622.

Stokinger, H. E. 1981a. "Copper," in *Patty's Industrial Hygiene and Toxicology, Vol. 2A,* G. D. Clayton and E. Clayton, eds. John Wiley & Sons, New York, pp. 1620–1630.

Stokinger, H.E. 1981b. Vanadium. In: G.D. Clayton and E. Clayton, Eds. Patty's Industrial Hygiene and Toxicology, 3rd rev. ed., vol. 2A. John Wiley and Sons, New York. pp. 2013-2033.

Storm, G.L., R.D. Andrews, R. L. Phillips, R.A. Bishop, D.B. Siniff, and J.R. Tester. 1976. "Morphology, reproduction, dispersal, and mortality of midwestern red fox populations." Wildl. Monogr.

Straube, E. F., N. H. Schuster, and A. J. Sinclair. 1980. "Zinc Toxicity in the Ferret." *J. Comparative Pathol.* 90, pp. 355–361.

Sundqvist, C., 1989. Mink Encyclopedia Release 1.0 Parts I and II. Mink Encyclopedia Project, Depart. Biology, Abo Akademi, Porthansgatan 3, Turku, Finland. Part I, 391 pp; Part II, 387 pp.

Suter, G. W. 1990. Screening level risk assessment for off-site ecological effects in surface waters downstream from the U.S. Department of Energy Oak Ridge Reservation. Environmental Sciences Division Publication 3483. ORNL/ER-8.

Suter, G. W., B. E. Sample, D. S. Jones, and T. L. Ashwood. 1994a. *Approach and Strategy for Performing Ecological Risk Assessments for the U.S. Department of Energy's Oak Ridge Reservation: 1994 Revision.* ES/ER/TM-33/R1, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Suter, G. W., et al. 1994b. "Baseline Ecological Risk Assessment," in *Remedial Investigation Report for Chestnut Ridge Operable Unit 2 (Filled Coal Ash Pond/Upper McCoy Branch) at the Oak Ridge Y-12 Plant, Oak Ridge.* DOE/OR/02-1238&DO, draft.

Suter, G. W., B. E. Sample, D. S. Jones, and T. L. Ashwood. 1995. *Approach and Strategy for Performing Ecological Risk Assessments for the U.S. Department of Energy's Oak Ridge Reservation: 1994 Revision.* ES/ER/TM-33/R2, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Sutton, W. R., and V. E. Nelson. 1937. "Studies on Zinc." *Proc. Soc. Exp. Biol. Med.* 36, pp. 211–213.

Sutou, S., K. Yamamoto, H. Sendota, and M. Sugiyama. 1980 Toxicity, fertility, teratogenicity, and dominant lethal tests in rats administered cadmium subchronically. I. Fertility, teratogenicity, and dominant lethal tests. Ecotoxicol. Environ. Safety. 4: 51-56.

Tannenbaum, A., and H. Silverstone. 1951. Some aspects of the toxicology of Uranium compounds. Pages 59-96 *in* A. Tannenbaum, ed. Toxicology of Uranium. National Nuclear Energy Series, Div. IV, Vol. 23, McGraw-Hill Book Co., Inc., New York.

Taylor, J. K. 1987. Quality assurance of chemical measurements. Lewis Publ., Inc., Chelsea, Mich.

Taylor, F.G., Jr., and P.D. Parr. 1978. Distribution of chromium in vegetation and small mammals adjacent to cooling towers. J. Tenn. Acad. Sci. 53: 87-91.

Tewe, O.O. and J.H. Maner. 1981. "Long-term and carry-over effect of dietary inorganic cyanide (KCN) in the life cycle performance and metabolism of rats." Toxicol. Appl. Pharmacol. 58: 1-7.

Thompson, D. R. 1996. Mercury in birds and terrestrial mammals. p. 341-356. In: W. N. Beyer, G. H. Heinz, and A. W. Redmon-Norwood (eds.), Environmental contaminants in wildlife. Lewis Publishers, NY, NY.

Travis, C. C., and A. D. Arms. 1988. "Bioconcentration of Organics in Beef, Milk, and Vegetation." *Environ. Sci. Technol.* 22, pp. 271–274.

Treon, J. F., and F. P. Cleveland. 1955. "Toxicity of Certain Chlorinated Hydrocarbon Insecticides for Laboratory Animals, with Special Reference to Aldrin and Dieldrin." *Ag. Food Chem.* 3, pp. 402–408.

USAF (U.S. Air Force). 1990. "Copper," in *The Installation Program Toxicology Guide, Vol. 5.* Wright-Patterson Air Force Base, Ohio, pp. 1–43.

U.S. Fish and Wildlife Service (USFWS). 1964. *Pesticide-wildlife Studies, 1963: A Review of Fish and Wildlife Service Investigations During the Calender Year.* FWS Circular 199.

Van Daele, L.J., and H.A. Van Daele. 1982. Factors affecting the productivity of ospreys nesting in west-central Idaho. Condor. 84: 292-299.

Venugopal, B., and T. D. Luckey. 1978. *Metal Toxicity in Mammals: Vol. 2. Chemical Toxicity of Metals and Metalloids.* Plenum press, New York.

Verschuuren, H.G., et al. 1976a. "Toxicity of Methylmercury in Rats—I. Short-term Study." *Toxicology* 6, pp. 85–96.

Verschuuren, H.G., et al. 1976b. "Toxicity of Methylmercury in Rats —II. Long-term Toxicity Study." *Toxicology* 6, pp. 107–123.

Verschuuren, H.G., et al. 1976c. "Toxicity of Methylmercury in Rats—I. Reproduction Study." *Toxicology* 6, pp. 97–106.

Vogtsberger, L.M. and G.W. Barrett. 1973. "Bioenergetics of captive red foxes." J. Wildl. Manage. 37(4): 495-500.

Vohra, P., and F. H. Kratzer. 1968. "Zinc, Copper and Manganese Toxicities in Turkey Poults and Their Alleviation by EDTA." *Poult. Sci.* 47, pp. 699–704.

Vos, J. G., H. L. Van Der Maas, A.Musch, and E. Ram. 1971. "Toxicity of Hexachlorobenzene in Japanese Quail with Special Reference to Porphyria, Liver Damage, Reproduction, and Tissue Residues." *Toxicol. Appl. Pharmacol.* 18, pp. 944–957.

Walters, M., and F. J. C. Roe. 1965. "A Study of the Effects of Zinc and Tin Administered Orally to Mice over a Prolonged Period." *Food Cosmet. Toxicol.* 3, pp. 271–276.

Washington-Allen, R. A., T. L. Ashwood, S. W. Christensen. 1995. *Terrestrial Mapping of the Oak Ridge Reservation: Phase 1.* ES/ER/TM-152, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Ware, G. W. 1978. *The Pesticide Book.* W. H. Freeman and Co., San Francisco, California.

Weber, C.W. and B.L. Reid. 1968. Nickel toxicity in growing chicks. J. Nutrition 95: 612-616.Agency for Toxic Substances and Disease Registry (ATSDR). 1990. Draft toxicological profile for uranium. ATSDR/U.S. Public Health Service, Atlanta, GA.

Weigel, H. J., D. Ilge, I. Elmadfa, and H. J. Jaeger. 1987. "Availability and Toxicological Effects of Low Levels of Biologically Bound Cadmium." *Arch. Environ. Contam. Toxicol.* 16(1), pp. 85–93.

Weir, R.J., and R.S. Fisher. 1972. "Toxicologica studies on borax and boric acid." *Toxicol. Appl. Pharmacol.* 23: 351-364.

Westmoreland, N., and W. G. Hoekstra. 1969. "Pathological Defects in the Epiphyseal Cartilage of Zinc-deficient Chicks." *J. Nutr.* 98, pp. 76–82.

Whanger, P. D. 1973. "Effect of Dietary Cadmium on Intracellular Distribution of Hepatic Iron in Rats." *Res. Commun. Chem. Pathol. Pharmacol.* 5, pp. 733–740.

White, D.H., and M.P. Dieter. 1978. Effects of dietary vanadium in mallard ducks. J. Toxicol. Environ. Health. 4: 43-50.

White, D. H., and M. T. Finley. 1978. "Uptake and Retention of Dietary Cadmium in Mallard Ducks." *Environ. Res.* 17, pp. 53–59.

White, D. H., M. T. Finley, and J. F. Ferrell. 1978. "Histopathological Effects of Dietary Cadmium on Kidneys and Testes of Mallard Ducks." *J. Toxicol. Environ. Health.*

Whitworth, M. R., G. W. Pendleton, D. J. Hoffman, and M. B. Camardese. 1991. "Effects of Dietary Boron and Arsenic on the Behavior of Mallard Ducklings." *Environ. Toxicol. Chem.* 10, pp. 911–916.

WHO (World Health Organization). 1984. "Chlordane." *Environ. Health Criter.* 34.

Wlostowski, T., W. Chetnicki, W. Gierlachowska-Baldyga, and B. Chycak. 1988. "Zinc, Iron, Copper, Manganese, Calcium and Magnesium Supply Status of Free-living Bank Voles." *Acta Theriol.* 33, pp. 555–573.

Wobeser, G. and M. Swift. 1976. Mercury poisoning in a wild mink. J. Wildl. Dis. 12:335-340.

Wobeser, G., N. O. Nielsen, and B. Schiefer. 1976. "Mercury and Mink—II. Experimental Methylmercury Intoxication." *Can. J. Comp. Med.* 40, pp. 34–45.

Wren, C.D. 1986. "A Review of Metal Accumulation and Toxicity in Wild Mammals–I. Mercury." *Environ. Res.* 40, pp. 210–244.

Wren, C. D., D. B. Hunter, J. F. Leatherland and P. M. Stokes. 1987. "The Effects of Polychlorinated Biphenyls and Methylmercury, Singly and in Combination on Mink—II: Reproduction and Kit Development." *Arch. Environ. Contam. Toxicol.* 16, pp. 449–454.

Zaporowska, H. and W. Wasilewski. 1991. Significance of reduced food and water consumption in rats intoxicated with vanadium. Comp. Biochem. Physiol. 99C (3): 349-352.

Appendix A

DATA SURVEY FOR THE OAK RIDGE RESERVATION ECOLOGICAL MONITORING AND ASSESSMENT PROGRAM TERRESTRIAL WILDLIFE RISK ASSESSMENT

DATA SURVEY FOR THE OAK RIDGE RESERVATION ECOLOGICAL MONITORING AND ASSESSMENT PROGRAM TERRESTRIAL WILDLIFE RISK ASSESSMENT

Michelle L. Bell and John S. Fackenthal
Environmental Assessment and Compliance Group
Environmental Sciences Division
Oak Ridge National Laboratory

INTRODUCTION

Staff of the Environmental Assessment and Compliance Group were asked to perform a data information survey for the Oak Ridge Reservation Ecological Monitoring and Assessment Program (ORR-EMAP). The survey's purpose was to identify datasets potentially relevant to an upcoming terrestrial wildlife ecological risk assessment.

SURVEY APPROACH

Primary datasets of interest were soil, sediment, biota, and surface water contaminant concentrations. Radiological studies and air sampling were not of interest to this project. The following Operable Units (OUs) were given priority based on their total non-urban or barren area:

K-25:	K-901 (Area 10), K-770, K-33, K-1007
ORNL:	WAG 2, WAG 3, WAG 4, WAG 5, WAG 6, WAG 7, WAG 8, WAG 11
Y-12:	Bear Creek, LEFPC, Bear Creek OU1, Chestnut Ridge OU2
Other OUs:	Freels Bend, South Campus

The survey took a "top-down" approach, starting with ER Program Managers and OU Facility and Project Managers. Most of these people referred to other individuals and programs they thought might have relevant information. (See Fig. 1: Referrals.) It was hoped that this strategy would provide good general coverage of available datasets and allow those with access to datasets the opportunity to contribute.

The survey was conducted by telephone and electronic mail from March 22 through April 6, 1995. After a brief introduction of the survey's purpose, respondents were asked if they were aware of any potentially relevant studies, reports, or research. General information requested from survey participants included the following:

- What OUs are you affiliated with?
- Are you aware of any potentially relevant studies, reports, or research?
- Do you know of any individuals or programs that may have information of interest?

For each person contacted, a survey form was filled out to the extent information was known. (See Fig. A.2: Survey Participant Form.)

If potentially relevant datasets were identified, further questions were asked regarding the nature of the data including the following:

- Have these datasets been entered into a data management system such as the Oak Ridge Environmental Information System (OREIS) or the Bechtel Environmental Information Data Management System (BEIDMS)?
- What types of samples were taken?
- Who has the data in electronic form?

If most of a dataset was thought to be in a data management system such as OREIS, no further questions regarding that dataset were asked since the findings could be obtained from the system. If a dataset was not thought to be in a data management system, a blank data survey form was faxed to those who might have relevant information. (See Fig. A.3: Dataset Information Form.) Unfortunately, many of these forms were not returned.

PERSONS CONTACTED

Persons contacted are listed in Table A.1. All are Lockheed Martin Energy Systems, Inc., employees or on-site subcontractors except where indicated.

SURVEY FINDINGS

Interviews and returned survey forms uncovered the following information regarding OUs of interest.

K-25

OREIS holds surface water, sediment, toxicity, and biota data for the K-901A holding pond. The K-25 Site Environmental Monitoring program takes monthly surface water and sediment samples from the K-901A pond. SAIC is currently collecting data for K-901. The ORNL Environmental Sciences Division (ESD) sampled Canadian geese near the K-1007 pond for PCBs. SAIC holds surface water, soil, and possibly sediment data for K-770. Additional soil and sediment data for K-25 can be found in OREIS.

ORNL

Surface water data from seeps, springs, and tributaries, and sediment and soil data including soil characterizations and core samples have been collected for WAG 2. Results from these studies are intended for inclusion in OREIS. Some Ni sampling has been conducted for WAG 4. Water and soil from Pit 1 of WAG 7 have been sampled. Bechtel holds data regarding WAG 5.

Y-12

Surface water, soil, sediment, and biological information for LEFPC are in OREIS. This data includes summaries of Hg distribution and results of tests for organics. A surface water compliance testing point is located at EFPC. OREIS holds data collected in 1992 and 1993 for the EFPC Remedial Investigation (RI). EFPC data not in OREIS includes pollutant data; old surface water data; and PCB, Hg, and pesticide data for fish and algae. SAIC is currently conducting EFPC studies. CDM obtained Chestnut Ridge soil, sediment, and surface water data. Small mammal and vegetation bioaccumulation studies have been conducted for Chestnut Ridge OU2. Two surface water sampling points for Y-12 surface water compliance are located at Bear Creek. The Bechtel Environmental Information Data Management System (BEIDMS) contains 1994 and 1995 Bear Creek Valley surface water data. A Bear Creek OU1 soils data project being conducted by SAIC is almost complete. Future studies for Y-12 include soil and sediment sampling near Bear Creek Road.

A historical data capture being conducted by SAIC has found the following surface water datasets for Bear Creek Valley:

- USGS water quality (inorganics, nitrate), 1984;
- NPDES data (inorganics and organic), 1990-94;
- organics, inorganics, and PCBs, 1990;
- organics, PCBs, inorganics, pesticides, 1993;
- inorganics, organic, 1987; and
- GWQAR data, organics, inorganics. 1986-1994 (in BEIDMS).

The Bear Creek Valley historical data capture contains the following soil and sediment information:

- organics, inorganics, PCBs, 1990 ;
- Upper Bear Creek Valley, inorganics, organics, pesticides, PCBs, 1983-84; and
- well borings, organics, inorganics, pesticides, PCBs, 1983-(unknown).

Other OUs

Jacobs Engineering holds Freels Bend data for soil, water, organics, inorganics, pesticides, PCBs, semi-volatiles, volatiles, and metals. This information is intended for inclusion in OREIS. Vegetation, soil, sediment, volatiles, and surface water data for South Campus are in OREIS.

Table A.1. Contacts for data survey for ORR-EMAP terrestrial wildlife risk assessment

Name	Employer	Phone	UserID	Notes/project affiliation
Jane Aiken		241-3439	XQ9	In charge of K-901
Terri Ball			TLS	WAG 6
Lisa Baron		574-7393	ISA	
Clay Bednarz		241-3926	NRZ	WAG 4 & 11 Project Manager
Donna Bennett		574-5839	DFH	UEFPC
Bud Brickeen		576-1579	WBR	WAG 3 & 8 Project Manager
Jeff Cange	Bechtel	220-2255		WAG 5 Task Manager
Jane Carr		241-3542	J5C	ORNL Document Management Center
Jennifer Chason	SAIC	481-8796		EFPC, Bear Creek
Roger Clapp		576-6619	UVA	WAG 2 Technical Lead
Mike Coffey		576-5477	C3Y	K-1007, K-901
Dennis Cope		241-3841	DGX	Y-12
Barnaby Cornaby	SAIC	481-8721		LEFPC
Chris Dearstone		576-5946, 574-7449	KTV	Y-12 Database Administrator
John Forstrom		576-5640	KAF	K-25
Don Garrett		241-3501	GA4	WAG 6, WAG 11
Patty Goddard		576-3692	PG2	K-25 ER Technical Coordinator
Steven Haase		241-5258	6SH	Y-12 Technical Support
Chuck Hadden	SAIC	481-8733		Bear Creek, LEFPC
Kim Hanzelka		574-4599	UKH	Y-12 surface water compliance
Al Hardesty		576-0311	AFQ	WAG 5
Larry Hawk		241-4874	HKV	Facility Manager (WAG 2, 3, 8, . . .)
Kelly Henry	Jacobs	482-5045		Freels Bend, South Campus
Steve Herbes		574-7336	SEH	WAG 2 Project Manager
Walter Hill		574-2828		LEFPC
Judy Hodgins		576-2368	H9S	Project Manager for soil sampling at Bear Creek Road

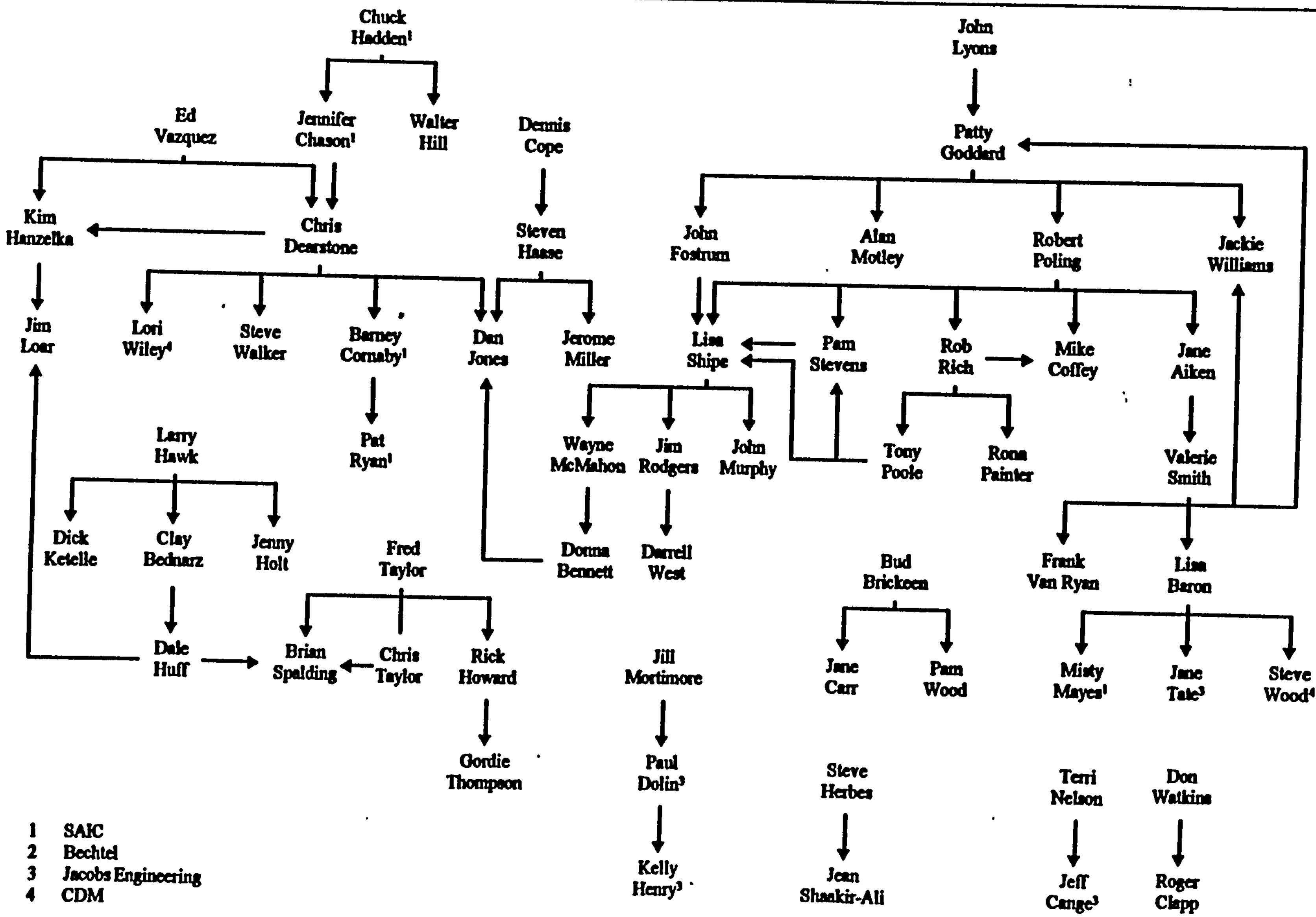
Table A.1 (continued)

Name	Employer	Phone	UserID	Notes/project affiliation
Jenny Holt		574-7336, 873-4821 (beeper)	VH2	
Rick Howard		241-2812	HR5	Facility Manager (WAG 4, 7, 11)
Dale Huff		574-7859	DDH	WAG 4
Dan Jones		241-5247		Y-12 Risk Assessment Group
Dick Ketelle		574-5762	KET	X-10
Jim Loar		574-7323	LOA	
John Lyons		574-3166	L9Y	K-25 ER Program Manager
Misty Mayes	SAIC	481-4617		K-901 pond
Wayne McMahon		574-7525	EIH	Y-12 EM Manager
Jerome Miller				LEFPC
Jill Mortimore		574-1462	JAO	Freels Bend, South Campus
Allen Motley		576-5782	A4Z	K-25
John Murphy		576-7929	JMU	X-10 EM Manager
Terri Nelson		574-7033	TRX	WAG 7 Facility and Project Manager, WAG 5 Facility Manager
Rona Painter		576-5477	RR9	K-25 Groundwater Program
Robert Poling		576-5493	P8O	K-25 Groundwater Program
Tony Poole		241-3591	D6P	K-25 ambient monitoring
Rob Rich		574-0678	RA3	ambient monitoring of K-901A and K-1007A ponds; stormwater sampling for Mitchell, Poplar, Clinch
Jim Rodgers		574-8982	JGR	Environmental Compliance for all sites
Jean Shaakir-Ali		574-5359	IJL	WAG 2
Lisa Shipe		241-2590	OLG	K-25 Monitoring Group
Valerie Smith		241-3518	VD5	K-901 and other K-25 OUs
Brian Spalding		574-7265	BPS	Pit 1 of WAG 7
Pam Stevens		576-5488	NPT	K-25 outfalls
Jane Tate	Jacobs	220-4872		South Campus

Table A.1 (continued)

Name	Employer	Phone	UserID	Notes/project affiliation
Chris Taylor		576-6813	YLO	WAG 1, WAG 7
Fred Taylor		435-3418	FGT	Former WAG 7 Project Manager
Ralph Turner		574-7856	RRT	Bear Creek
Frank Van Ryn		574-1907	XS2	K-770
Ed Vazquez		576-1930	EAV	Y-12 Data Management Program
Steve Walker				Technical Lead for future soil sampling at Bear Creek Road
Ben Watts		576-4710	BW3	K-25 Data Management Program
Don Watkins		576-9931	W5T	WAG 2
Darrell West		574-7367	DAR	
Lori Wiley	CDM			UEFPC soil sampling
Jackie Williams		241-5119	XLW	K-25 Data Management Program
Kirk Wilson		576-5290	QRG	WAG 6 Facility Manager
Pam Wood		576-9925	PW7	ORNL editor, Document control
Steve Wood	CDM	482-1065		Chestnut Ridge OU2: soil, sediment, and surface water

FIG. A.1. REFERRALS



1 SAIC
2 Bechtel
3 Jacobs Engineering
4 CDM

FIG. A.2. SURVEY PARTICIPANT FORM

PROJECT TO LOCATE DATA FOR THE OAK RIDGE RESERVATION
WHICH COULD SUPPORT ECOLOGICAL RISK ASSESSMENTS

INFORMATION ABOUT PERSONS CONTACTED (DRAFT)
(Complete information is requested only for authorities and custodians of surface water or soil data)

Name of person contacted
(last, first, middle initial)

Job title

Three-character User ID (or E-mail name if person has no User ID)

Phone number

Fax number

How was this person identified to be contacted? (e.g., referred to by program manager; name selected from organizational chart...)

Location

Employer (MMES, SAIC, Bechtel, ...)

Programmatic affiliation (ER, Compliance, BMAP, general research, ...)

Job responsibilities (Free form and flexible)

Operable Unit affiliations (which OU's does this person work with?)

Main role in identifying or providing data (check all that apply):

1. ____ Broad knowledge about multiple data sets

2. ____ Broad knowledge about a major program

3. ____ Detailed knowledge about one or more subprograms or tasks

4. ____ Data system expert

5. ____ Data custodian (of what data?) ________________________________
   (Add names of the data authorities)

6. ____ Data authority (of what data?) ________________________________
   (Add the name of the person who collected the data for which this person is an authority, or who was in charge of the field teams)

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FIG. A.2. SURVEY PARTICIPANT FORM (CONTINUED)

What programs, subprograms, or data systems is this person knowledgeable about?

What subject areas (and, if relevant, specialties) (e.g., chemistry-mercury, biology-benthic macroinvertebrates, radionuclide concentrations, data management, project management...) is this person knowledgeable about?

Expected usefulness of this contact in similar future data searches

High Intermediate Low

Comments on expected usefulness:

Other comments

Contact made by:

Date(s):

Method (e.g., in person, by phone, E-mail, correspondence):

FIG. A.3. DATASET INFORMATION FORM

DRAFT ORR-EMAP-ORNL Environmental Restoration Data Inventory

Interview Form for Relevant Data in the 3/95 search for data to support the ORR-EMAP (Terrestrial) Ecological Risk Assessment for the Reservation (As determined by Media/Sample Matrix meeting the filter specifications)

1. Organization (Program/Project/Division):________________________

2. SubProgram or Task:________________________

3. Data File or Model Name:________________________

4. Data Path or Location:________________________

5. Data Purpose:________________________

6. Site Area Description:________________________

7. Location Description:________________________

8. Approximate Date Range: [__/__/__ - __/__/__]

9. Media/Sample Matrix:________________________

10. Primary Custodian of Dataset:________________________

11. Phone Numbers:________________________ User ID:__________

12. Secondary Custodian of Dataset:________________________

13. Phone Numbers:________________________ User ID:__________

14. Primary Data Authority: ________________________

15. Phone Numbers:________________________ User ID:__________

16. Secondary Data Authority:________________________

17. Phone Numbers:________________________ User ID:__________

18. Data Generator:________________________
    (Subcontractor, if applicable)

19. Phone Numbers:________________________ User ID:__________

20. Approximate Time of Last Data Base Update: [__/__/__]

21. Intended Frequency of Data Base Update:________________________
    (Monthly, Quarterly, Annually, etc.)

FIG. A.3. DATASET INFORMATION FORM (CONTINUED)

22. Abstract:____

23. Archive Software: ____________________
(Current Database)

24. Hardware Used:__________
(Original Platform)

25. Presentation Format:____________________
Tabular (Spreadsheet)
Textual (Word Processing)
Graphical (non-spatial raster image)
Spatial (True Earth GIS file)

26. Grid System:________
(X-10, Admin, TN SP, Lat/Long)

27. Distribution Point:____
(ORNL Domain Name, IP Address)

28. Comments/Other Information:____________________________________

29. Keywords:____

30. Identifiers:____

31. Estimated Size:____

32. Validation/Evaluation (Yes/No):________________ 33. If "Yes," Describe Type:

34. Data Dictionary (Yes/No):____

35. Reports: (attach additional page, if needed)

1) DMC Number:______________________________ Date Published:______
Title:____

2) DMC Number:______________________________ Date Published:______
Title:____

3) DMC Number:______________________________ Date Published:______
Title:____

FIG. A.3. DATASET INFORMATION FORM (CONTINUED)

This information SUPPLEMENTS that obtained for the Draft ORR-EMAP-ORNL Environmental Restoration Data Inventory Interview Form (from Gordie Thompson) as supported by its "Classification Scheme"

Number (hand-assigned) of the Interview Form which this sheet supplements________________

Name by which data are known, or a descriptive name for the data. (Example: "BMAP Fish Community sampling data")

Types of samples

Contaminant levels   Toxicity   General water quality   Biota status

Other____

Types of contaminants, biota, or other measurements represented by the data (e.g., toxicity of noncharacterized water to Ceriodaphnia dubia; levels of n congeners of PCB's; metals; bioaccumulation study of x in blue herons; ...) (also attach a list of variables or a summary of data if available)

How many stations or locations were sampled? (approximate is OK)?

If soil samples are included, were these ____Surface? ____Shallow (<12")? ____Deep (>12")?

What is/was the frequency of sampling?

Is sampling ongoing?

If ongoing, provide the scheduled end date if there is one

Sampling method(s)

FIG. A.3. DATASET INFORMATION FORM (CONTINUED)

Analysis method(s)

Are qualifiers included in the data set (Y/N)? ____ If yes, indicate type(s) included
_____ Lab?
_____ Validation?
_____ Other? ______________________________

Are nondetects included in the data set? _____

Please characterize the level of data assessment (QA/QC):

_____ Validation/evaluation performed?
(If yes, what type of validation/evaluation was performed?)

_____ Are validation/Evaluation results included in the electronic data?

_____ Collected under ER standards prevailing at the time of collection?

What approximate percentage of relevant data are in the Oak Ridge Environmental Information System (OREIS)?

Recommended media for transfer (obtain from OREIS; electronically via ftp; diskette(s),...)

Cutoff date for fully validated data

Cutoff date for unvalidated but available data

Any special considerations relating to use of the data?

FIG. A.3. DATASET INFORMATION FORM (CONTINUED)

Person who compiled this information

Date information was compiled

1. All persons are thought to be employees of Lockheed Martin Energy Systems, Inc. (LMES) except where indicated.

2. E-mail address is UserID@ORNL.GOV

Appendix B

TABLES FOR CHAPTER 3: EVALUATION OF THE POTENTIAL USE OF OPERABLE UNITS ON THE OAK RIDGE RESERVATION BY WILDLIFE

Table B.1. Habitat requirements for assessment and measurement endpoints on the ORR

Species	General habitat requirements	Citation
Mallard duck	Ponds, lakes, slow-moving streams or rivers. shallow water (<41 cm) for feeding	DeGraaf and Rudis 1986
Cumberland slider	Found in shallow freshwaters with lots of aquatic vegetation. They will inhabit mainly larger bodies of water with deep water avilable (3 feet or more).	Meyers-Schone and Walton 1994
Mink	Streambanks, lakeshores, and marshes. Favors forested wetlands with abundant cover such as thickets, rocks, or windfalls.	DeGraaf and Rudis 1986
River otter	Borders of streams, lakes or other wetlands in forested areas.	DeGraaf and Rudis 1986
Great blue heron	All sizes and types of bodies of water that contain fish	DeGraaf and Rudis 1986
Belted kingfisher	Earthen bank for nesting; pond, lake, stream, or river for feeding.	DeGraaf and Rudis 1986
Bald eagle	Large bodies of water that contain fish, large living trees for nesting. Low human disturbance.	DeGraaf and Rudis 1986
Osprey	Near large bodies of water that support abundant fish. Along rivers and lakes	DeGraaf and Rudis 1986
Double-crested cormorant	Found on rocky coasts, beaches, inland lakes and rivers.	National Geographic Society 1987
Black-crowned night heron	Ponds, lakes, marshes, slow streams with pools, or rivers	DeGraaf and Rudis 1986
Northern water snake	Aquatic and semi aquatic habitats	DeGraaf and Rudis 1986
Pied-billed grebe	Lakes, rivers, or ponds with emergent vegetation and open water	DeGraaf and Rudis 1986
Leopard frog	all types of shallow freshwater habitats; includes streams, rivers, ponds, or lakes	Conant 1986
Hellbender	Almost always found in rivers and larger streams where water is running and ample shelter is available in the form of large rocks, snags, or debris.	Conant 1986
Rough-winged swallows	Nearly any open area with adequate nest sites and a water supply (usually a stream). Often river valleys and lake shores.	DeGraaf and Rudis 1986

Table B.1 (continued)

Species	General habitat requirements	Citation
Gray bat	Cave residents year-round, although different caves are occupied in summer and winter. Forage over lakes and rivers.	Harvey 1992
Indiana bat	Favors limestone caves with pools of water. Solitary females or small maternity colonies bear young in hollow trees or under loose bark. Forages over riparian forest and associated fields	DeGraaf and Rudis 1986 Mumford and Whitaker 1982
Eastern small footed bat	In or near woodland in caves, mine tunnels, buildings, crevices in rocks. Maternity colonies have been observed in buildings. Forages low over trees and brush	DeGraaf and Rudis 1986 Burt and Grossenheider 1976
Rafinesque's big-eared bat	Hibernate in caves, mines or similar habitats. Maternity colonies are usually found in abandoned buildings. Siuspected to be a forest-inhabiting bat.	Harvey 1992 Mumford and Whitaker 1982
American toad	Almost any habitat: gardens, woods, yards with cover, damp soil, and a food supply Usually in moist upland woods	DeGraaf and Rudis 1986
American woodcock	Moist woodlands in early stages of succession, swamps, stream banks, bogs, rich bottomlands, brushy edges of woods, dry open woods and fields.	DeGraaf and Rudis 1986
European starling	Farm, city, orchard, gardens, parks; Prefers rural areas w/pastures or hayfields; If forests, prefers stands with low percent canopy cover. More common in vicinity of human habitations.	DeGraaf and Rudis 1986
American robin	Open woods and fields. Forages primarily in lawns, gardens, grassy fields, etc.	DeGraaf and Rudis 1986
Short-tailed shrew	Both timbered fairly open habitats: deciduous, mixed, and less often coniferous forests with moist loose humus; especially common along banks of streams and in meadows with tall rank grasses or sedges, brush piles, and stone walls. Avoids dry, warm sites.	DeGraaf and Rudis 1986
Long-tailed shrew	found in deciduous and mixed forest.	DeGraaf and Rudis 1986
Masked shrew	Damp deciduous and coniferous woodlands with grasses, rocks, logs, or stumps for cover; bogs and other moist areas.	DeGraaf and Rudis 1986

Table B.1 (continued)

Species	General habitat requirements	Citation
Smokey shrew	Damp, boulder-strewn, upland woods with thick leafmold. Typically near streams with moss-covered banks.	DeGraaf and Rudis 1986
Southeastern shrew	Open fields and woodlots	Burt and Grossenheider 1976
Six-line racerunner	Dry regions in sparse woods with loose/sandy soil and short grasses.	Smith 1967
Slender glass snake	dry grasslands or dry open woods	Conant 1986
Tennessee cave salamander	caves with water (species has external gills)	Conant 1986
Green salamander	humid rocky areas where rock faces remain moist and well protected from sun and direct rain.	Conant 1986
Raccoon	Wooded areas interrupted by fields and water courses. Not usually found in dense forests, commonly found in wetlands near human habitation.	DeGraaf and Rudis 1986
Wood duck	Shallow waters of ponds, lakes, or marshes having abundant floating and emergent vegetation. Wooded swamps or open flooded lowland forests where food is available.	DeGraaf and Rudis 1986
Muskrat	Marshes, shallow portions of lakes, ponds, swamps, sluggish streams, drainage ditches. Most abundant in areas with cattails.	DeGraaf and Rudis 1986
White-tailed deer	Mosaic of forests and open areas	DeGraaf and Rudis 1986
Wild turkey	Mast-producing woodlands. Ideal habitat is a network of open, mixed forests and fields.	DeGraaf and Rudis 1986
Canada goose	marshes, shores of ponds and lakes, grassy fields or agricultural lands that provide additional grazing areas.	DeGraaf and Rudis 1986
Eastern cottontail	Farmlands, pastures, fallow fields, open woodlands, thickets along fence rows and stone walls, edges of forests. swamps and marshes, suburban areas with adequate food and cover. Avoids dense woods.	DeGraaf and Rudis 1986
Groundhog	Open land. Edges of woodlands (seldom in interior), open cultivated land, pastures, meadows, open brushy hillsides.	DeGraaf and Rudis 1986

Table B.1 (continued)

Species	General habitat requirements	Citation
Grasshopper sparrow	Hayfields, weedy fallow fields, prairies. Avoids shrubby fields. Birds favor uplands with ground vegetation of various densities.	DeGraaf and Rudis 1986
Henslow's sparrow	Neglected weedy fields-commonly of broomsedge-wet meadows, saltmarsh edges. Occaisionally in dry and cultivated uplands. May fovor moist lowland habitat and may use areas with widely scattered shrubs.	DeGraaf and Rudis 1986
Lark sparrow	generally prefers sites with grasslands or open woodlands	National Geographc Society 1987
Vesper sparrow	Breed in short-grass meadows, pastures, hayfields, cultivated grain fields, dry open uplands, burned and cut-over areas in forests, country roadsides. Birds favor sparsely vegetated uplands and may use areas with widely scattered shrubs.	DeGraaf and Rudis 1986
Red-tailed hawk	Deciduous and mixed woodlands interspersed with meadows, brushy pastures, open bogs, and swampy areas. Large openings for foraging.	DeGraaf and Rudis 1986
Golden eagle	Elevated nest sites, especially cliffs. Broad expanses of open land for hunting. 50 to 100 square mile home range.	DeGraaf and Rudis 1986
Northern harrier	Open country with herbaceous or low woody vegetation for nest concealment.	DeGraaf and Rudis 1986
Cooper's hawk	Extensive deciduous or mixed woodlands that are dense or open, scattered woodlots interspersed with open fields. Occupies similar forest niche as Sharp-shinned Hawk but has broadened its habitat by moving into more open agricultural areas. Flood plain forests and wooded swamps.	DeGraaf and Rudis 1986
Red-shouldered hawk	Moist hardwood or mixed woodlands, wooded swamps, bottomlands and wooded margins of marshes often close to cultivated fields.	DeGraaf and Rudis 1986
Sharp-shinned hawk	Open mixed or coniferous woodlands, clearing, edges. Extensive open mixed woodlands that are free from human disturbance.	DeGraaf and Rudis 1986
Barn owl	Almost anywhere in open country but prefers vicinity of farms and villages. Avoids woodlands and higher elevations.	DeGraaf and Rudis 1986
Black vulture	Common in open country and around human settlements, avoids heavily forested areas	Ehrlich et al. 1988

Table B.1 (continued)

Species	General habitat requirements	Citation
Cougar	Found throughout all habitat types and successional stages. Requires isolation away from human disturbance. Home ranges may vary in size from 5 to 96 square miles.	DeGraaf and Rudis 1986
Red fox	A mixture of forest and open areas is preferred. Unbroken fields and dense forests avoided. Edges used heavily.	DeGraaf and Rudis 1986
Snapping turtle	Any permanent body of freshwater, large or small.	DeGraaf and Rudis 1986
Black rat snake	Variety of habitats including woodlands, thickets, field edges, farmlands, rocky hillsides, river bottoms, old barns.	DeGraaf and Rudis 1986
Northern pine snake	Flat, sandy pine barrens, sandhills, and dry mountain ridges, most often in or near pine woods.	Conant 1986

Table B.2. Summary of landcover types identified on the ORR and expected use by assessment and measurement endpoints

Species	Landcover types[a] on the ORR									
	Urban	Water	Pine forest	Pine plant.	Decid. forest	Mixed forest	Pasture	Trans.	Barren	Other
Mallard duck		X								
Cumberland slider		X								
Mink		X			X	X				water primary; forest secondary
River otter		X			X	X				water primary; forest secondary
Great blue heron		X								
Belted kingfisher		X								
Bald eagle		X								large bodies of water
Osprey		X								large bodies of water
Double-crested cormorant		X								large bodies of water
Black-crowned night heron		X								
Northern water snake		X								
Pied-billed grebe		X								
Leopard frog		X								
Hellbender		X								

Table B.2 (continued)

Species	Landcover types[a] on the ORR									
	Urban	Water	Pine forest	Pine plant.	Decid. forest	Mixed forest	Pasture	Trans.	Barren	Other
Rough-winged swallows		X					X	X		Earthen Banks
Gray bat		X								large bodies of water, caves
Indiana bat		X			X	X	X	X		
Eastern small footed bat					X		X	X		
Rafinesque's big-eared bat	X (buiildings)		X	X	X	X				Caves
American toad		X	X	X	X	X				forest primary; water secondary
American woodcock					X	X	X	X		
European starling	X		X	X	X	X	X	X		
American robin	X		X	X	X	X	X	X		
Short-tailed shrew			X	X	X	X		X		
Long-tailed shrew					X	X				
Masked shrew					X	X				
Smokey shrew					X	X				
Southeastern shrew			X	X	X	X	X	X		
Six-line racerunner			X	X	X	X	X	X		
Slender glass snake			X	X	X	X	X	X		

Table B.2 (continued)

Species	Landcover types[a] on the ORR								
	Urban	Water	Pine forest	Pine plant.	Decid. forest	Mixed forest	Pasture	Trans.	Barren	Other
Tennessee cave salamander										Caves
Green salamander										moist, rocky sites
Raccoon	X	X	X	X	X	X	X	X		
Wood duck		X			X	X				
Muskrat		X								
White-tailed deer			X	X	X	X	X	X		
Wild turkey			X	X	X	X	X	X		
Canada goose	X	X					X			
Eastern cottontail	X						X	X		
Groundhog	X						X	X		
Grasshopper sparrow							X	X		
Henslow's sparrow							X	X		
Lark sparrow					X	X	X	X		
Vesper sparrow							X	X		
Red-tailed hawk			X	X	X	X	X	X		
Golden eagle										use of ORR unlikely[B]
Northern harrier							X	X		

Table B.2 (continued)

Species	Landcover types[a] on the ORR									
	Urban	Water	Pine forest	Pine plant.	Decid. forest	Mixed forest	Pasture	Trans.	Barren	Other
Cooper's hawk					X	X	X	X		
Red-shouldered hawk					X	X				
Sharp-shinned hawk					X	X				
Barn owl	X						X	X		
Black vulture							X	X		
Cougar			X	X	X	X	X	X		use of ORR unlikely[C]
Red fox			X	X	X	X	X	X		
Snapping turtle		X								
Black rat snake	X		X	X	X	X	X	X		
Northern pine snake			X	X		X				

[a] Definitions of habitat types are presnted in Table 1. X in cell indicates use of habitat by listed endpoint species.
[B] While golden eagles may migrate through the ORR, because the ORR does not contain large expanses of open habitat, significant use of any area on the ORR is highly unlikely.
[C] Because the ORR does not contain large expanses of habitat away from human disturbance, significant use of any area on the ORR is highly unlikely.

Table B.3. Summary of landcover types identified on OUs on the ORR

OU	Area (ha) by landcover type									
	Urban	Water	Pine forest	Pine plant.	Decid. forest	Mixed forest	Pasture	Trans.	Barren	Total
Area 10 (K-901)	15.94	3.56	1.75	0.31	6.87	7.62	3.19	38.31		77.5
K-33	65	0.12			2.94	0.87	5.06	13.94	0.37	88.3
K-1064	110.6						0.19	3.56	0.06	14.87
K-1410	3.19							0.31		3.5
K-29	25.62						0.62	0.88		27.12
K-1007	13.75	7.62					0.19	0.75		22.31
K-1413	1.31									1.31
K-1004	2.94									2.94
K-1070-C/D	6.56				1.69	0.19	0.25	4.37		13.06
K-1401	8.06									8.06
K-1420	2.31									2.31
K-1407	12.31	0[a]						4.19		16.5
K-770	43.81	2	2.37	1.06	4.37	3.12	4.19	28	0.06	88.98
WAG 1	48.18	0[a]	0.81		1.25	0.81	0.94			51.99
WAG 2	13	9	1		15.75	29	0.06	14.81		82.62
WAG 3	0.56		0.19		1.06	2.19	0.06	8.12		12.18
WAG 4	6.37	0[a]			2.19	1.19	4.5	1.06		15.31

Table B.3 (continued)

OU	Area (ha) by landcover type									
	Urban	Water	Pine forest	Pine plant.	Decid. forest	Mixed forest	Pasture	Trans.	Barren	Total
WAG 5	10.19	0[a]	0.25		3.56	6.44	7.69	9.06		37.19
WAG 6	25.5	0.75			5.06	2.06	0.5	2.94		36.81
WAG 7	5.37	0[a]	1.44		17.25	25.31	0.12	8.31		57.8
WAG 8	17.81		3.44		1.44	3.785		5.12		31.56
WAG 9	1.37				0.25	0.06		0.31		1.99
WAG 10	0.5		0.12		0.06	0.19		0.25		1.12
WAG 11	0.31		4.56		0.81	3.81	0.37	5.12		14.98
WAG 13	0.56		0.12		0.18	0.44	0.37	1.81		3.48
Bear Creek	85.37	0[a]	37.37	20.94	192.81	140.56	14.62	246.06	0.44	738.17
BC OU1	9.5				8.19	0.25	9.19	24	0.25	51.38
BC OU2	4.12							0.62	0.06	4.8
CR OU1	1.5					0.19	2.5	2.06		6.25
CR OU2	0.94	0.06			3.81	0.38		2.62		7.81
CR OU3	0.31						0.19			0.5
CR OU4	1.44	3.94			0.06	0.06	0.19	0.56	0.31	6.56
Lower East Fork Poplar Creek	99.81	0.19	7.37	2.62	41.06	50.87	8.5	133.87	2	344.29
UEFPC OU2	3.56									3.56
UEFPC OU3	5.19									5.19

Table B.3 (continued)

OU	Area (ha) by landcover type									
	Urban	Water	Pine forest	Pine plant.	Decid. forest	Mixed forest	Pasture	Trans.	Barren	Total
Freels Bend	0.75	1.12		0.06	2.06	3.88	0.81	4.56		13.49
South Campus Facility	9.81	0.44	0.06	0.06			13.25	4.5	0.44	28.56

[a] While no surface water was observed in the satellite image, surface water is known to be present at this site.

Table B.4. Summary of habitat availability for assessment and measurment endpoints at K-25 OUs.[a]

	K-901	K-33	K-1064	K-1410	K-29	K-1007	K-1413	K-1004	K-1070-C/D	K-1401	K-1420	K-1407	K-770
Mallard duck	x	x				x						x	x
Cumberland slider	x	x				x						x	x
Mink	x	x				x						x	x
River otter	x	x				x						x	x
Great blue heron	x	x				x						x	x
Belted kingfisher	x	x				x						x	x
Bald eagle	x					x							
Osprey	x					x							
Double-crested cormorant	x					x							
Black-crowned night heron	x	x				x						x	x
Northern Water snake	x	x				x						x	x
Pied-billed grebe	x	x				x						x	x
Leopard frog	x	x				x						x	x
Hellbender													
Rough-winged swallows	x	x				x			x			x	x
Gray bat	x					x							
Indiana bat	x	x	x	x	x	x			x			x	x
Eastern small footed bat	x	x	x	x	x	x			x			x	x

Table B.4 (continued)

	K-901	K-33	K-1064	K-1410	K-29	K-1007	K-1413	K-1004	K-1070-C/D	K-1401	K-1420	K-1407	K-770
Rafinesque's big-eared bat	x	x	x	x	x	x	x	x	x	x	x	x	x
American toad	x	x							x				x
American woodcock	x	x	x	x	x	x			x			x	x
European starling	x	x	x	x	x	x	x	x	x	x	x	x	x
American robin	x	x	x	x	x	x	x	x	x	x	x	x	x
Short-tailed shrew	x	x							x				x
Long-tailed shrew	x	x							x				x
Masked shrew	x	x							x				x
Smokey shrew	x	x							x				x
Southeastern shrew	x	x	x	x	x	x			x			x	x
Six-line racerunner	x	x	x	x	x	x			x			x	x
Slender glass snake	x	x	x	x	x	x			x			x	x
Tennessee cave salamander													
Green salamander													
Raccoon	x	x	x	x	x	x	x	x	x	x	x	x	x
Wood duck	x	x				x						x	x
Muskrat	x	x				x						x	x
White-tailed deer	x	x	x	x	x	x			x			x	x
Wild turkey	x	x	x	x	x	x			x			x	x
Canada goose	x	x	x	x	x	x	x	x	x	x	x	x	x

Table B.4 (continued)

	K-901	K-33	K-1064	K-1410	K-29	K-1007	K-1413	K-1004	K-1070-C/D	K-1401	K-1420	K-1407	K-770
Eastern cottontail	x	x	x	x	x	x	x	x	x	x	x	x	x
Groundhog	x	x	x	x	x	x	x	x	x	x	x	x	x
Grasshopper sparrow	x	x	x	x	x	x			x			x	x
Henslow's sparrow	x	x	x	x	x	x			x			x	x
Lark sparrow	x	x	x	x	x	x			x			x	x
Vesper sparrow	x	x	x	x	x	x			x			x	x
Red-tailed hawk	x	x	x	x	x	x			x			x	x
Golden eagle													
Northern harrier	x	x	x	x	x	x			x			x	x
Cooper's hawk	x	x	x	x	x	x			x			x	x
Red-shouldered hawk	x	x							x				x
Sharp-shinned hawk	x	x							x				x
Barn owl	x	x	x	x	x	x	x	x	x	x	x	x	x
Black vulture	x	x	x	x	x	x			x			x	x
Cougar													
Red fox	x	x	x	x	x	x			x			x	x
Snapping turtle	x	x				x						x	x
Black rat snake	x	x	x	x	x	x	x	x	x	x	x	x	x
Northern pine snake	x	x							x				x
Total number of endpoints/OU	52	48	26	26	26	44	9	9	35	9	9	40	48

[a] X=presence of at least one habitat category prefered by the endpoint. Amount of suitable habitat not considered; only presence/absence of habitat.

Table B.5. Summary of habitat availability for assessment and measurment endpoints at X-10 OUs[a]

	WAG 1	WAG 2	WAG 3	WAG 4	WAG 5	WAG 6	WAG 7	WAG 8	WAG 9	WAG 10	WAG 11	WAG 13
Mallard duck	x	x		x	x	x	x					
Cumberland slider	x	x		x	x	x	x					
Mink	x	x		x	x	x	x					
River otter		x		x	x	x	x					
Great blue heron	x	x		x	x	x	x					
Belted kingfisher	x	x		x	x	x	x					
Bald eagle		x (WOL)[b]										
Osprey		x (WOL)[b]										
Double-crested cormorant		x (WOL)[b]										
Black-crowned night heron	x	x		x	x	x	x					
Northern water snake	x	x		x	x	x	x					
Pied-billed grebe	x	x		x	x	x	x					
Leopard frog	x	x		x	x	x	x					
Hellbender		x		x	x	x	x					
Rough-winged swallows	x	x	x	x	x	x	x	x	x	x	x	x
Gray bat		x (WOL)[b]										
Indiana bat	x	x	x	x	x	x	x	x	x	x	x	x

Table B.5 (continued)

	WAG 1	WAG 2	WAG 3	WAG 4	WAG 5	WAG 6	WAG 7	WAG 8	WAG 9	WAG 10	WAG 11	WAG 13
Eastern small footed bat	x	x	x	x	x	x	x	x	x	x	x	x
Rafinesque's big-eared bat	x	x	x	x	x	x	x	x	x	x	x	x
American toad	x	x	x	x	x	x	x	x	x	x	x	x
American woodcock	x	x	x	x	x	x	x	x	x	x	x	x
European starling	x	x	x	x	x	x	x	x	x	x	x	x
American robin	x	x	x	x	x	x	x	x	x	x	x	x
Short-tailed shrew	x	x	x	x	x	x	x	x	x	x	x	x
Long-tailed shrew	x	x	x	x	x	x	x	x	x	x	x	x
Masked shrew	x	x	x	x	x	x	x	x	x	x	x	x
Smokey shrew	x	x	x	x	x	x	x	x	x	x	x	x
Southeastern shrew	x	x	x	x	x	x	x	x	x	x	x	x
Six-line racerunner	x	x	x	x	x	x	x	x	x	x	x	x
Slender glass snake	x	x	x	x	x	x	x	x	x	x	x	x
Tennessee cave salamander												
Green salamander												
Raccoon	x	x	x	x	x	x	x	x	x	x	x	x
Wood duck	x	x		x	x	x	x					
Muskrat	x	x		x	x	x	x					
White-tailed deer	x	x	x	x	x	x	x	x	x	x	x	x
Wild turkey	x	x	x	x	x	x	x	x	x	x	x	x
Canada goose	x	x	x	x	x	x	x	x	x	x	x	x

Table B.5 (continued)

	WAG 1	WAG 2	WAG 3	WAG 4	WAG 5	WAG 6	WAG 7	WAG 8	WAG 9	WAG 10	WAG 11	WAG 13
Eastern cottontail	x	x	x	x	x	x	x	x	x	x	x	x
Groundhog	x	x	x	x	x	x	x	x	x	x	x	x
Grasshopper sparrow	x	x	x	x	x	x	x	x	x	x	x	x
Henslow's sparrow	x	x	x	x	x	x	x	x	x	x	x	x
Lark sparrow	x	x	x	x	x	x	x	x	x	x	x	x
Vesper sparrow	x	x	x	x	x	x	x	x	x	x	x	x
Red-tailed hawk	x	x	x	x	x	x	x	x	x	x	x	x
Golden eagle												
Northern harrier	x	x	x	x	x	x	x	x	x	x	x	x
Cooper's hawk	x	x	x	x	x	x	x	x	x	x	x	x
Red-shouldered hawk	x	x	x	x	x	x	x	x	x	x	x	x
Sharp-shinned hawk	x	x	x	x	x	x	x	x	x	x	x	x
Barn owl	x	x	x	x	x	x	x	x	x	x	x	x
Black vulture	x	x	x	x	x	x	x	x	x	x	x	x
Cougar												
Red fox	x	x	x	x	x	x	x	x	x	x	x	x
Snapping turtle	x	x		x	x	x	x					
Black rat snake	x	x	x	x	x	x	x	x	x	x	x	x
Northern pine snake	x	x	x	x	x	x	x	x	x	x	x	x
Total number of endpoints/OU	47	53	35	49	49	49	49	35	35	35	35	35

[a] X=presence of at least one habitat category prefered by the endpoint. Amount of suitable habitat not considered; only presence/absence of habitat.
[b] WOL = suitable habitat only at White Oak Lake.

Table B.6. Summary of habitat availability for assessment and measurment endpoints at Y-12 OUs, Freel's Bend, and the South Campus Facility[a]

	Bear Creek	BC OU1	BC OU2	CR OU1	CR OU2	CR OU3	CR OU4	LEFPC	UEFPC OU2	UEFPC OU3	Freels Bend	SCF
Mallard duck	x						x	x			x	x
Cumberland slider	x						x	x			x	x
Mink	x						x	x			x	x
River otter	x						x	x			x	x
Great blue heron	x						x	x			x	x
Belted kingfisher	x						x	x			x	x
Bald eagle												
Osprey												
Double-crested cormorant												
Black-crowned night heron	x						x	x			x	x
Northern water snake	x						x	x			x	x
Pied-billed grebe	x						x	x			x	x
Leopard frog	x						x	x			x	x
Hellbender	x							x				
Rough-winged swallows	x	x	x	x	x		x	x			x	x
Gray bat												
Indiana bat	x	x	x	x	x	x	x	x			x	x
Eastern small footed bat	x	x	x	x	x	x	x	x			x	x
Rafinesque's big-eared bat	x	x	x	x	x	x	x	x	x	x	x	x

Table B.6 (continued)

	Bear Creek	BC OU1	BC OU2	CR OU1	CR OU2	CR OU3	CR OU4	LEFPC	UEFPC OU2	UEFPC OU3	Freels Bend	SCF
American toad	x	x		x	x		x	x			x	x
American woodcock	x	x	x	x	x	x	x	x			x	x
European starling	x	x	x	x	x	x	x	x	x	x	x	x
American robin	x	x	x	x	x	x	x	x	x	x	x	x
Short-tailed shrew	x	x		x	x		x	x			x	x
Long-tailed shrew	x	x		x	x		x	x			x	
Masked shrew	x	x		x	x		x	x			x	
Smokey shrew	x	x		x	x		x	x			x	
Southeastern shrew	x	x	x	x	x	x	x	x			x	x
Six-line racerunner	x	x	x	x	x	x	x	x			x	x
Slender glass snake	x	x	x	x	x	x	x	x			x	x
Tennessee cave salamander												
Green salamander												
Raccoon	x	x	x	x	x	x	x	x	x	x	x	x
Wood duck	x						x	x			x	x
Muskrat	x						x	x			x	x
White-tailed deer	x	x	x	x	x	x	x	x			x	x
Wild turkey	x	x	x	x	x	x	x	x			x	x
Canada goose	x	x	x	x	x	x	x	x	x	x	x	x
Eastern cottontail	x	x	x	x	x	x	x	x	x	x	x	x

Table B.6 (continued)

	Bear Creek	BC OU1	BC OU2	CR OU1	CR OU2	CR OU3	CR OU4	LEFPC	UEFPC OU2	UEFPC OU3	Freels Bend	SCF
Groundhog	x	x	x	x	x	x	x	x	x	x	x	x
Grasshopper sparrow	x	x	x	x	x	x	x	x			x	x
Henslow's sparrow	x	x	x	x	x	x	x	x			x	x
Lark sparrow	x	x	x	x	x	x	x	x			x	x
Vesper sparrow	x	x	x	x	x	x	x	x			x	x
Red-tailed hawk	x	x	x	x	x	x	x	x			x	x
Golden eagle												
Northern harrier	x	x	x	x	x	x	x	x			x	x
Cooper's hawk	x	x	x	x	x	x	x	x			x	x
Red-shouldered hawk	x	x		x	x		x	x			x	
Sharp-shinned hawk	x	x		x	x		x	x			x	
Barn owl	x	x	x	x	x	x	x	x	x	x	x	x
Black vulture	x	x	x	x	x	x	x	x			x	x
Cougar												
Red fox	x	x	x	x	x	x	x	x			x	x
Snapping turtle	x						x	x			x	x
Black rat snake	x	x	x	x	x	x	x	x	x	x	x	x
Northern pine snake	x	x		x	x		x	x			x	x
Total number of endpoints/OU	49	35	27	35	35	26	48	49	9	9	48	43

[a] X=presence of at least one habitat category prefered by the endpoint. Amount of suitable habitat not considered; only presence/absence of habitat.

Table B.7. Ranking of endpoint species by the number of OUs that provide at least one favored habitat type

Endpoint Species	Total OUs W/habitat	Endpoint Species	Total OUs W/habitat
Barn owl	37	American Toad	24
Groundhog	37	Long-tailed shrew	23
European starling	37	Red-shouldered hawk	23
American robin	37	Sharp-shinned hawk	23
Rafinesque's big-eared bat	37	Masked shrew	23
Raccoon	37	Smokey shrew	23
Eastern cottontail	37	Snapping turtle	16
Black rat snake	37	Mallard duck	16
Canada goose	37	Muskrat	16
American woodcock	31	Pied-billed grebe	16
Henslow's sparrow	31	Mink	16
Southeastern shrew	31	Great blue heron	16
Wild turkey	31	Belted kingfisher	16
Slender glass snake	31	Black-crowned night heron	16
Grasshopper sparrow	31	Wood duck	16
Six-line racerunner	31	Northern Water snake	16
Eastern small footed bat	31	Leopard frog	16
Indiana bat	31	Cumberland slider	16
Lark sparrow	31	River otter	15
Red fox	31	Hellbender	7
Black vulture	31	Bald eagle	3
Cooper's hawk	31	Gray bat	3
Northern harrier	31	Double-crested cormorant	3
White-tailed deer	31	Osprey	3
Red-tailed hawk	31	Green salamander	0
Vesper sparrow	31	Golden eagle	0
Rough-winged swallows	27	Tennessee cave salamander	0
Short-tailed shrew	24	Cougar	0
Northern pine snake	24		

Table B.8. Ranking of OUs on the ORR by the number of species for which they provide habitat

OUs	Total species per OU	Ous	Total species per OU
WAG 2	53	WAG 9	35
K-901	52	WAG 10	35
Lower East Fork Poplar Creek	49	WAG 11	35
Bear Creek	49	WAG 13	35
WAG 4	49	BC OU1	35
WAG 5	49	CR OU1	35
WAG 6	49	CR OU2	35
WAG 7	49	BC OU2	27
K-33	48	K-1064	26
K-770	48	K-1410	26
CR OU4	48	K-29	26
Freel's Bend	48	CR OU3	26
WAG 1	47	K-1413	9
K-1007	44	K-1004	9
South Campus Facility	43	K-1401	9
K-1407	40	K-1420	9
K-1070-C/D	35	UEFPC OU2	9
WAG 3	35	UEFPC OU3	9
WAG 8	35		

Appendix C

TABLES AND FIGURES FOR CHAPTER 4: ASSESSMENT OF RISK TO PISCIVORES ON THE OAK RIDGE RESERVATION

Table C.1. Life history parameters for mink

Parameter	Value	Comments	Reference
Body Weight	1.0 kg (mean ♂+♀)		EPA 1993b
Food Consumption Rate	0.137 kg/d (mean ♂+♀)		Bleavins and Aulerich 1981
Water Consumption Rate	0.099 L/d	estimated using allometric equation[a] assuming 1.0 kg bw	After Calder and Braun 1983
Diet Composition	Diverse diet includes: mammals, fish, aquatic invertebrates, amphibians, and birds		Hamilton 1940, Sealander 1943, Korschgen 1958, Burgess and Bider 1980 Alexander 1977
	Proportion of aquatic prey (fish, amphibians, inverts, etc.) = 0.546±0.21	Proportion represents means of values from five studies	
	fish sizes: 0-10 cm=72% 11-20 cm=28%		
Home Range	2.63 km (♂) 1.85 km (♀)	stream - Sweden	Gerell 1970
	770 ha (♂)	prairie potholes, Manitoba	Arnold and Fritzell 1987
		range size and shape depends on habitat - linear along streams, circular in marshes	EPA 1993a.
Habitat Requirements	aquatic habitats - streams, lakes, marshes;		Burt and Grossenheider 1976
Population Density	0.03 - 0.085 /ha	river - Montana	Mitchell 1961
	0.6/km	river - Michigan	EPA 1993a
Behavior	nocturnal active year-round, does not hibernate		EPA 1993a

Table C.2. Life history parameters for river otter

Parameter	Value	Comments	Reference
Body Weight	**8.0** kg (mean ♂+♀)		EPA 1993b
Food Consumption Rate	**0.9** kg/d (mean ♂+♀)		EPA 1993b
Water Consumption Rate	**0.64** L/d		EPA 1993b
Diet Composition	Almost exclusively fish 2-50 cm in size; most ≥30 cm.		Melquist and Hornocker 1983
	50% large and 50% small fish		EPA 1993b
Home Range	10-78 km	river-Idaho	Melquist and Hornocker 1983
		range size and shape depends on habitat - linear along streams, circular in marshes	EPA 1993b
Habitat Requirements	aquatic habitats - streams, lakes, marshes;		EPA 1993b
Population Density	0.17 - 0.37 /km	river-Idaho	Melquist and Hornocker 1983
	0.0094-0.014/ha		EPA 1993b
Behavior	Generally most active morning and evening, but may be active at any time in day.		Melquist and Hornocker 1983
	active year-round, does not hibernate		EPA 1993b

Table C.3. Life history parameters for belted kingfisher

Parameter	Value	Comments	Reference
Body Weight	0.148 kg		Dunning 1984
Food Consumption Rate	50% bw		Alexander 1977
	0.075 kg/d	assuming 0.148 kg bw	
Water Consumption Rate	0.016 L/d	estimated using allometric equation[a] assuming 0.148 kg bw	
Soil Consumption Rate	as a piscivore, assumed to be negligible		
Diet Composition	Cyprinids - 76.4% other fish - 10.2% crayfish - 13.3%	Ohio - creek	Davis 1982
	lizards, small snakes, frogs, salamanders, and insects may be consumed if fish are unavailable		Landrum et al. 1993
Home Range	1.03 km (breeding) 0.39 km (non-breeding)	Ohio - creek	Davis 1982
	2.19 km (breeding)	Pennsylvania - stream summer	Brooks and Davis 1987
Habitat Requirements	uses a diverse aquatic habitats (stream, river, lake, marsh, coastline)		Brooks and Davis 1987
	require high vertical banks composed of >75% sand and <7% clay for nest construction		
	prefer relatively clear waters free of thick vegetation		Bent 1940.
Population Density	0.11 - 0.19 pairs/km shore	Pennsylvania - stream summer	Brooks and Davis 1987
Behavior	while most migrate from northern parts of range, some may stay in areas where water remains ice-free		Bent 1940.

Table C.4. Life history parameters for great blue heron

Parameter	Value	Comments	Reference
Body Weight	2.576 kg (♂) 2.204 kg (♀)		Dunning 1984
	2.39 kg (mean♂+♀)		
Food Consumption Rate	**0.42** kg/d	estimated using allometric equation[a] specific for herons and egrets	Kushlan 1978
		assuming 2.39 kg bw	
Water Consumption Rate	**0.1058** L/d	estimated using allometric equation[b] assuming 2.39 kg bw	After Calder and Braun 1983
Diet Composition	diet predominantly fish but may include crustaceans, insects, snails, amphibians, reptiles, birds, and mammals		Kushlan 1978 Callazo 1985 Hoffman 1978
	fish sizes: 0-10 cm=39.2% 11-20 cm=47.1% 21-30 cm=13.7%		Alexander 1977
Home Range (foraging distance from colony)	3.1 km	up to 24.2 km - S. Dakota - river	EPA 1993a.
	7 - 8 km	N. Carolina - coastal	Short and Cooper 1985
Habitat Requirements	use both coastal and inland water-associated habitats		Short and Cooper 1985
	Foraging: shallow shores of ponds, lakes, streams, wet meadows, wooded swamps, bays, and marshes		DeGraaf et al. 1981
	breeding: trees for rookery sites. In absence of trees will use rock ledges, cliffs, and artificial structures		Short and Cooper 1985

Table C.4 (continued)

Parameter	Value	Comments	Reference
Population Density	nest colonially, therefore population density depends on availability of nest habitat and suitable foraging habitat		EPA 1993a
	2.3 - 3.6 /km	North Dakota rivers and streams	
Behavior	may or may not defend a feeding territory depending on local population size and food availability		Kushlan 1978
	Migrates in northern U.S. and southern Canada; year round resident from WV, PA south.		National Geographic Society 1987.

Table C.5. Life history parameters for osprey

Parameter	Value	Comments	Reference
Body Weight	1.5 kg (♂+♀)		EPA 1993c
Food Consumption Rate	0.3 kg/d	fresh weight	EPA 1993c
Water Consumption Rate	0.077 L/d		EPA 1993c
Diet Composition	almost 100% fish	all parts of fish consumed except large bones	EPA 1993c
	fish sizes: 0-10 cm=3.3% 11-20 cm=42.1% 21-30 cm=46.7% 31-40 cm=6.6% >41 cm=1.3%		Van Daele and Van Daele 1982
Home Range (foraging distance from nest site)	10-15 km		VanDaele and VanDaele 1982
Habitat Requirements	Coastal areas plus large rivers and lakes Nesting habitat requires open, shallow water nearby plus abundant fish. Nests atop isolated (often dead) trees and man-made structures		EPA 1993b
Population Density	0.005-0.1 nests/ha		EPA 1993b
Behavior	year-round resident in southern part of range (i.e. Florida) Migratory in Tennessee		EPA 1993b

Table C.6. Summary statistics for fish data from the ORR

Analyte	Location	Watershed	Size	Obs	Det	Contaminant concentrations in fish (mg/kg)					
						Mean	Standard error	95% UCL	Maximum	Lognormal mean	Lognormal standard deviation
Mercury	BCK 0.6	Bear Creek	small	24	24	0.269	0.020	0.304	0.549	0.269	0.091
Mercury	BCK 3.3	Bear Creek	small	8	8	0.060	0.006	0.071	0.086	0.060	0.016
Mercury	BCK 4.5	Bear Creek	small	11	11	0.194	0.021	0.233	0.339	0.195	0.067
Mercury	BCK 9.4	Bear Creek	small	8	8	0.079	0.006	0.090	0.110	0.079	0.015
Mercury	BCK 12.4	Bear Creek	small	8	8	0.120	0.010	0.139	0.170	0.120	0.026
Mercury	EFK 2.1	East Fork	small	28	28	0.281	0.012	0.301	0.436	0.281	0.065
Mercury	EFK 6.3	East Fork	small	24	24	0.420	0.016	0.447	0.549	0.420	0.082
Mercury	EFK 13.8	East Fork	small	24	24	0.425	0.022	0.462	0.612	0.426	0.112
Mercury	EFK 18.2	East Fork	small	25	25	0.430	0.014	0.454	0.549	0.430	0.069
Mercury	EFK 24.0	East Fork	small	24	24	0.411	0.028	0.459	0.761	0.410	0.125
Mercury	EFK 23.4	East Fork	small	24	24	0.420	0.028	0.467	1.009	0.418	0.099
Mercury	EFK 24.5	East Fork	small	24	24	0.762	0.031	0.815	0.956	0.766	0.187
Mercury	EFK 6.3	East Fork	large	12	12	0.339	0.036	0.403	0.580	0.341	0.128
Mercury	EFK 13.8	East Fork	large	12	12	0.307	0.023	0.348	0.418	0.310	0.096
Mercury	EFK 18.2	East Fork	large	12	12	0.300	0.037	0.366	0.580	0.301	0.126
Mercury	EFK 24.0	East Fork	large	4	4	0.400	0.029	0.467	0.483	0.401	0.055
Mercury	K-901	K-25	small	8	8	0.035	0.004	0.042	0.050	0.035	0.012
Mercury	K-710	K-25	small	8	8	0.089	0.004	0.097	0.106	0.089	0.013
Mercury	K-1007b P1	K-25	small	8	8	0.070	0.003	0.075	0.078	0.070	0.009
Mercury	K-1007b P5	K-25	small	8	8	0.047	0.005	0.055	0.072	0.047	0.013
Mercury	CRK 15	K-25	small	29	29	0.112	0.008	0.126	0.245	0.113	0.046
Mercury	MIK 0.2	K-25	small	8	8	0.219	0.030	0.276	0.354	0.221	0.090
Mercury	PCK 1.6	K-25	small	28	27	0.179	0.014	0.202	0.383	0.179	0.075

Table C.6 (continued)

Analyte	Location	Watershed	Size	Obs	Det	Contaminant concentrations in fish (mg/kg)					
						Mean	Standard error	95% UCL	Maximum	Lognormal mean	Lognormal standard deviation
Mercury	PCK 2.3	K-25	small	11	11	0.183	0.016	0.211	0.247	0.187	0.075
Mercury	PCK 6.9	K-25	small	8	8	0.203	0.009	0.220	0.237	0.203	0.026
Mercury	PCK 7.2	K-25	small	12	12	0.278	0.025	0.323	0.361	0.288	0.142
Mercury	PCK 7.4	K-25	small	12	12	0.212	0.019	0.246	0.394	0.212	0.056
Mercury	PCK 8.2	K-25	small	16	16	0.251	0.017	0.281	0.443	0.252	0.063
Mercury	PCK 8.5	K-25	small	9	7	0.233	0.021	0.272	0.335	0.223	0.096
Mercury	PCK 8.9	K-25	small	9	9	0.290	0.030	0.346	0.408	0.294	0.111
Mercury	PCK 9.7	K-25	small	10	10	0.108	0.032	0.167	0.311	0.105	0.086
Mercury	PCK 18.2	K-25	small	8	8	0.052	0.003	0.058	0.066	0.052	0.009
Mercury	K-901	K-25	large	18	18	0.174	0.025	0.223	0.483	0.171	0.084
Mercury	CRK 15	K-25	large	20	15	0.146	0.018	0.178	0.343	0.149	0.092
Mercury	PCK 1.6	K-25	large	20	20	0.284	0.031	0.337	0.645	0.282	0.121
Mercury	PCK 2.3	K-25	large	2	2	0.269	0.019	0.392	0.288	0.269	0.028
Mercury	PCK 7.2	K-25	large	1	1	0.321	0.321				
Mercury	PCK 7.4	K-25	large	5	5	0.376	0.078	0.543	0.602	0.387	0.203
Mercury	PCK 8.5	K-25	large	2	2	0.531	0.192	1.744	0.723	0.571	0.330
Mercury	MEK 0.2	White Oak	small	24	24	0.090	0.006	0.099	0.161	0.090	0.025
Mercury	NTK 0.2	White Oak	small	8	8	0.123	0.008	0.139	0.157	0.124	0.026
Mercury	WCK 0.9	White Oak	small	16	16	0.103	0.006	0.114	0.161	0.103	0.024
Mercury	WCK 1.5	White Oak	small	16	16	0.096	0.009	0.111	0.166	0.096	0.035
Mercury	WCK 2.3	White Oak	small	8	8	0.154	0.020	0.191	0.261	0.155	0.052
Mercury	WCK 2.9	White Oak	small	8	8	0.176	0.016	0.207	0.245	0.177	0.046
Mercury	WCK 3.5	White Oak	small	16	16	0.111	0.007	0.124	0.166	0.112	0.033
Mercury	WCK 1.5	White Oak	large	16	16	0.154	0.018	0.185	0.301	0.155	0.082

Table C.6 (continued)

Analyte	Location	Watershed	Size	Obs	Det	Contaminant concentrations in fish (mg/kg)					
						Mean	Standard error	95% UCL	Maximum	Lognormal mean	Lognormal standard deviation
PCBs	BCK 0.6	Bear Creek	small	24	24	0.718	0.083	0.860	1.703	0.727	0.464
PCBs	BCK 3.3	Bear Creek	small	8	8	0.978	0.150	1.272	1.750	0.978	0.417
PCBs	BCK 4.5	Bear Creek	small	11	11	1.951	0.368	2.618	3.766	2.342	3.011
PCBs	BCK 9.4	Bear Creek	small	8	8	2.855	0.494	3.823	4.500	2.961	2.004
PCBs	BCK 12.4	Bear Creek	small	8	8	0.275	0.066	0.403	0.610	0.285	0.250
PCBs	EFK 2.1	East Fork	small	28	28	0.613	0.063	0.720	1.564	0.644	0.489
PCBs	EFK 6.3	East Fork	small	24	24	0.663	0.086	0.810	2.166	0.658	0.363
PCBs	EFK 13.8	East Fork	small	24	24	0.869	0.138	1.106	3.360	0.864	0.620
PCBs	EFK 18.2	East Fork	small	24	24	1.364	0.181	1.673	3.856	1.373	0.938
PCBs	EFK 24.0	East Fork	small	24	24	5.705	0.852	7.165	17.430	6.217	7.126
PCBs	EFK 23.4	East Fork	small	24	24	2.543	0.629	3.620	15.746	2.372	1.922
PCBs	EFK 24.5	East Fork	small	24	24	7.479	2.208	11.264	53.442	7.268	9.933
PCBs	EFK 6.3	East Fork	large	12	12	2.281	0.664	3.473	7.514	2.442	3.539
PCBs	EFK 13.8	East Fork	large	12	12	3.225	0.636	4.368	8.185	3.268	2.367
PCBs	EFK 18.2	East Fork	large	12	12	2.410	0.347	3.033	5.007	2.454	1.377
PCBs	EFK 24.0	East Fork	large	4	4	10.920	0.911	13.063	12.770	10.961	1.878
PCBs	K-901	K-25	small	8	8	6.338	1.470	9.218	15.000	6.346	4.186
PCBs	K-1007b P1	K-25	small	4	4	4.538	1.773	8.710	8.597	5.805	8.868
PCBs	K-1007b P5	K-25	small	4	4	0.123	0.018	0.165	0.164	0.124	0.040
PCBs	CRK 15	K-25	small	6	6	0.870	0.057	0.985	1.110	0.872	0.136
PCBs	MIK 0.2	K-25	small	3	3	3.099	0.262	3.864	3.464	3.112	0.477
PCBs	PCK 1.6	K-25	small	14	13	0.984	0.106	1.172	1.830	0.978	0.378
PCBs	PCK 7.4	K-25	small	2	2	2.460	0.459	5.358	2.919	2.504	0.681
PCBs	K-901	K-25	large	9	9	1.013	0.321	1.641	2.884	0.972	0.834

Table C.6 (continued)

Analyte	Location	Watershed	Size	Obs	Det	Contaminant concentrations in fish (mg/kg)					
						Mean	Standard error	95% UCL	Maximum	Lognormal mean	Lognormal standard deviation
PCBs	K-710	K-25	large	4	4	0.806	0.237	1.363	1.481	0.835	0.502
PCBs	K-1007b P1	K-25	large	14	14	29.964	3.346	35.890	58.212	30.166	13.015
PCBs	K-1007b P5	K-25	large	2	2	1.327	0.962	7.403	2.290	2.124	4.453
PCBs	CRK 15	K-25	large	38	38	2.509	0.134	2.734	4.036	2.528	0.965
PCBs	PCK 1.1	K-25	large	10	10	0.937	0.078	1.080	1.328	0.940	0.244
PCBs	PCK 1.6	K-25	large	40	39	3.242	0.143	3.482	5.281	3.245	1.019
PCBs	PCK 2.3	K-25	large	10	10	1.073	0.112	1.278	1.840	1.075	0.332
PCBs	PCK 6.9	K-25	large	8	8	1.988	0.178	2.326	2.715	1.996	0.513
PCBs	PCK 7.2	K-25	large	8	8	1.554	0.184	1.901	2.575	1.566	0.544
PCBs	PCK 7.4	K-25	large	8	8	2.789	0.254	3.271	3.808	2.807	0.793
PCBs	PCK 8.5	K-25	large	12	11	2.916	0.184	3.247	3.512	2.931	0.810
PCBs	PCK 8.9	K-25	large	8	8	0.842	0.097	1.025	1.128	0.859	0.361
PCBs	PCK 9.7	K-25	large	4	4	0.776	0.130	1.081	1.102	0.789	0.282
PCBs	MEK 0.2	White Oak	small	20	15	0.247	0.062	0.355	1.330	0.257	0.384
PCBs	NTK 0.2	White Oak	small	8	8	0.290	0.108	0.495	0.992	0.300	0.344
PCBs	WCK 0.9	White Oak	small	13	13	0.587	0.110	0.783	1.724	0.609	0.470
PCBs	WCK 1.5	White Oak	small	24	24	2.097	0.284	2.584	6.587	2.100	1.371
PCBs	WCK 2.3	White Oak	small	8	8	1.592	0.304	2.169	3.502	1.603	0.805
PCBs	WCK 2.9	White Oak	small	16	16	1.107	0.195	1.448	2.915	1.141	0.978
PCBs	WCK 3.5	White Oak	small	16	16	1.300	0.160	1.580	2.303	1.349	0.889
PCBs	WCK 0.9	White Oak	large	10	10	6.483	1.236	8.748	13.008	7.501	8.244
PCBs	WCK 1.5	White Oak	large	16	16	13.149	1.814	16.329	28.445	13.520	9.065
PCBs	WCK 0.3	White Oak	large	4	4	5.829	0.421	6.819	6.702	5.847	0.887

Table C.7. Estimated exposure of mink on the ORR to mercury and PCBs

Analyte	Drainage	Sampling station	Dietary exposure (mg/kg-d)	NOAEL HQ	LOAEL HQ
Mercury	East Fork	EFK 2.1	0.0225	1.50	0.90
Mercury	East Fork	EFK 6.3	0.0334	2.23	1.34
Mercury	East Fork	EFK 13.8	0.0346	2.31	1.38
Mercury	East Fork	EFK 18.2	0.0339	2.26	1.36
Mercury	East Fork	EFK 23.4	0.0349	2.33	1.40
Mercury	East Fork	EFK 24.0	0.0343	2.29	1.37
Mercury	East Fork	EFK 24.5	0.0609	4.06	2.44
Mercury	Bear Creek	BCK 0.6	0.0227	1.51	0.91
Mercury	Bear Creek	BCK 3.3	0.0053	0.35	0.21
Mercury	Bear Creek	BCK 4.5	0.0174	1.16	0.70
Mercury	Bear Creek	BCK 9.4	0.0067	0.45	0.27
Mercury	Bear Creek	BCK 12.4	0.0104	0.69	0.42
Mercury	K-25	CRK 15	0.0094	0.63	0.38
Mercury	K-25	K-901	0.0032	0.21	0.13
Mercury	K-25	K-710	0.0073	0.48	0.29
Mercury	K-25	PCK 1.6	0.0151	1.01	0.61
Mercury	K-25	K-1007b P1	0.0056	0.37	0.22
Mercury	K-25	K-1007b P5	0.0041	0.28	0.17
Mercury	K-25	PCK 2.3	0.0158	1.05	0.63
Mercury	K-25	PCK 6.9	0.0165	1.10	0.66
Mercury	K-25	PCK 7.2	0.0242	1.61	0.97
Mercury	K-25	PCK 7.4	0.0184	1.22	0.73
Mercury	K-25	MIK 0.2	0.0206	1.37	0.82
Mercury	K-25	PCK 8.2	0.0210	1.40	0.84
Mercury	K-25	PCK 8.5	0.0203	1.36	0.81
Mercury	K-25	PCK 8.9	0.0259	1.72	1.04
Mercury	K-25	PCK 9.7	0.0125	0.83	0.50
Mercury	K-25	PCK 18.2	0.0043	0.29	0.17
Mercury	White Oak	WCK 0.9	0.0085	0.57	0.34
Mercury	White Oak	WCK 1.5	0.0083	0.55	0.33
Mercury	White Oak	WCK 2.3	0.0143	0.95	0.57
Mercury	White Oak	MEK 0.2	0.0074	0.49	0.30
Mercury	White Oak	WCK 2.9	0.0155	1.03	0.62
Mercury	White Oak	WCK 3.5	0.0093	0.62	0.37
Mercury	White Oak	NTK 0.2	0.0104	0.69	0.42
PCBs	East Fork	EFK 2.1	0.0538	0.38	0.08
PCBs	East Fork	EFK 6.3	0.0606	0.43	0.09
PCBs	East Fork	EFK 13.8	0.0827	0.59	0.12
PCBs	East Fork	EFK 18.2	0.1251	0.89	0.18
PCBs	East Fork	EFK 23.4	0.2708	1.93	0.39

Table C.7 (continued)

Analyte	Drainage	Sampling station	Dietary exposure (mg/kg-d)	NOAEL HQ	LOAEL HQ
PCBs	East Fork	EFK 24.0	0.5360	3.83	0.78
PCBs	East Fork	EFK 24.5	0.8426	6.02	1.22
PCBs	Bear Creek	BCK 0.6	0.0644	0.46	0.09
PCBs	Bear Creek	BCK 3.3	0.0951	0.68	0.14
PCBs	Bear Creek	BCK 4.5	0.1959	1.40	0.28
PCBs	Bear Creek	BCK 9.4	0.2860	2.04	0.41
PCBs	Bear Creek	BCK 12.4	0.0301	0.22	0.04
PCBs	K-25	CRK 15	0.0736	0.53	0.11
PCBs	K-25	K-901	0.6895	4.93	1.00
PCBs	K-25	K-710	0.1020	0.73	0.15
PCBs	K-25	PCK 1.1	0.0808	0.58	0.12
PCBs	K-25	PCK 1.6	0.0876	0.63	0.13
PCBs	K-25	K-1007b P1	0.6516	4.65	0.94
PCBs	K-25	K-1007b P5	0.0123	0.09	0.02
PCBs	K-25	PCK 2.3	0.0956	0.68	0.14
PCBs	K-25	PCK 6.9	0.1740	1.24	0.25
PCBs	K-25	PCK 7.2	0.1422	1.02	0.21
PCBs	K-25	PCK 7.4	0.4008	2.86	0.58
PCBs	K-25	MIK 0.2	0.2891	2.06	0.42
PCBs	K-25	PCK 8.5	0.2429	1.73	0.35
PCBs	K-25	PCK 8.9	0.0767	0.55	0.11
PCBs	K-25	PCK 9.7	0.0809	0.58	0.12
PCBs	White Oak	WCK 0.3	0.5101	3.64	0.74
PCBs	White Oak	WCK 0.9	0.0586	0.42	0.08
PCBs	White Oak	WCK 1.5	0.1933	1.38	0.28
PCBs	White Oak	WCK 2.3	0.1622	1.16	0.24
PCBs	White Oak	MEK 0.2	0.0265	0.19	0.04
PCBs	White Oak	WCK 2.9	0.1083	0.77	0.16
PCBs	White Oak	WCK 3.5	0.1182	0.84	0.17
PCBs	White Oak	NTK 0.2	0.0370	0.26	0.05

Table C.8. Estimated exposure of river otter on the ORR to mercury and PCBs

Analyte	Drainage	Sampling station	Dietary exposure (mg/kg-d)	NOAEL HQ	LOAEL HQ
Mercury	EFK 2.1	East Fork	0.0339	3.77	2.26
Mercury	EFK 6.3	East Fork	0.0478	5.31	3.19
Mercury	EFK 13.8	East Fork	0.0456	5.07	3.04
Mercury	EFK 18.2	East Fork	0.0461	5.12	3.07
Mercury	EFK 23.4	East Fork	0.0526	5.84	3.50
Mercury	EFK 24.0	East Fork	0.0521	5.79	3.47
Mercury	EFK 24.5	East Fork	0.0917	10.18	6.11
Mercury	BCK 0.6	Bear Creek	0.0342	3.80	2.28
Mercury	BCK 3.3	Bear Creek	0.0080	0.89	0.53
Mercury	BCK 4.5	Bear Creek	0.0262	2.91	1.74
Mercury	BCK 9.4	Bear Creek	0.0101	1.13	0.68
Mercury	BCK 12.4	Bear Creek	0.0156	1.74	1.04
Mercury	CRK 15	K-25	0.0171	1.90	1.14
Mercury	K-901	K-25	0.0149	1.66	0.99
Mercury	K-710	K-25	0.0109	1.22	0.73
Mercury	PCK 1.6	K-25	0.0303	3.37	2.02
Mercury	K-1007b P1	K-25	0.0084	0.94	0.56
Mercury	K-1007b P5	K-25	0.0062	0.69	0.42
Mercury	PCK 2.3	K-25	0.0339	3.77	2.26
Mercury	PCK 6.9	K-25	0.0248	2.76	1.65
Mercury	PCK 7.2	K-25	0.0363	4.03	2.42
Mercury	PCK 7.4	K-25	0.0443	4.93	2.96
Mercury	MIK 0.2	K-25	0.0310	3.45	2.07
Mercury	PCK 8.2	K-25	0.0316	3.51	2.11
Mercury	PCK 8.5	K-25	0.1134	12.60	7.56
Mercury	PCK 8.9	K-25	0.0389	4.32	2.59
Mercury	PCK 9.7	K-25	0.0188	2.09	1.25
Mercury	PCK 18.2	K-25	0.0065	0.73	0.44
Mercury	WCK 0.9	White Oak	0.0128	1.43	0.86
Mercury	WCK 1.5	White Oak	0.0166	1.85	1.11
Mercury	WCK 2.3	White Oak	0.0215	2.39	1.43
Mercury	MEK 0.2	White Oak	0.0111	1.24	0.74
Mercury	WCK 2.9	White Oak	0.0233	2.59	1.55
Mercury	WCK 3.5	White Oak	0.0140	1.55	0.93
Mercury	NTK 0.2	White Oak	0.0157	1.74	1.04
PCBs	BCK 0.6	Bear Creek	0.0968	1.17	0.24
PCBs	BCK 3.3	Bear Creek	0.1431	1.72	0.35
PCBs	BCK 4.5	Bear Creek	0.2946	3.55	0.72
PCBs	BCK 9.4	Bear Creek	0.4301	5.18	1.05
PCBs	BCK 12.4	Bear Creek	0.0453	0.55	0.11

Table C.8 (continued)

Analyte	Drainage	Sampling station	Dietary exposure (mg/kg-d)	NOAEL HQ	LOAEL HQ
PCBs	EFK 2.1	East Fork	0.0810	0.98	0.20
PCBs	EFK 6.3	East Fork	0.2409	2.90	0.59
PCBs	EFK 13.8	East Fork	0.3079	3.71	0.75
PCBs	EFK 18.2	East Fork	0.2647	3.19	0.65
PCBs	EFK 23.4	East Fork	0.4073	4.91	0.99
PCBs	EFK 24.0	East Fork	1.1379	13.71	2.78
PCBs	EFK 24.5	East Fork	1.2672	15.27	3.09
PCBs	CRK 15	K-25	0.2092	2.52	0.51
PCBs	K-901	K-25	0.6108	7.36	1.49
PCBs	K-710	K-25	0.1533	1.85	0.37
PCBs	PCK 1.1	K-25	0.1215	1.46	0.30
PCBs	PCK 1.6	K-25	0.2618	3.15	0.64
PCBs	K-1007b P1	K-25	2.5088	30.23	6.12
PCBs	K-1007b P5	K-25	0.4257	5.13	1.04
PCBs	PCK 2.3	K-25	0.1438	1.73	0.35
PCBs	PCK 6.9	K-25	0.2616	3.15	0.64
PCBs	PCK 7.2	K-25	0.2139	2.58	0.52
PCBs	PCK 7.4	K-25	0.4853	5.85	1.18
PCBs	MIK 0.2	K-25	0.4347	5.24	1.06
PCBs	PCK 8.5	K-25	0.3653	4.40	0.89
PCBs	PCK 8.9	K-25	0.1154	1.39	0.28
PCBs	PCK 9.7	K-25	0.1216	1.47	0.30
PCBs	WCK 0.3	White Oak	0.7671	9.24	1.87
PCBs	WCK 0.9	White Oak	0.5362	6.46	1.31
PCBs	WCK 1.5	White Oak	1.0638	12.82	2.59
PCBs	WCK 2.3	White Oak	0.2440	2.94	0.60
PCBs	MEK 0.2	White Oak	0.0399	0.48	0.10
PCBs	WCK 2.9	White Oak	0.1629	1.96	0.40
PCBs	WCK 3.5	White Oak	0.1777	2.14	0.43
PCBs	NTK 0.2	White Oak	0.0557	0.67	0.14

Table C.9. Estimated exposure of belted kingfisher on the ORR to mercury and PCBs

Analyte	Drainage	Sampling station	Dietary exposure (mg/kg-d)	NOAEL HQ	LOAEL HQ
Mercury	EFK 2.1	East Fork	0.1527	25.46	2.39
Mercury	EFK 6.3	East Fork	0.2264	37.73	3.54
Mercury	EFK 13.8	East Fork	0.2343	39.05	3.66
Mercury	EFK 18.2	East Fork	0.2299	38.32	3.59
Mercury	EFK 23.4	East Fork	0.2368	39.46	3.70
Mercury	EFK 24.0	East Fork	0.2327	38.78	3.64
Mercury	EFK 24.5	East Fork	0.4129	68.81	6.45
Mercury	BCK 0.6	Bear Creek	0.1539	25.64	2.40
Mercury	BCK 3.3	Bear Creek	0.0360	6.00	0.56
Mercury	BCK 4.5	Bear Creek	0.1178	19.64	1.84
Mercury	BCK 9.4	Bear Creek	0.0456	7.60	0.71
Mercury	BCK 12.4	Bear Creek	0.0704	11.74	1.10
Mercury	CRK 15	K-25	0.0638	10.63	1.00
Mercury	K-901	K-25	0.0215	3.58	0.34
Mercury	K-710	K-25	0.0493	8.21	0.77
Mercury	PCK 1.6	K-25	0.1025	17.08	1.60
Mercury	K-1007b P1	K-25	0.0381	6.34	0.59
Mercury	K-1007b P5	K-25	0.0281	4.68	0.44
Mercury	PCK 2.3	K-25	0.1070	17.83	1.67
Mercury	PCK 6.9	K-25	0.1117	18.61	1.75
Mercury	PCK 7.2	K-25	0.1639	27.31	2.56
Mercury	PCK 7.4	K-25	0.1244	20.73	1.94
Mercury	MIK 0.2	K-25	0.1397	23.28	2.18
Mercury	PCK 8.2	K-25	0.1423	23.72	2.22
Mercury	PCK 8.5	K-25	0.1377	22.96	2.15
Mercury	PCK 8.9	K-25	0.1753	29.21	2.74
Mercury	PCK 9.7	K-25	0.0846	14.10	1.32
Mercury	PCK 18.2	K-25	0.0294	4.90	0.46
Mercury	WCK 0.9	White Oak	0.0579	9.65	0.90
Mercury	WCK 1.5	White Oak	0.0560	9.34	0.88
Mercury	WCK 2.3	White Oak	0.0969	16.16	1.51
Mercury	MEK 0.2	White Oak	0.0502	8.37	0.78
Mercury	WCK 2.9	White Oak	0.1048	17.47	1.64
Mercury	WCK 3.5	White Oak	0.0630	10.50	0.98
Mercury	NTK 0.2	White Oak	0.0706	11.77	1.10
PCBs	BCK 0.6	Bear Creek	0.4360	2.42	0.24
PCBs	BCK 3.3	Bear Creek	0.6446	3.58	0.36
PCBs	BCK 4.5	Bear Creek	1.3269	7.37	0.74
PCBs	BCK 9.4	Bear Creek	1.9373	10.76	1.08
PCBs	BCK 12.4	Bear Creek	0.2042	1.13	0.11

Table C.9 (continued)

Analyte	Drainage	Sampling station	Dietary exposure (mg/kg-d)	NOAEL HQ	LOAEL HQ
PCBs	EFK 2.1	East Fork	0.3647	2.03	0.20
PCBs	EFK 6.3	East Fork	0.4105	2.28	0.23
PCBs	EFK 13.8	East Fork	0.5602	3.11	0.31
PCBs	EFK 18.2	East Fork	0.8478	4.71	0.47
PCBs	EFK 23.4	East Fork	1.8345	10.19	1.02
PCBs	EFK 24.0	East Fork	3.6311	20.17	2.02
PCBs	EFK 24.5	East Fork	5.7083	31.71	3.17
PCBs	CRK 15	K-25	0.4989	2.77	0.28
PCBs	K-901	K-25	4.6713	25.95	2.60
PCBs	K-710	K-25	0.6907	3.84	0.38
PCBs	PCK 1.1	K-25	0.5473	3.04	0.30
PCBs	PCK 1.6	K-25	0.5937	3.30	0.33
PCBs	K-1007b P1	K-25	4.4141	24.52	2.45
PCBs	K-1007b P5	K-25	0.0836	0.46	0.05
PCBs	PCK 2.3	K-25	0.6476	3.60	0.36
PCBs	PCK 6.9	K-25	1.1786	6.55	0.65
PCBs	PCK 7.2	K-25	0.9635	5.35	0.54
PCBs	PCK 7.4	K-25	2.7151	15.08	1.51
PCBs	MIK 0.2	K-25	1.9583	10.88	1.09
PCBs	PCK 8.5	K-25	1.6453	9.14	0.91
PCBs	PCK 8.9	K-25	0.5196	2.89	0.29
PCBs	PCK 9.7	K-25	0.5480	3.04	0.30
PCBs	WCK 0.3	White Oak	3.4556	19.20	1.92
PCBs	WCK 0.9	White Oak	0.3969	2.21	0.22
PCBs	WCK 1.5	White Oak	1.3093	7.27	0.73
PCBs	WCK 2.3	White Oak	1.0990	6.11	0.61
PCBs	MEK 0.2	White Oak	0.1797	1.00	0.10
PCBs	WCK 2.9	White Oak	0.7339	4.08	0.41
PCBs	WCK 3.5	White Oak	0.8005	4.45	0.44
PCBs	NTK 0.2	White Oak	0.2508	1.39	0.14

Table C.10. Estimated exposure of great blue heron on the ORR to mercury and PCBs

Analyte	Drainage	Sampling station	Dietary exposure (mg/kg-d)	NOAEL HQ	LOAEL HQ
Mercury	EFK 2.1	East Fork	0.0530	8.83	0.83
Mercury	EFK 6.3	East Fork	0.0785	13.08	1.23
Mercury	EFK 13.8	East Fork	0.0812	13.54	1.27
Mercury	EFK 18.2	East Fork	0.0797	13.29	1.25
Mercury	EFK 23.4	East Fork	0.0821	13.68	1.28
Mercury	EFK 24.0	East Fork	0.0807	13.45	1.26
Mercury	EFK 24.5	East Fork	0.1432	23.86	2.24
Mercury	BCK 0.6	Bear Creek	0.0534	8.89	0.83
Mercury	BCK 3.3	Bear Creek	0.0125	2.08	0.20
Mercury	BCK 4.5	Bear Creek	0.0409	6.81	0.64
Mercury	BCK 9.4	Bear Creek	0.0158	2.64	0.25
Mercury	BCK 12.4	Bear Creek	0.0244	4.07	0.38
Mercury	CRK 15	K-25	0.0221	3.68	0.35
Mercury	K-901	K-25	0.0075	1.24	0.12
Mercury	K-710	K-25	0.0171	2.85	0.27
Mercury	PCK 1.6	K-25	0.0355	5.92	0.56
Mercury	K-1007b P1	K-25	0.0132	2.20	0.21
Mercury	K-1007b P5	K-25	0.0097	1.62	0.15
Mercury	PCK 2.3	K-25	0.0371	6.18	0.58
Mercury	PCK 6.9	K-25	0.0387	6.46	0.61
Mercury	PCK 7.2	K-25	0.0568	9.47	0.89
Mercury	PCK 7.4	K-25	0.0431	7.19	0.67
Mercury	MIK 0.2	K-25	0.0484	8.07	0.76
Mercury	PCK 8.2	K-25	0.0493	8.22	0.77
Mercury	PCK 8.5	K-25	0.0478	7.96	0.75
Mercury	PCK 8.9	K-25	0.0608	10.13	0.95
Mercury	PCK 9.7	K-25	0.0293	4.89	0.46
Mercury	PCK 18.2	K-25	0.0102	1.70	0.16
Mercury	WCK 0.9	White Oak	0.0201	3.34	0.31
Mercury	WCK 1.5	White Oak	0.0194	3.24	0.30
Mercury	WCK 2.3	White Oak	0.0336	5.60	0.53
Mercury	MEK 0.2	White Oak	0.0174	2.90	0.27
Mercury	WCK 2.9	White Oak	0.0364	6.06	0.57
Mercury	WCK 3.5	White Oak	0.0218	3.64	0.34
Mercury	NTK 0.2	White Oak	0.0245	4.08	0.38
PCBs	EFK 2.1	East Fork	0.1265	0.70	0.07
PCBs	EFK 6.3	East Fork	0.1424	0.79	0.08
PCBs	EFK 13.8	East Fork	0.1943	1.08	0.11
PCBs	EFK 18.2	East Fork	0.2940	1.63	0.16
PCBs	EFK 23.4	East Fork	0.6362	3.53	0.35

Table C.10 (continued)

Analyte	Drainage	Sampling station	Dietary exposure (mg/kg-d)	NOAEL HQ	LOAEL HQ
PCBs	EFK 24.0	East Fork	1.2592	7.00	0.70
PCBs	EFK 24.5	East Fork	1.9795	11.00	1.10
PCBs	BCK 0.6	Bear Creek	0.1512	0.84	0.08
PCBs	BCK 3.3	Bear Creek	0.2235	1.24	0.12
PCBs	BCK 4.5	Bear Creek	0.4601	2.56	0.26
PCBs	BCK 9.4	Bear Creek	0.6718	3.73	0.37
PCBs	BCK 12.4	Bear Creek	0.0708	0.39	0.04
PCBs	CRK 15	K-25	0.1730	0.96	0.10
PCBs	K-901	K-25	1.6199	9.00	0.90
PCBs	K-710	K-25	0.2395	1.33	0.13
PCBs	PCK 1.1	K-25	0.1898	1.05	0.11
PCBs	PCK 1.6	K-25	0.2059	1.14	0.11
PCBs	K-1007b P1	K-25	1.5307	8.50	0.85
PCBs	K-1007b P5	K-25	0.0290	0.16	0.02
PCBs	PCK 2.3	K-25	0.2246	1.25	0.12
PCBs	PCK 6.9	K-25	0.4087	2.27	0.23
PCBs	PCK 7.2	K-25	0.3341	1.86	0.19
PCBs	PCK 7.4	K-25	0.9415	5.23	0.52
PCBs	MIK 0.2	K-25	0.6791	3.77	0.38
PCBs	PCK 8.5	K-25	0.5706	3.17	0.32
PCBs	PCK 8.9	K-25	0.1802	1.00	0.10
PCBs	PCK 9.7	K-25	0.1900	1.06	0.11
PCBs	WCK 0.3	White Oak	1.1983	6.66	0.67
PCBs	WCK 0.9	White Oak	0.1377	0.76	0.08
PCBs	WCK 1.5	White Oak	0.4540	2.52	0.25
PCBs	WCK 2.3	White Oak	0.3811	2.12	0.21
PCBs	MEK 0.2	White Oak	0.0623	0.35	0.03
PCBs	WCK 2.9	White Oak	0.2545	1.41	0.14
PCBs	WCK 3.5	White Oak	0.2776	1.54	0.15
PCBs	NTK 0.2	White Oak	0.0870	0.48	0.05

Table C.11. Estimated exposure of osprey on the ORR to mercury and PCBs

Analyte	Drainage	Sampling station	Dietary exposure (mg/kg-d)	NOAEL HQ	LOAEL HQ
Mercury	CRK 15	K-25	0.0260	4.33	0.41
Mercury	K-901	K-25	0.0113	1.89	0.18
Mercury	K-710	K-25	0.0194	3.24	0.30
Mercury	PCK 1.6	K-25	0.0426	7.10	0.67
Mercury	K-1007b P1	K-25	0.0150	2.50	0.23
Mercury	K-1007b P5	K-25	0.0111	1.85	0.17
Mercury	PCK 2.3	K-25	0.0451	7.51	0.70
Mercury	PCK 6.9	K-25	0.0441	7.35	0.69
Mercury	PCK 7.2	K-25	0.0646	10.77	1.01
Mercury	PCK 7.4	K-25	0.0538	8.97	0.84
Mercury	MIK 0.2	K-25	0.0551	9.19	0.86
Mercury	PCK 8.2	K-25	0.0562	9.36	0.88
Mercury	PCK 8.5	K-25	0.0776	12.94	1.21
Mercury	PCK 8.9	K-25	0.0692	11.53	1.08
Mercury	PCK 9.7	K-25	0.0334	5.56	0.52
Mercury	PCK 18.2	K-25	0.0116	1.93	0.18
Mercury	WCK 0.9	White Oak	0.0228	3.81	0.36
Mercury	WCK 1.5	White Oak	0.0233	3.88	0.36
PCBs	CRK 15	K-25	0.2245	1.25	0.12
PCBs	K-901	K-25	1.7239	9.58	0.96
PCBs	K-710	K-25	0.2726	1.51	0.15
PCBs	PCK 1.1	K-25	0.2160	1.20	0.12
PCBs	PCK 1.6	K-25	0.2708	1.50	0.15
PCBs	K-1007b P1	K-25	2.1715	12.06	1.21
PCBs	K-1007b P5	K-25	0.1474	0.82	0.08
PCBs	PCK 2.3	K-25	0.2556	1.42	0.14
PCBs	PCK 6.9	K-25	0.4651	2.58	0.26
PCBs	PCK 7.2	K-25	0.3803	2.11	0.21
PCBs	PCK 7.4	K-25	1.0386	5.77	0.58
PCBs	MIK 0.2	K-25	0.7729	4.29	0.43
PCBs	PCK 8.5	K-25	0.6493	3.61	0.36
PCBs	PCK 8.9	K-25	0.2051	1.14	0.11
PCBs	PCK 9.7	K-25	0.2163	1.20	0.12
PCBs	WCK 0.3	White Oak	1.3638	7.58	0.76
PCBs	WCK 0.9	White Oak	0.2825	1.57	0.16
PCBs	WCK 1.5	White Oak	0.7339	4.08	0.41

Table C.12. Biomass of fish observed at fish sampling locations in Bear Creek in 1993

Sample location		Fish biomass (g/m^2)			
Fish community	Bioaccumulation	Spring	Fall	Mean annual biomass	Proportion of total biomass at sampled locations
BCK 0.7	BCK 0.6	5.84	4.73	5.29	0.18
BCK 3.25	BCK 3.3	2.57	3.29	2.93	0.1
BCK 3.25	BCK 4.5	2.57	3.29	2.93	0.1
BCK 9.4	BCK 9.4	5.37	12.59	8.98	0.30
BCK 12.36	BCK 12.4	14.43	4.43	9.43	0.32

Source: Hinzman et al. 1995.

Table C.13. Density of fish observed at fish sampling locations in East Fork Poplar Creek

Sample location		Fish Density (no./m^2)		
Fish community	Bioaccumulation	Year	Mean annual density	Proportion of total density at sampled locations
EFK 2.3 [a]	EFK 2.1	1991	16.4	0.25
EFK 7.3 [a]	EFK 6.3	1991	4.4	0.067
EFK 10.8 [a]	EFK 13.8	1991	16.6	0.253
EFK 17.6[b]	EFK 18.2	1991	2.8	0.043
EFK 23.4[b]	EFK 23.4	1993-1995	11.1	0.169
EFK 23.4+24.4[b]	EFK 24.0	1993-1995	8.5	0.129
EFK 24.4[b]	EFK 24.5	1993-1995	5.9	0.09

[a] Source:SAIC. 1994.
[b] Source: unpublished UEFPC BMAP data (to be in UEFPC RI workplan)

Table C.14. Total biomass of fish observed at fish sampling locations in White Oak Creek Watershed

Sample location		Fish biomass (g/m^2)				Proportion of total biomass at sampled locations	
Fish community	Bioaccumulation	Spring	Fall	Year	Mean annual biomass	data from all 8 locations	data from only 7 locations
WOL [a]	WCK 0.3	-	-	1987	53.66	0.248	
WOL [a]	WCK 0.9	-	-	1987	53.66	0.248	0.33
WOL [a]	WCK 1.5	-	-	1987	53.66	0.248	0.33
WCK 2.3 [b]	WCK 2.3	10.49	17.06	1993	13.78	0.064	0.085
MEK 0.6 [b]	MEK 0.2	10.52	9.6	1993	10.06	0.046	0.062
WCK 2.9 [b]	WCK 2.9	10.80	13.34	1993	12.07	0.056	0.075
WCK 3.4 [b]	WCK 3.5	17.16	14.30	1993	15.73	0.073	0.097
NTK 0.3 [b]	NTK 0.2	3.27	4.50	1993	3.89	0.018	0.024

[a] Source:Loar et al. 1992.
[b] Source:Ashwood et al. 1994.

Table C.15. Results of Monte Carlo simulation of exposure for piscivores on the ORR

Location	Analyte	Species	No. of sampling locations	Mean	Standard deviation	80th percentile	%> NOAEL	%> LOAEL
Bear Creek	Mercury	Mink	5	0.0102	0.0025	0.0121	5%	<5%
East Fork Poplar Creek	Mercury	Mink	7	0.0310	0.0060	0.0361	>95%	80%
K-25	Mercury	Mink	17	0.0119	0.0019	0.0135	5%	<5%
White Oak Creek	Mercury	Mink	7	0.0083	0.0019	0.0098	<5%	<5%
Bear Creek	Mercury	Otter	5	0.0153	0.0022	0.0170	>95%	50%
East Fork Poplar Creek	Mercury	Otter	7	0.0447	0.0034	0.0477	>95%	>95%
K-25	Mercury	Otter	17	0.0213	0.0020	0.0228	>95%	>95%
White Oak Creek	Mercury	Otter	7	0.0136	0.0018	0.0150	>95%	25%
Bear Creek	Mercury	Kingfisher	5	0.0691	0.0101	0.0769	>95%	65-70%
East Fork Poplar Creek	Mercury	Kingfisher	7	0.2118	0.0230	0.2308	>95%	>95%
K-25	Mercury	Kingfisher	17	0.0816	0.0091	0.0889	>95%	>95%
White Oak Creek	Mercury	Kingfisher	7	0.0564	0.0077	0.0625	>95%	15%
Bear Creek	Mercury	Heron	5	0.0238	0.0034	0.0263	>95%	<5%
East Fork Poplar Creek	Mercury	Heron	7	0.0792	0.0074	0.0851	>95%	>95%
K-25	Mercury	Heron	17	0.0282	0.0031	0.0306	>95%	<5%
White Oak Creek	Mercury	Heron	7	0.0198	0.0028	0.0220	>95%	<5%
K-25	Mercury	Osprey	17	0.0330	0.0033	0.0355	>95%	<5%
White Oak Creek	Mercury	Osprey	7	0.0202	0.0037	0.0229	>95%	<5%
Bear Creek	PCBs	Mink	5	0.1102	0.0610	0.1481	20-25%	<5%
East Fork Poplar Creek	PCBs	Mink	7	0.1735	0.1021	0.2301	50-55%	<5%
K-25	PCBs	Mink	17	0.1476	0.0406	0.1752	50%	<5%
White Oak Creek	PCBs	Mink	8	0.1785	0.0563	0.2194	75%	<5%

Table C.15 (continued)

Location	Analyte	Species	No. of sampling locations	Mean	Standard deviation	80th percentile	%> NOAEL	%> LOAEL
Bear Creek	PCBs	Otter	5	0.1627	0.0752	0.2067	90-95%	<5%
East Fork Poplar Creek	PCBs	Otter	7	0.3483	0.1038	0.4057	>95%	15-20%
K-25	PCBs	Otter	17	0.3222	0.0659	0.3638	>95%	5-10%
White Oak Creek	PCBs	Otter	8	0.5242	0.1784	0.6249	>95%	70-75%
Bear Creek	PCBs	Kingfisher	5	0.7212	0.3406	0.9271	>95%	<5%
East Fork Poplar Creek	PCBs	Kingfisher	7	1.1850	0.6537	1.5290	>95%	10-15%
K-25	PCBs	Kingfisher	17	1.0332	0.3337	1.1631	>95%	<5%
White Oak Creek	PCBs	Kingfisher	8	1.2136	0.2056	1.3590	>95%	<5%
Bear Creek	PCBs	Heron	5	0.2532	0.1169	0.3225	70-75%	<5%
East Fork Poplar Creek	PCBs	Heron	7	0.5017	0.3609	0.6358	>95%	<5%
K-25	PCBs	Heron	17	0.3573	0.1075	0.4051	>95%	<5%
White Oak Creek	PCBs	Heron	8	0.4202	0.0753	0.4721	>95%	<5%
K-25	PCBs	Osprey	17	0.4318	0.1073	0.4859	>95%	<5%
White Oak Creek	PCBs	Osprey	8	0.6605	0.1144	0.7489	>95%	<5%

Table C.16. Estimated NOAELs and LOAELs for mink and river otter

Contaminant	Experimental information						Estimated NOAEL (mg/kg/d)		Estimated LOAEL (mg/kg/d)	
	Form	Test species	NOAEL (mg/kg/d) and duration	LOAEL (mg/kg/d) and duration	Endpoint	Citation	mink	otter	mink	otter
Mercury	methyl	mink	0.015[2] 93 d	0.025[2] 93 d	mortality	Wobeser et al. 1976	0.01 5	0.009	0.025	0.015
PCB's	Aroclor 1254	mink	0.14 4.5 mo.	0.69 4.5 mo.	reproduction	Aulerich and Ringer 1987	0.14	0.083	0.69	0.41

[2] Estimated value: subchronic-chronic factor of 10 applied.

Table C.17. Estimated NOAELs and LOAELs for belted kingfisher, great blue heron, and osprey

Contaminant	Experimental information						Estimated Values (mg/kg/d)	
	Form	Test species	NOAEL (mg/kg/d) and duration	LOAEL (mg/kg/d) and duration	Endpoint	Citation	NOAEL	LOAEL
Mercury	methyl	mallard duck	0.006[2] 3 gen.	0.064 3 gen.	reproduction	Heinz 1979	0.006	0.064
PCB's	Aroclor 1254	Ring-necked Pheasant	0.18[2] 17 wk	1.8 17 wk	reproduction	Dahlgren et al. 1972	0.18	1.8

[2] Estimated NOAEL: LOAEL-NOAEL factor of 10 applied.

Table C.18 Contaminant concentrations (mg/kg) found in Kingfisher egg shells and feathers found on the ORR

Matrix	Burrow[a]	As	Cd	Se	Pb	Hg	^{60}Co (pCi/g)	^{137}Cs (pCi/g)
egg shell	CRD	0.135	< 0.0333[b]	1.58	2.0	< 0.020	< 7.45	< 9.09
egg shell	WOC	0.0536	0.0583	1.41	5.31	0.182	< 1.89	58.1 _ 1.7
feathers	CRU	0.074	0.0132	5.72	0.657	1.03	< 0.21	< 0.18
feathers	CRU	0.0449	< 0.0102	6.54	1.42	1.01	< 0.18	< 0.19
feathers	CRU	0.052	< 0.010	5.72	1.67	1.04	< 0.17	< 0.18
feathers	CRU	0.0755	0.0755	6.83	1.91	0.726	< 0.25	< 0.16

[a]CRD = Clinch River downstream of WOL Embayment; WOC = White Oak Creek downstream of WCK 3.5; CRU = Clinch River upstream of Oak Ridge Reservation.

[b]Less than values are below minimum detection limit.

Table C.19 Contaminant concentrations in tissues of the three kingfishers found on the ORR

Bird No.	Watershed and Location	Organ	^{137}Cs (pCi/g)	Cd (mg/kg)[a]	Pb (mg/kg)[a]	Se (mg/kg)	Hg (mg/kg)
1	East Fork Poplar Creek, Lake Reality	whole body	<2				
		feathers		ND	2.67	5.38	13.9
		kidney		4.04	ND	5.81	8.65
		liver		0.95	ND	2.71	3.69
		heart		ND	ND	1.25	1.1
		muscle		ND	ND	ND	0.572
2	East Fork Poplar Creek	feathers		7.21	1.86	5.63	4.55
		kidney		0.40	ND	3.14	1.46
		liver		0.23	ND	3.45	0.955
		heart		ND	ND	2.01	0.594
		muscle	3	ND	ND	1.04	0.805
3	White Oak Creek, Bldg. 4505	whole body	13,690				
		feathers		0.34	4.88	7.29	2.72
		kidney	69	1.53	0.42	6.01	26.8
		liver	76	0.90	0.40	7.5	17.6
		heart	81	ND	ND	2.2	9.52
		muscle	151	ND	0.58	1.84	6.34

[a]ND= Nondetect: As- <0.40 mg/kg, Cd- <0.20 mg/kg, Pb- <0.40 mg/kg, and Se-<0.40 mg/kg.

Table C.20. Summary of number of locations where HQs>1 were observed

Watershed	Endpoint	Analyte	No. locations where NOAEL-based HQ>1	No. locations where LOAEL-based HQ>1
Bear Creek	Mink	Hg	2	0
		PCBs	2	0
	River Otter	Hg	4	3
		PCBs	4	1
	Kingfisher	Hg	5	3
		PCBs	5	1
	Heron	Hg	5	0
		PCBs	3	0
East Fork Poplar Creek	Mink	Hg	7	6
		PCBs	3	1
	Otter	Hg	7	7
		PCBs	6	2
	Kingfisher	Hg	7	7
		PCBs	7	3
	Heron	Hg	7	6
		PCBs	5	1
K-25	Mink	Hg	9	1
		PCBs	7	0
	Otter	Hg	13	11
		PCBs	15	5
	Kingfisher	Hg	16	10
		PCBs	14	4
	Heron	Hg	16	0
		PCBs	13	0
	Osprey	Hg	16	3
		PCBs	14	1
White Oak Creek	Mink	Hg	1	0
		PCBs	3	0
	Otter	Hg	7	3

Table C.20 (continued)

Watershed	Endpoint	Analyte	No. locations where NOAEL-based HQ>1	No. locations where LOAEL-based HQ>1
		PCBs	6	3
	Kingfisher	Hg	7	3
		PCBs	7	1
	Heron	Hg	7	0
		PCBs	5	0
	Osprey	Hg	2	0
		PCBs	3	0

Table C.21. Summary of number of individuals of piscivore endpoint species estimated to be experiencing adverse effects by watershed and for the ORR

Location	Analyte	Species	%> LOAEL	Number in Watershed	Number Adversely Affected	Percent Adversely Affected
Bear Creek	Mercury	Mink	<5%	7	0	0%
East Fork Poplar Creek	Mercury	Mink	80%	15	12	80%
K-25	Mercury	Mink	<5%	14	0	0%
White Oak Creek	Mercury	Mink	<5%	4	0	0%
ORR-wide	Mercury	Mink		40	12	30%
Bear Creek	Mercury	Otter	50%	5	2	40%
East Fork Poplar Creek	Mercury	Otter	>95%	9	9	100%
K-25	Mercury	Otter	>95%	9	9	100%
White Oak Creek	Mercury	Otter	25%	2	0	0%
ORR-wide	Mercury	Otter		25	20	80%
Bear Creek	Mercury	Kingfisher	65-70%	5	3	60%
East Fork Poplar Creek	Mercury	Kingfisher	>95%	10	10	100%
K-25	Mercury	Kingfisher	>95%	9	9	100%
White Oak Creek	Mercury	Kingfisher	15%	3	0	0%
ORR-wide	Mercury	Kingfisher		27	22	81.5%
Bear Creek	Mercury	Heron	<5%	29	0	0%
East Fork Poplar Creek	Mercury	Heron	>95%	57	57	100%
K-25	Mercury	Heron	<5%	54	0	0%
White Oak Creek	Mercury	Heron	<5%	15	0	0%
ORR-wide	Mercury	Heron		155	57	36.8%
K-25	Mercury	Osprey	<5%		0	0%
White Oak Creek	Mercury	Osprey	<5%		0	0%
Bear Creek	PCBs	Mink	<5%	7	0	0%

Table C.21 (continued)

Location	Analyte	Species	%> LOAEL	Number in Watershed	Number Adversely Affected	Percent Adversely Affected
East Fork Poplar Creek	PCBs	Mink	<5%	15	0	0%
K-25	PCBs	Mink	<5%	14	0	0%
White Oak Creek	PCBs	Mink	<5%	4	0	0%
ORR-wide	PCBs	Mink		40	0	0%
Bear Creek	PCBs	Otter	<5%	5	0	0%
East Fork Poplar Creek	PCBs	Otter	15-20%	9	1	11%
K-25	PCBs	Otter	5-10%	9	0	0%
White Oak Creek	PCBs	Otter	70-75%	2	1	50%
ORR-wide	PCBs	Otter		25	2	8%
Bear Creek	PCBs	Kingfisher	<5%	5	0	0%
East Fork Poplar Creek	PCBs	Kingfisher	10-15%	10	0	0%
K-25	PCBs	Kingfisher	<5%	9	0	0%
White Oak Creek	PCBs	Kingfisher	<5%	3	0	0%
ORR-wide	PCBs	Kingfisher		27	0	0%
Bear Creek	PCBs	Heron	<5%	29	0	0%
East Fork Poplar Creek	PCBs	Heron	<5%	57	0	0%
K-25	PCBs	Heron	<5%	54	0	0%
White Oak Creek	PCBs	Heron	<5%	15	0	0%
ORR-wide	PCBs	Heron		155	0	0%
K-25	PCBs	Osprey	<5%		0	0%
White Oak Creek	PCBs	Osprey	<5%		0	0%

Table C.22. Simulation of exposure of mink to mercury and PCBs in toxicity test diets

Diet	Analyte	Concentration in diet				Distribution used in simulation	Modeled exposure (mg/kg-d)			% > NOAEL [a]	% > LOAEL [a]
		Mean	STD	Min	Max		Mean	STD	80th percentile		
A	Mercury	0.02	0	0.02	0.03	Triangular	0.0034	0.0009	0.0042	<5%	<5%
B	Mercury	0.05	0	0.04	0.06	Triangular	0.0074	0.0019	0.0088	<5%	<5%
C	Mercury	0.09	0	0.08	0.11	Triangular	0.0138	0.0035	0.016	30%	<5%
D	Mercury	0.15	0.01			Normal	0.022	0.0059	0.026	>95%	25%
E	Mercury	0.22	0.01			Normal	0.033	0.008	0.038	>95%	85%
A	PCB 1260	0.169	0.002			Normal	0.025	0.0063	0.029	<5%	<1%
B	PCB 1260	11.44	0.327			Normal	1.70	0.43	1.97	>95%	>95%
C	PCB 1260	4.697	0.174			Normal	0.698	0.18	0.82	>95%	40-45%
D	PCB 1260	10.41	0.25			Normal	1.54	0.39	1.79	>95%	>95%
E	PCB 1260	20.67	0.458			Normal	3.07	0.77	3.55	>95%	>95%

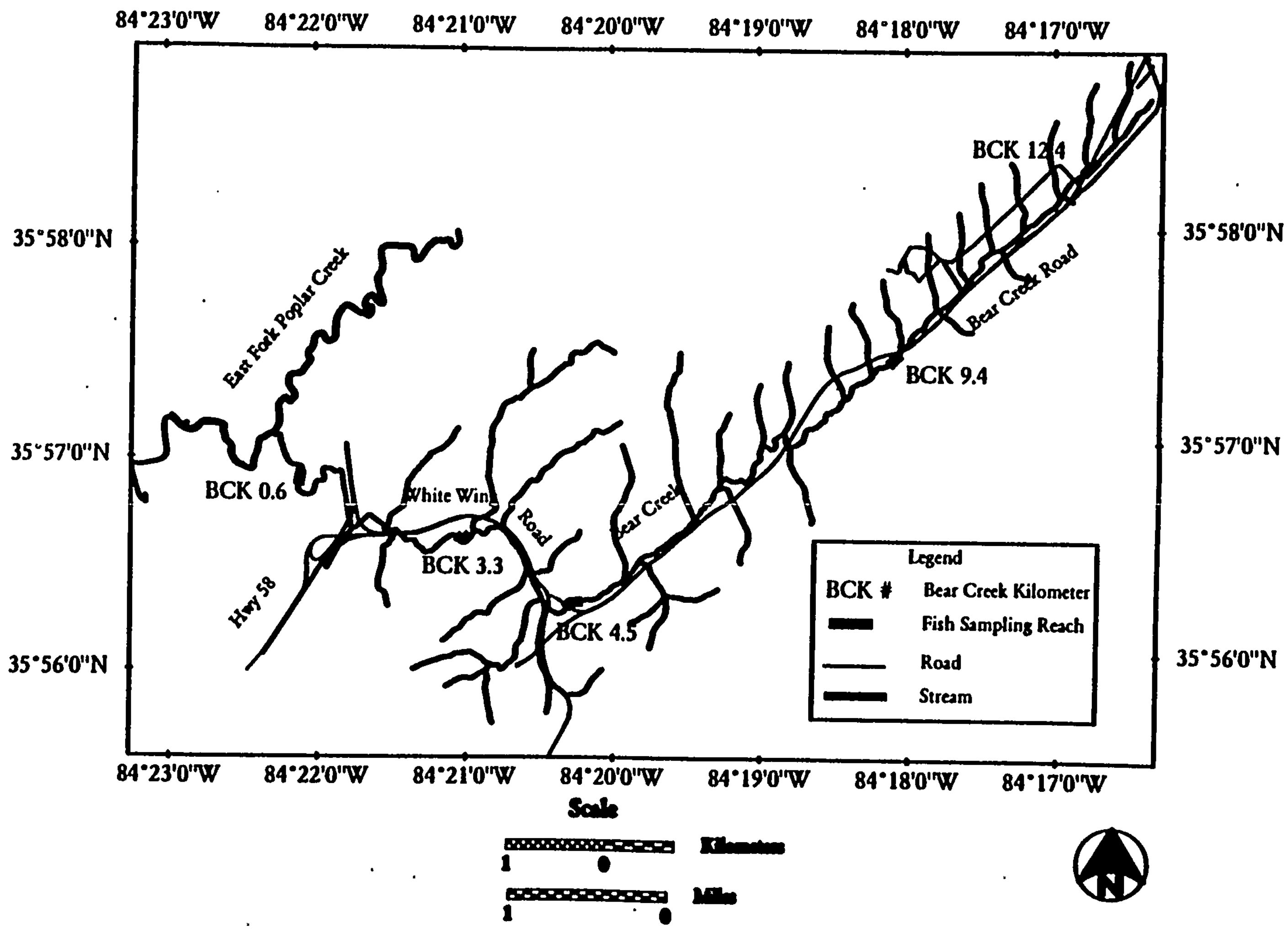

Fig. C.1. The Bear Creek fish sampling locations used in the ORR-wide ecological risk assessment. The map projection is Tennessee State Plane (TSP) meters, Zone 5301, and NAD 83. The study site location data is from BMAP and OREIS spatial database. The map was prepared by R.A. Washington-Allen, Environmental Sciences Division (ESD) ORNL on July 27, 1995.

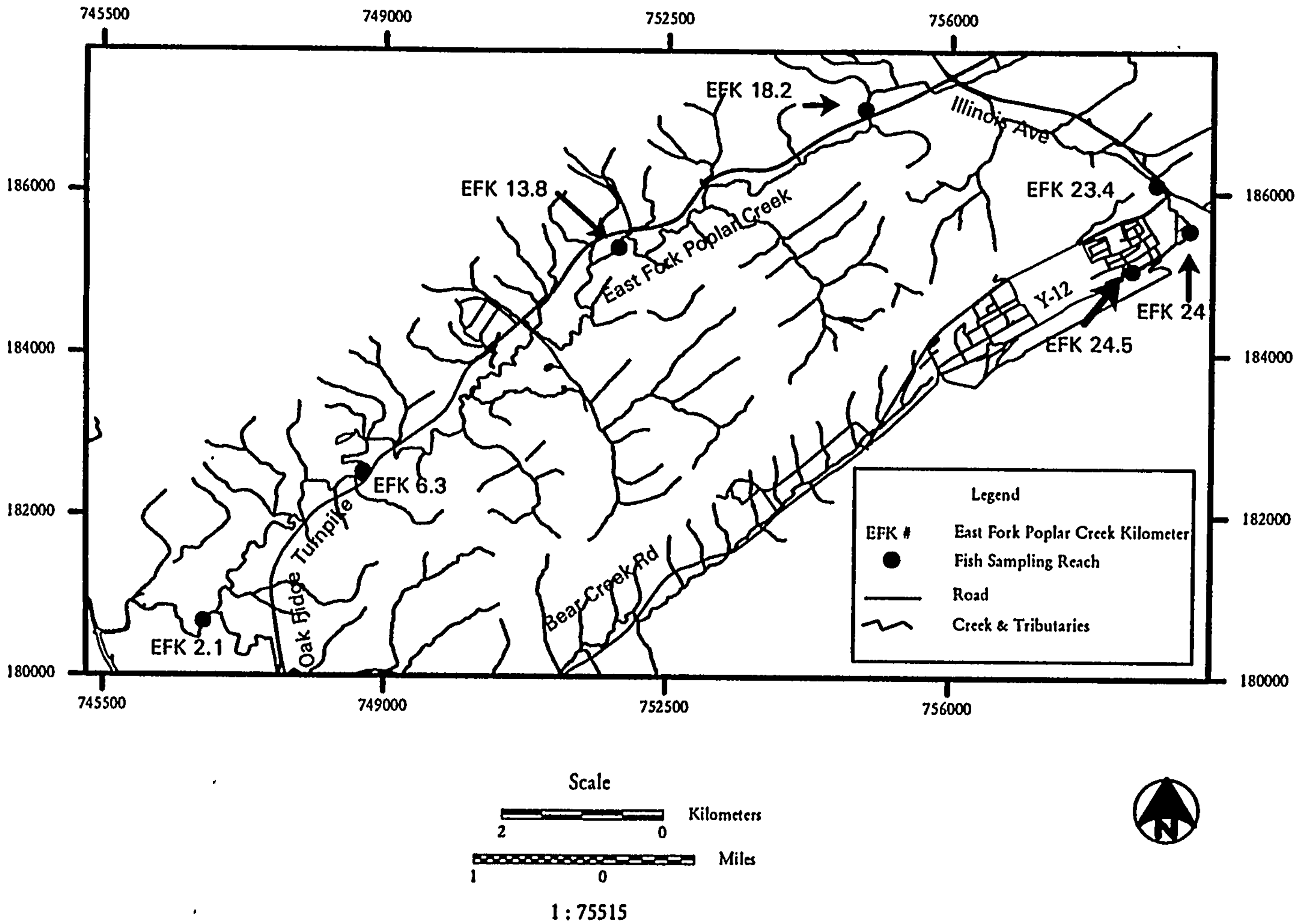

Fig. C.2. The East Fork Poplar Creek fish and ecological sampling locations (from EFPC RI) used in the ORR-wide ecological risk assessement. The map projection is Tennessee State Plane meters, Zone 5301, and NAD 83. The study site location data is from SAIC, BMAP, and OREIS spatial database. The map was prepared by R. A. Washington-Allen, Environmental Sciences Division, ORNL on September 11, 1996.

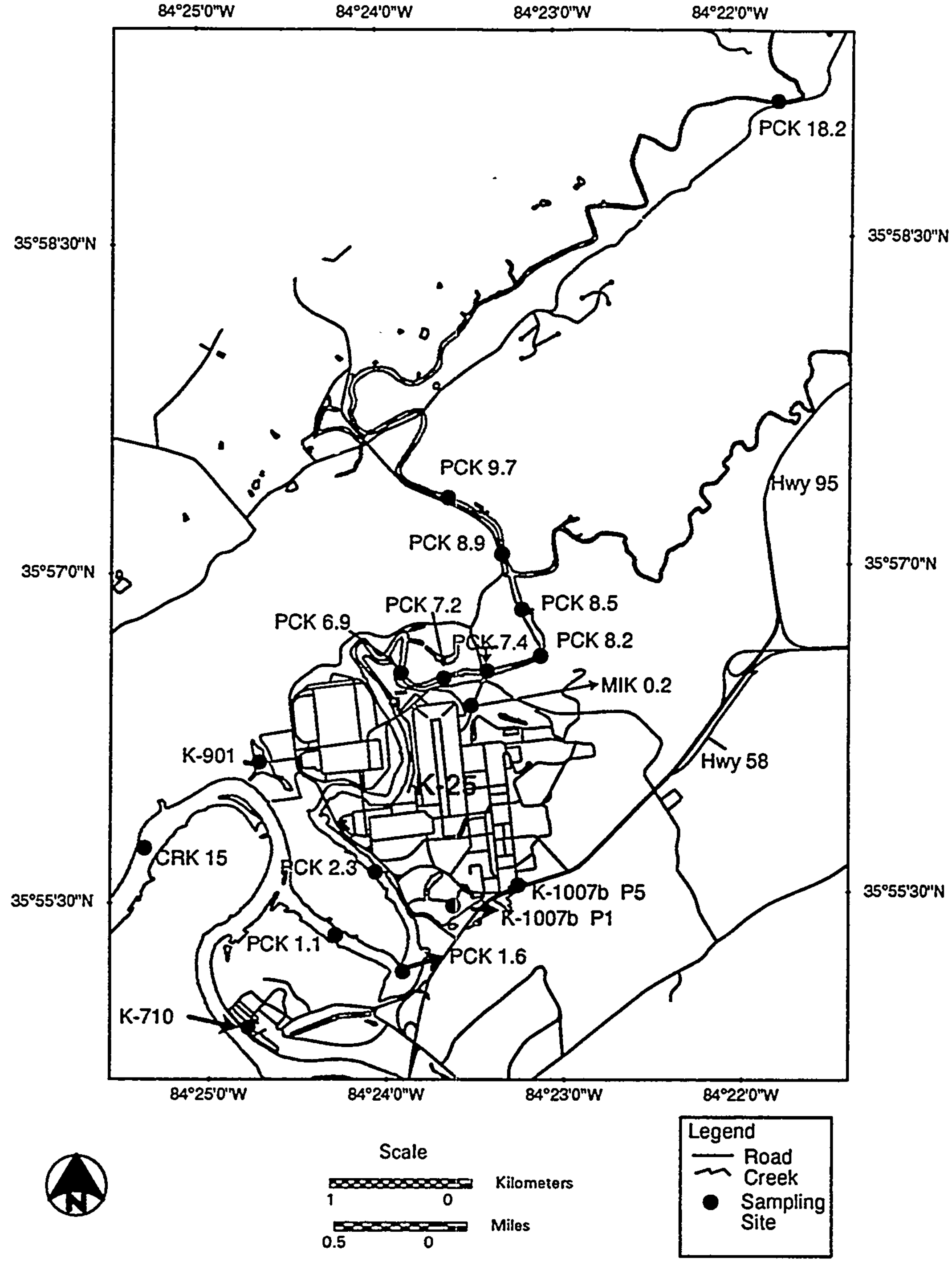

Fig. C.3. The Poplar Creek sampling locations and ponds used to evaluate risks in the K-25 vicinity for the ORR-wide ecological risk assessment. The map projection is Tennessee State Plane meters, Zone 5301, and NAD 83. The study site location data is from BMAP and OREIS spatial database. The map was prepared by R. A. Washington-Allen, Environmental Sciences Division, ORNL on September 11, 1996.

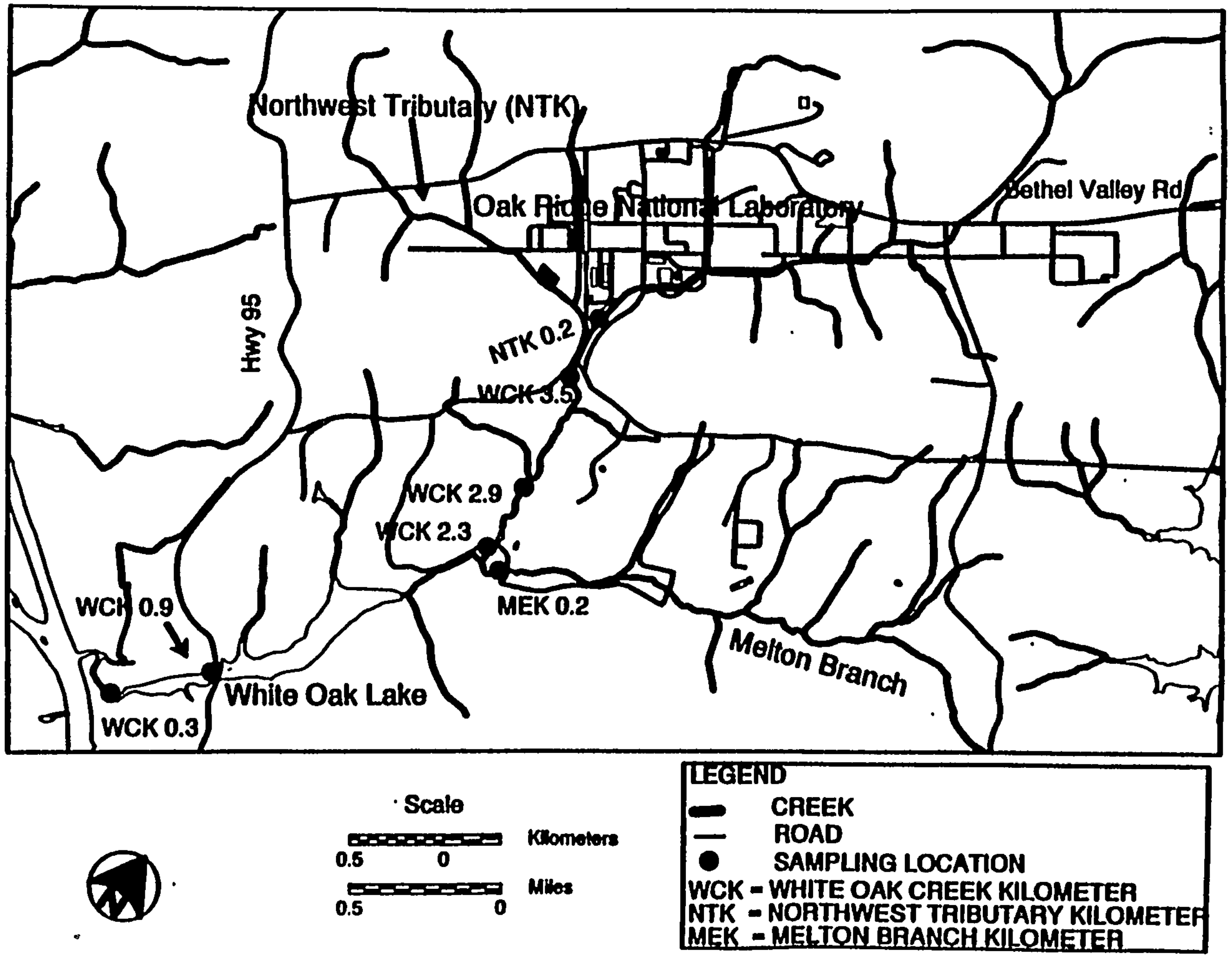

Fig. C.4. The White Oak Creek fish sampling locations used in the ORR-wide ecological risk assessment. The map projection is Tennessee State Plane (TSP) meters, Zone 5301, and NAD 83. The study site location data is from BMAP and OREIS spatial database. The map was prepared by R.A. Washington-Allen, Environmental Sciences Division (ESD) ORNL on July 27, 1995.

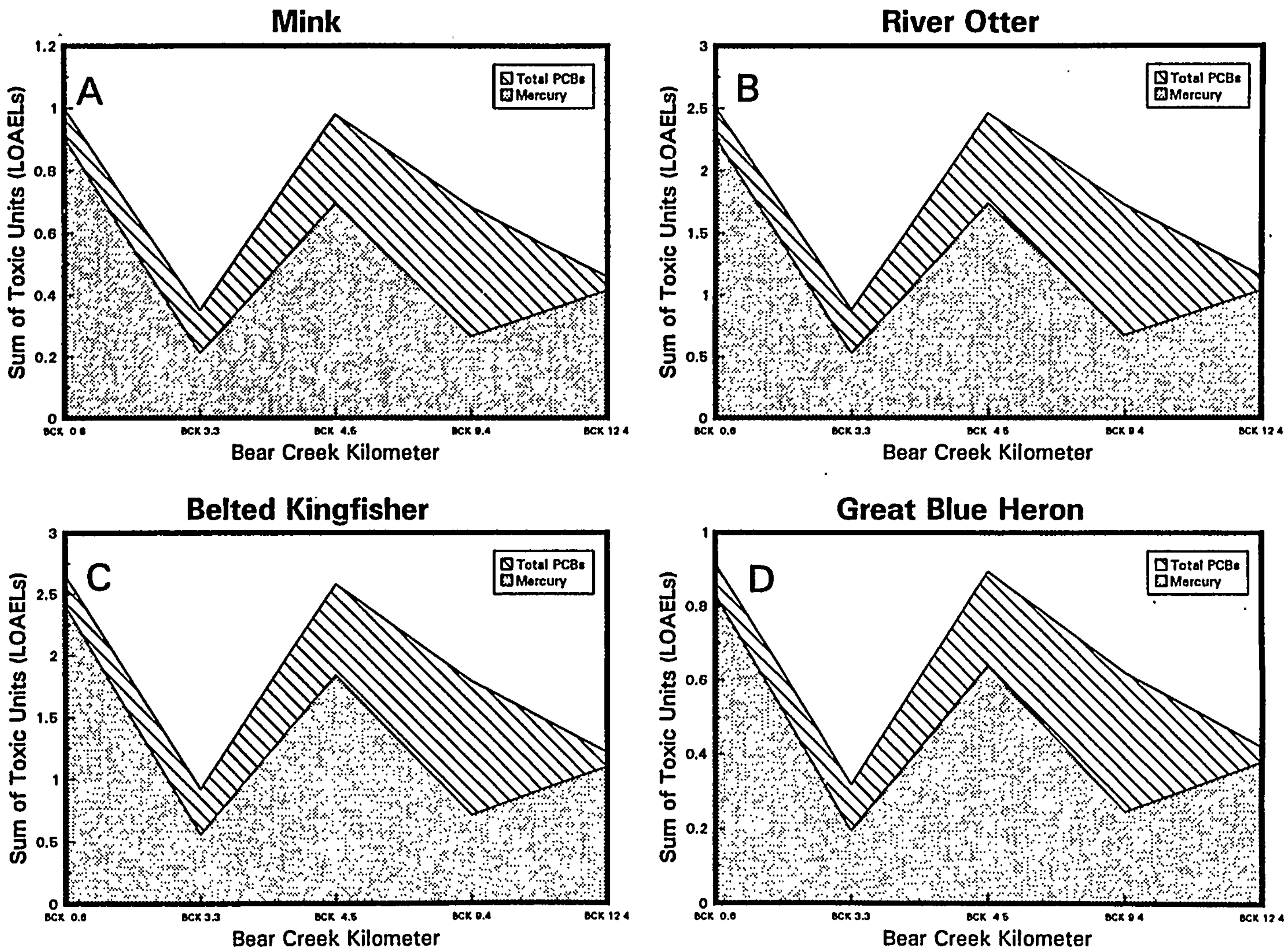

Fig. C.5. Sum of LOAEL-based toxic units for evaluation of risks to piscivores in the Bear Creek Watershed.

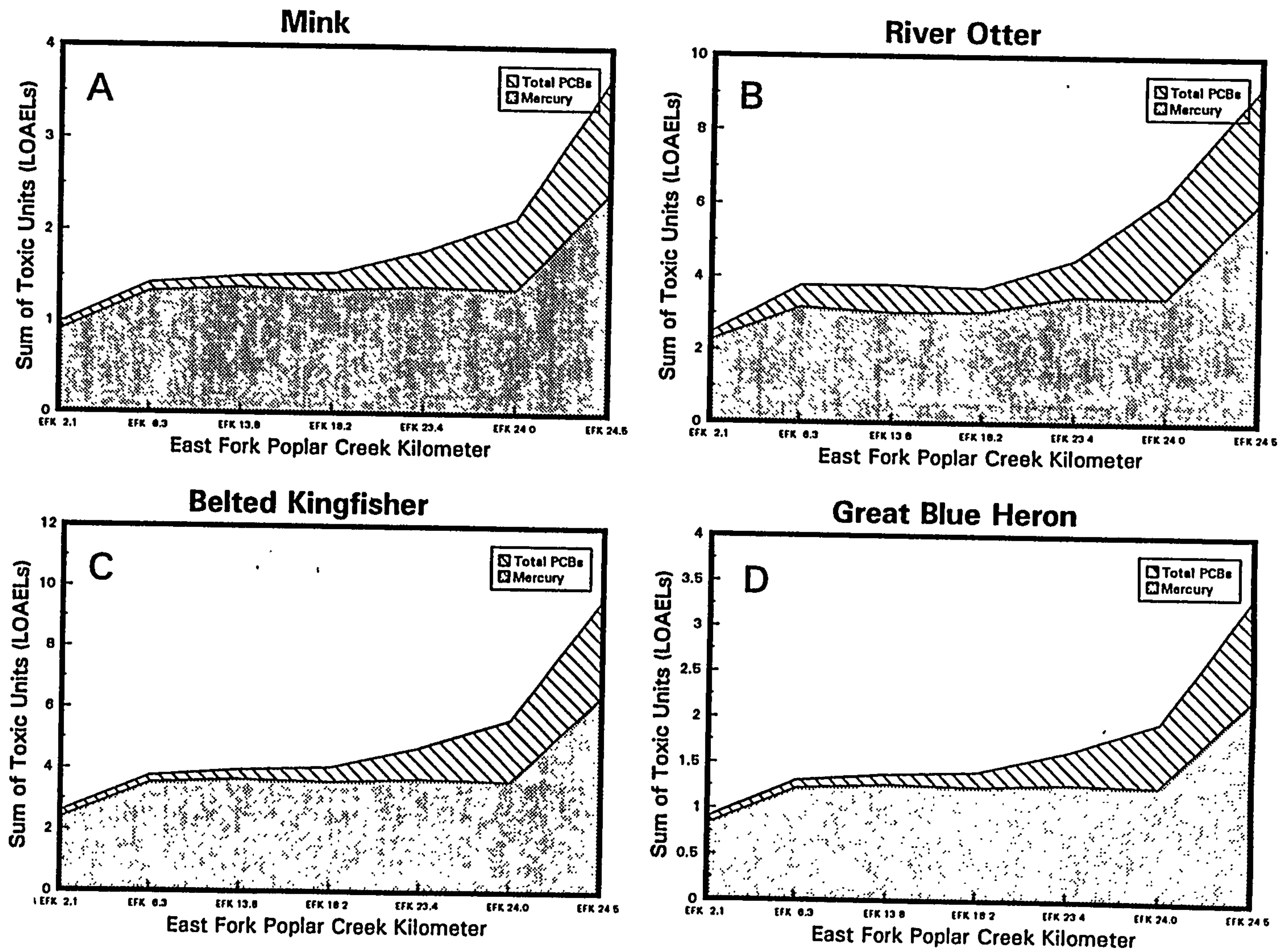

Fig. C.6. Sum of LOAEL-based toxic units for evaluation of risks to piscivores in the East Fork Poplar Creek Watershed.

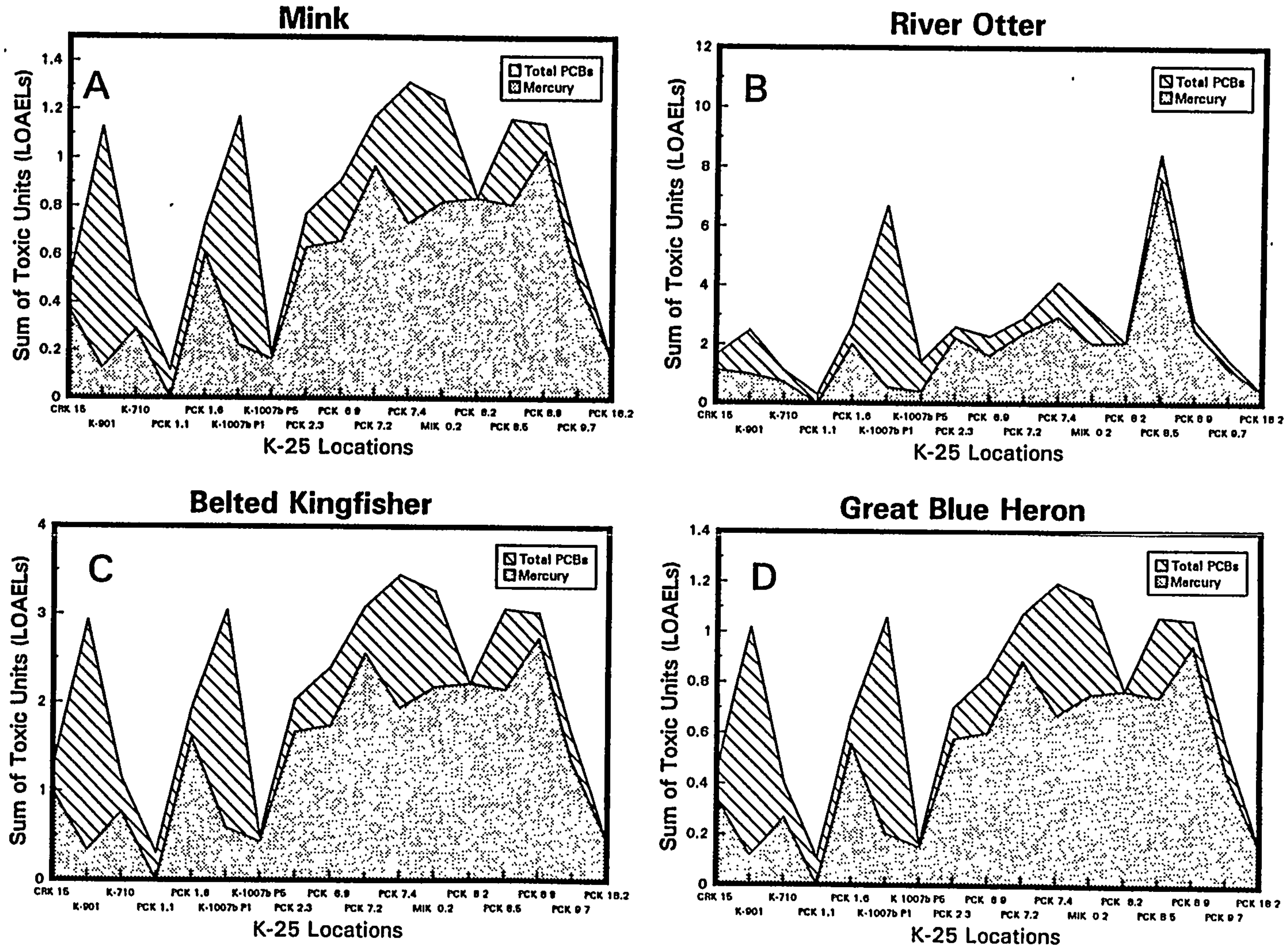

Fig. C.7. Sum of LOAEL-based toxic units for evaluation of risks to piscivores in the K-25 vicinity.

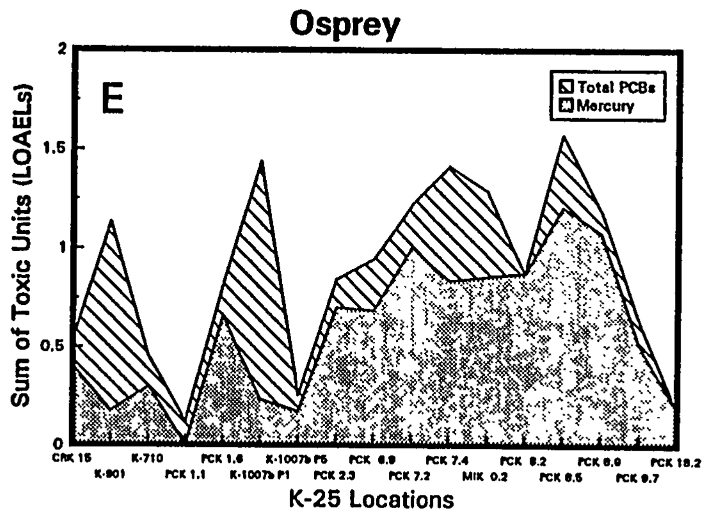

Fig. C.7 (continued)

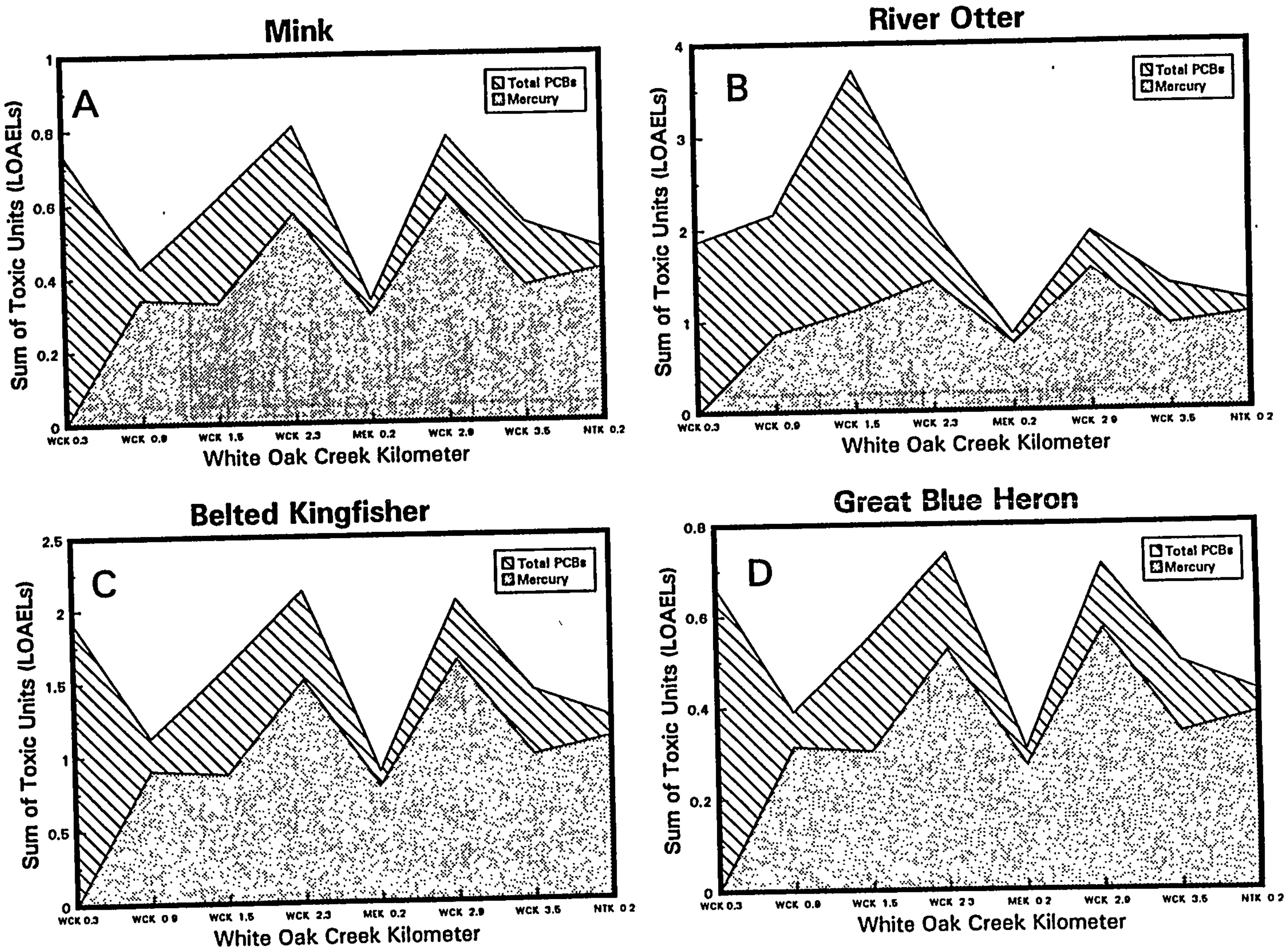

Fig. C.8. Sum of LOAEL-based toxic units for evaluation of risks to piscivores in the White Oak Creek Watershed.

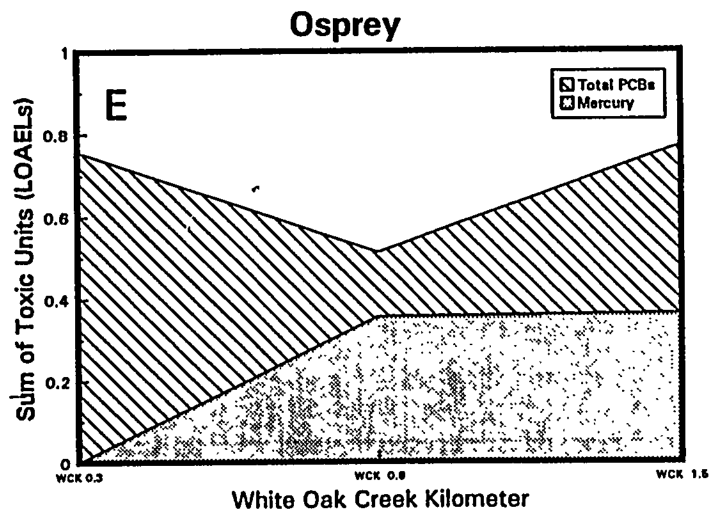

Fig. C.8 (continued)

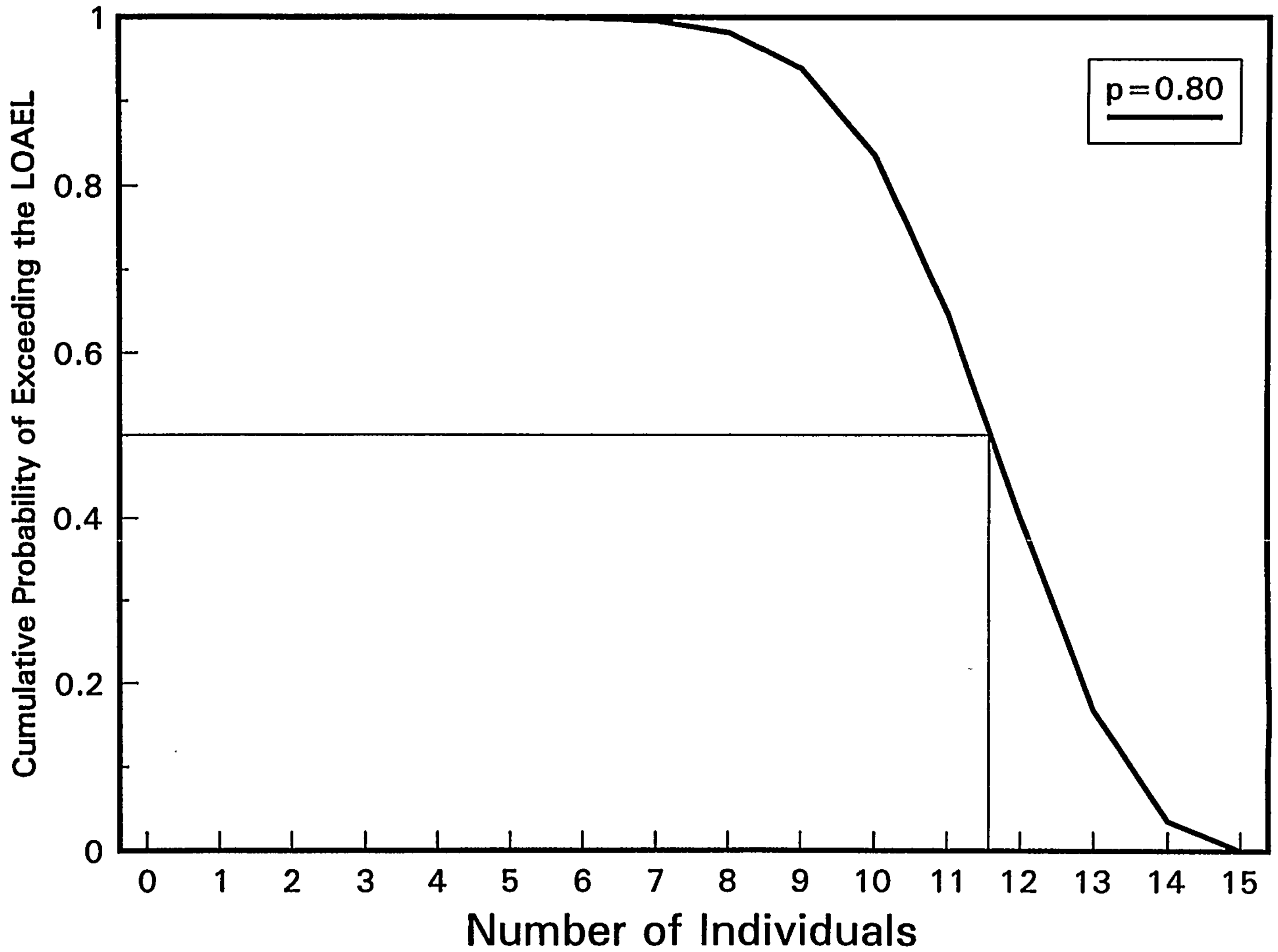

Fig. C.9. Cumulative binomial probability of mink experiencing exposure to mercury in East Fork Poplar Creek in excess of the LOAEL.

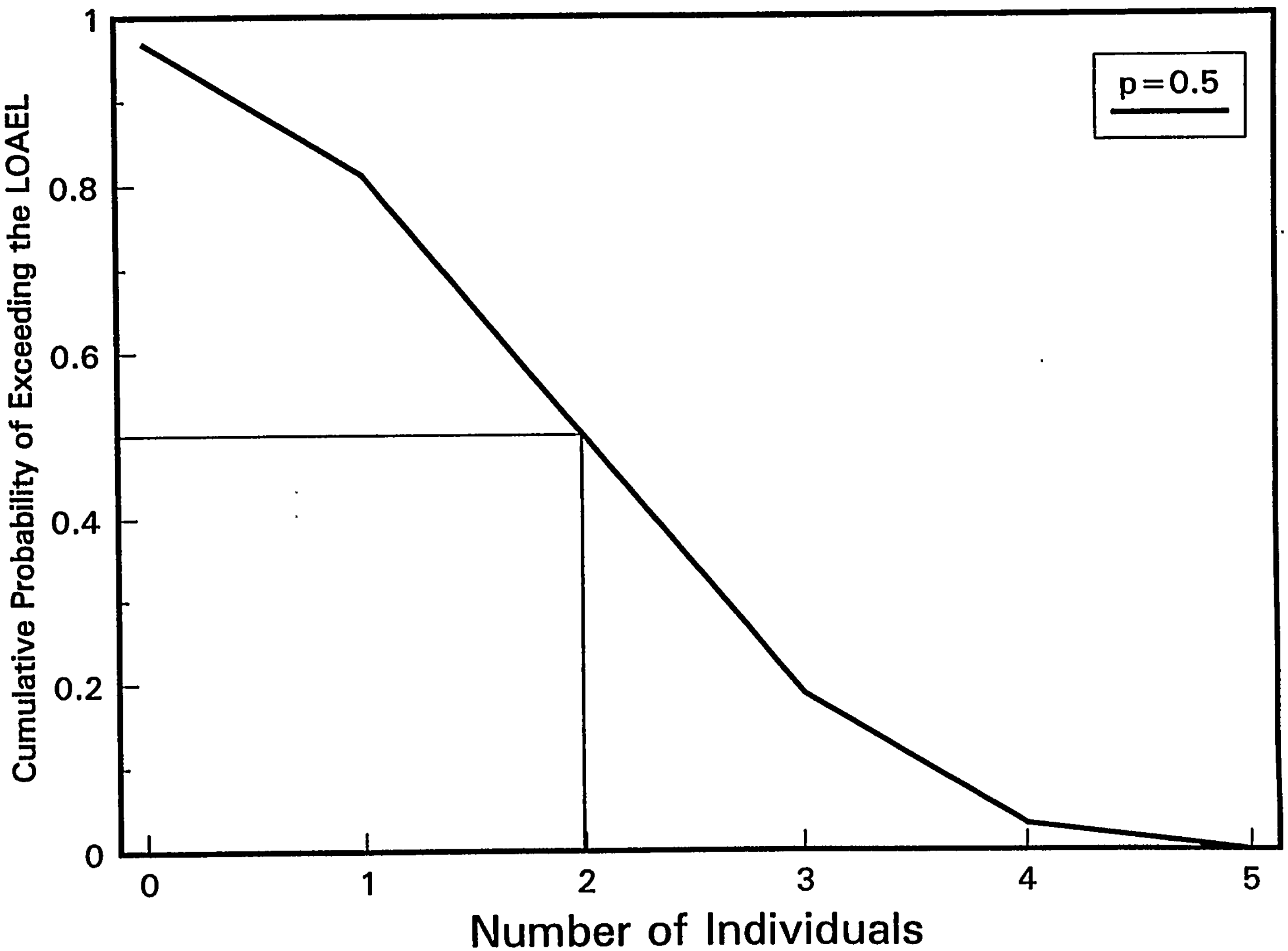

Fig. C.10. Cumulative binomial probability of river otter experiencing exposure to mercury in Bear Creek in excess of the LOAEL.

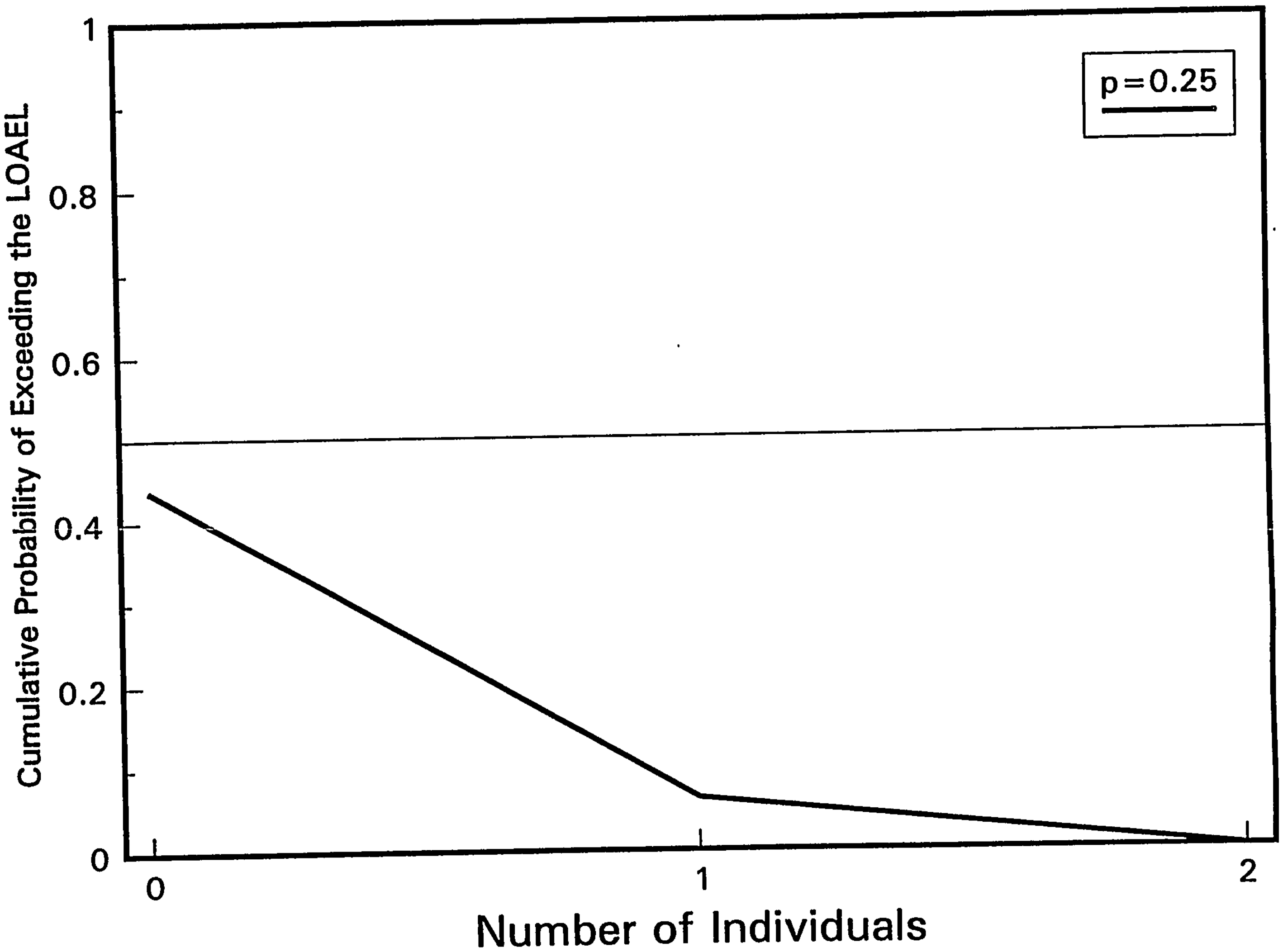

Fig. C.11. Cumulative binomial probability of river otter experiencing exposure to mercury in White Oak Creek in excess of the LOAEL.

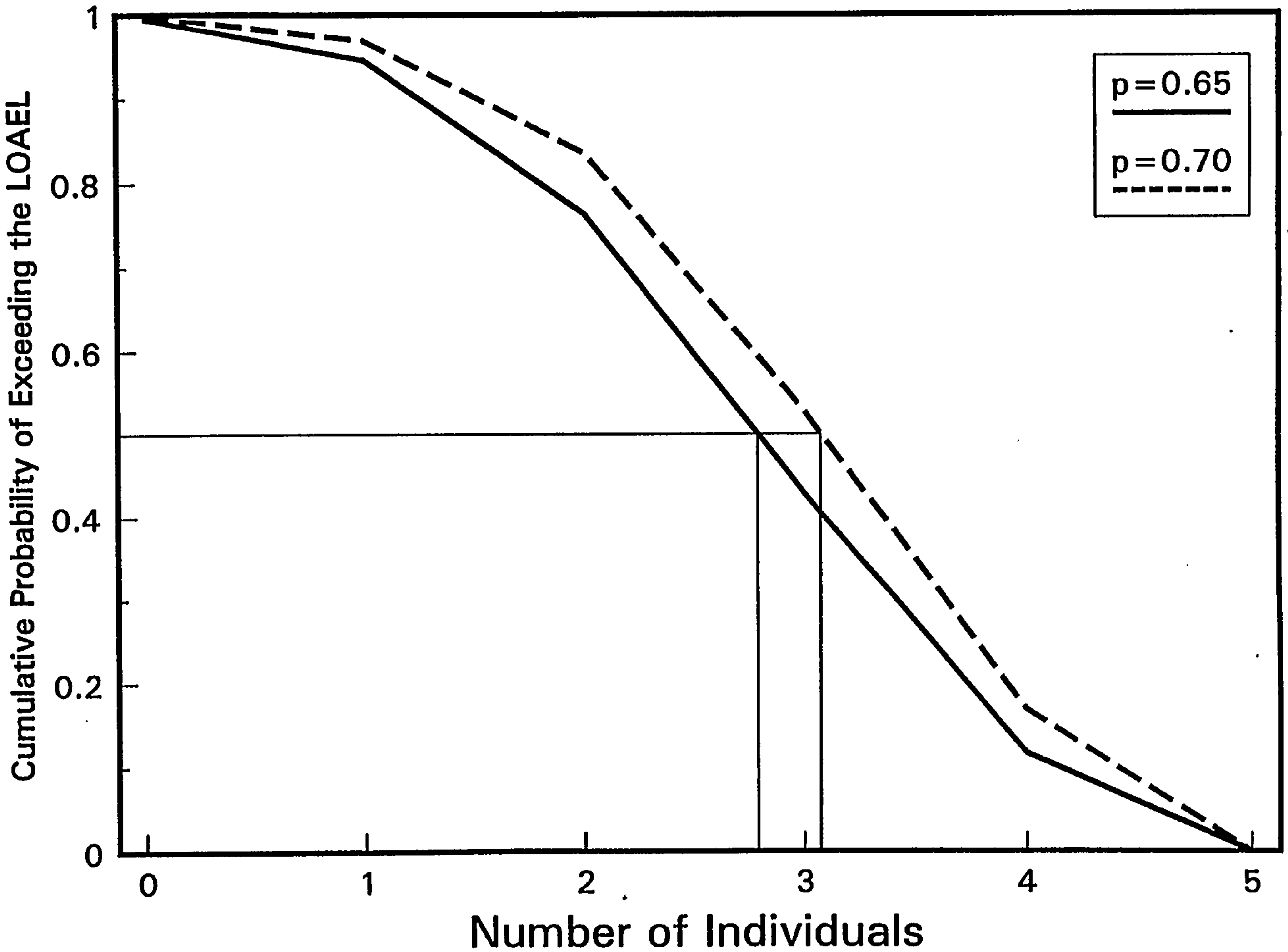

Fig. C.12. Cumulative binomial probability of belted kingfisher experiencing exposure to mercury in Bear Creek in excess of the LOAEL.

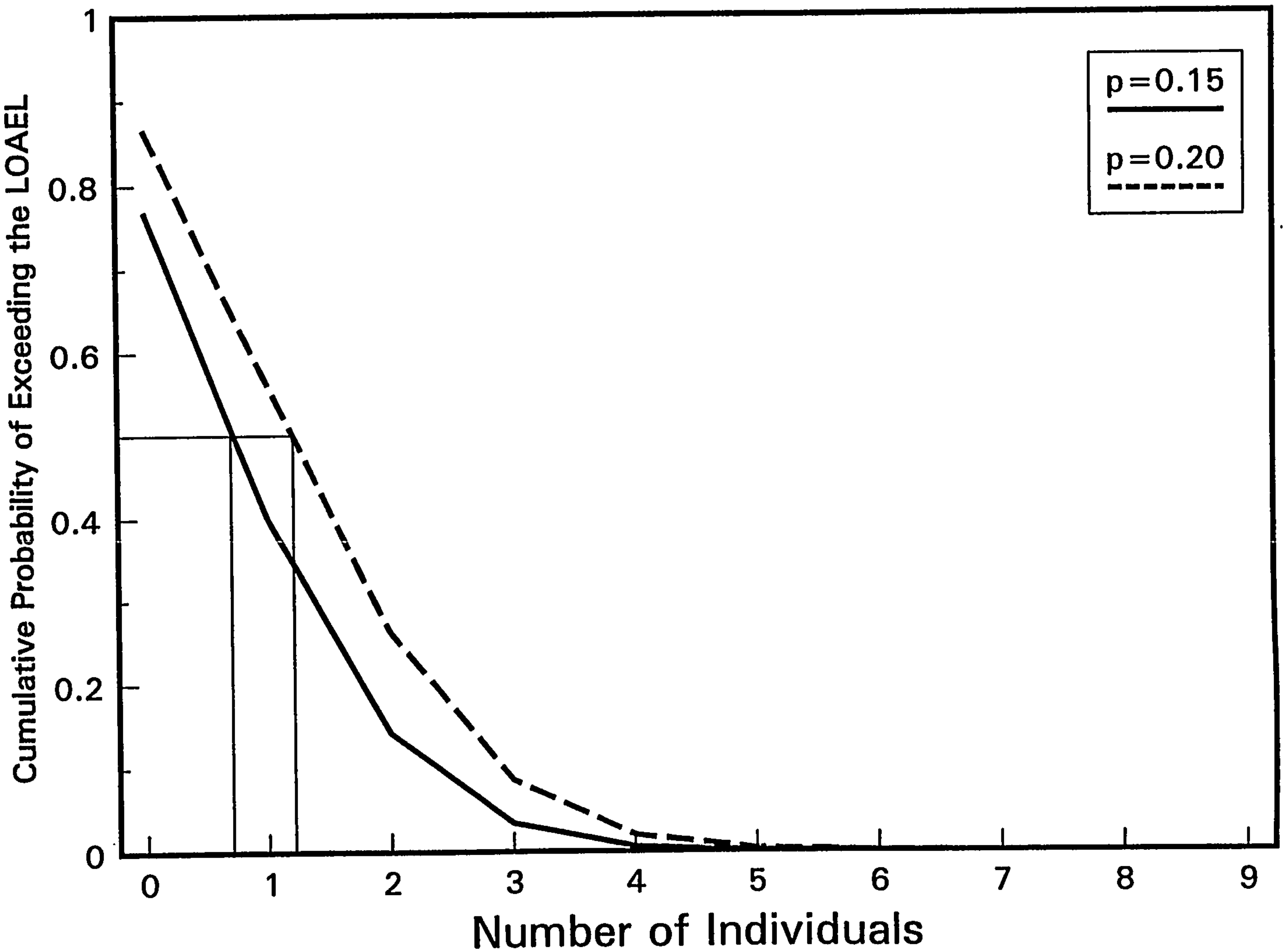

Fig. C.13. Cumulative binomial probability of river otter experiencing exposure to PCBs in East Fork Poplar Creek in excess of the LOAEL.

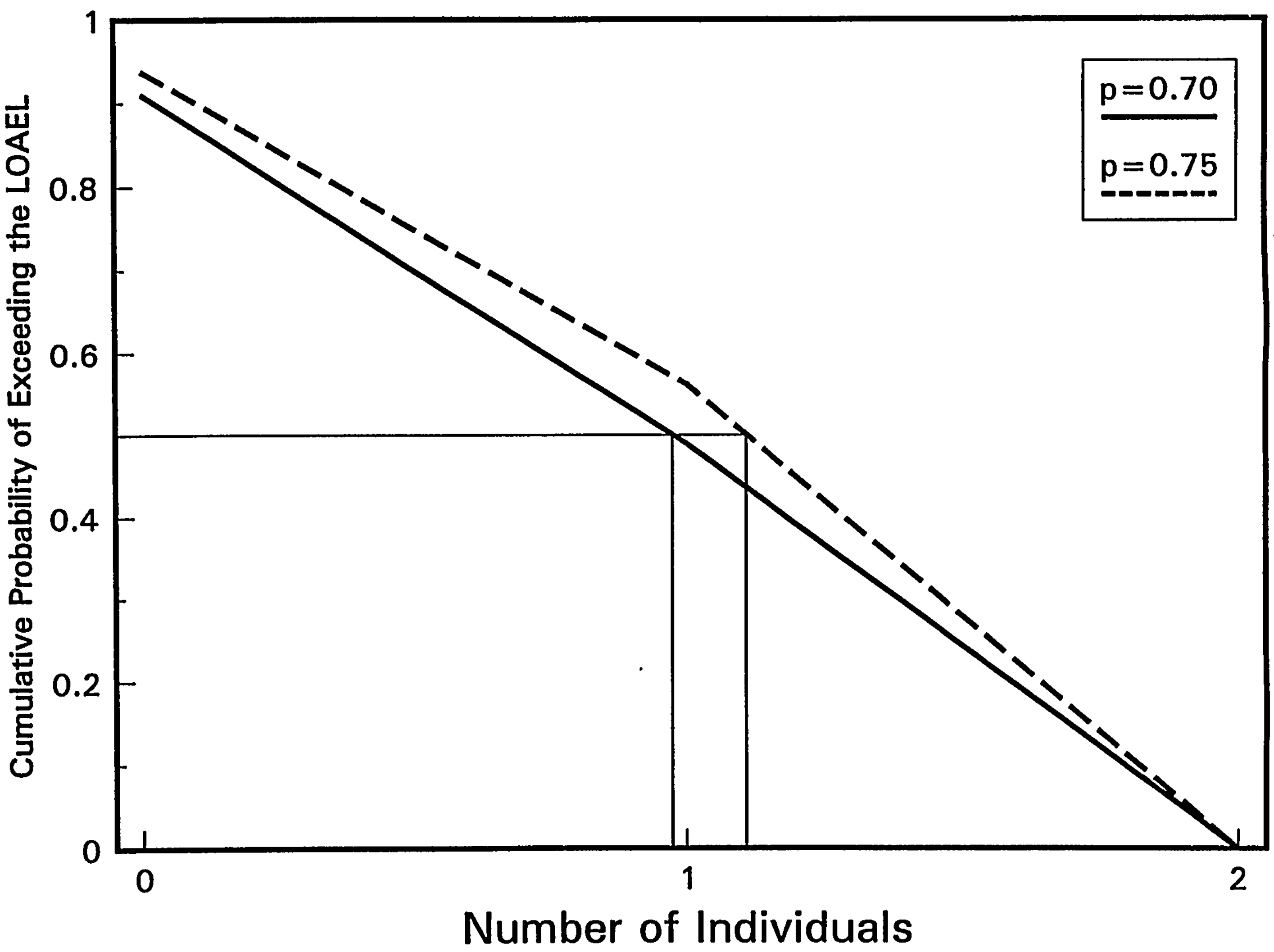

Fig. C.14. Cumulative binomial probability of river otter experiencing exposure to PCBs in White Oak Creek in excess of the LOAEL.

Appendix D

TOXICOLOGICAL PROFILES

TOXICOLOGICAL PROFILES

Aluminum. Aluminum is an ubiquitous metal, being the third most abundant element in the earth's crust (Krueger et al. 1984). Relative to other metals, the toxicity of aluminum is low (Sorensen et al. 1974). The oral LD_{50} for mice ranges from 770 to 980 mg aluminum/kg body weight (Ondreicka et al. 1966). The principal effect of aluminum is to interfere with phosphorous metabolism; in the alimentary canal, aluminum forms insoluble compounds with phosphorous resulting in an imbalance of calcium and phosphorous (Carrerie et al. 1986). Other effects of aluminum include neurotoxicity. Rats exposed to aluminum display behavioral abnormalities and have reduced acetylcholinesterase activity (Krueger et al. 1984). Mice consuming diets containing 500 to 1000 ppm aluminum displayed ataxia and paralysis of the hind limbs (Golub et al. 1987). In humans, aluminum has been associated with several degenerative diseases of the nervous system, including Alzheimer's disease, Parkinson's disease, and amyotrophic lateral sclerosis (Ganrot 1986).

Ondreicka et al. (1966) evaluated the effects of aluminum on mammalian reproduction. Mice received 19.3 mg aluminum/kg bodyweight/day (as $AlCl_3$) in drinking water for three generations. While the number of litters and offspring per litter was not reduced, growth was significantly reduced among all offspring in the second and third generations. In a similar study, rats received daily intragastric doses of 0, 180, 360, or 720 mg aluminum/kg body weight/day (Domingo et al. 1987) for one generation. Growth and survival of young was reduced among the groups that received 360 and 720 mg aluminum/kg/day. Other studies also report that while aluminum does not appear to affect the number of litters or number of offspring/litter, growth and survival of offspring of aluminum exposed parents is reduced (Golub et al. 1987; Paternain et al. 1988).

Due to it's interference with phosphorous and calcium metabolism, it has been suggested that aluminum may impair eggshell formation by birds, resulting in eggshell thinning (Nyholm 1981). To test this hypothesis, Carriere et al. (1986) fed breeding ring doves (*Streptopelia risoria*) a diet containing 1000 ppm aluminum (and adequate but reduced calcium and phosphorous) and observed reproduction. While no reproductive effects or embryonic malformations were observed at this dosage level, significant reproductive effects resulted when birds were fed a diet deficient in calcium and phosphorous that contained 750 ppm aluminum. Therefore, among birds it appears that the manifestation of toxic effects of aluminum are dependent upon the nutritional quality of their diet.

Arsenic. Arsenic is present in the earth's crust at approximately 2 ppm, but tissues of animals generally contain an average of <0.5 ppm (Venugopal and Luckey 1978). Arsenic may be a required micronutrient; growth, survival, and reproduction of goats is poor if the diet contains <0.05 ppm As (NAS 1977).

Arsenic is a carcinogen and teratogen. Other effects include reduced growth, hearing/sight loss, liver/kidney damage, and death (Eisler 1988a). Inorganic arsenic is usually more toxic than organic arsenic compounds. Wildlife mortality and malformations have been observed for chronic doses of 1-10 mg As/kg bw and dietary concentrations of 5-50 ppm (Eisler 1988a). Acute LD_{50}s for mammals of 35–100 mg calcium arsenate/kg body weight and 10-50 mg lead arsenate/kg body weight have been reported (NRCC 1978).

Schroeder and Mitchner (1971) exposed mice to 5 ppm sodium arsenite in drinking water for three generations. While mice fed arsenic survived well, litter size decreased in subsequent generations. A dose of 0.38 mg arsenic/kg over a lifetime was sufficient to cause a slight decrease in the median lifespan of laboratory mice (Schroeder and Balassa 1967), but it had no effect on growth. As little as 3 mg arsenic trioxide/kg body weight or 1 mg sodium arsenite/kg body weight can be lethal (NAS 1977).

Because metabolism of arsenic in rats is unlike that in other animals, results of toxicity studies using rats generally should not be extrapolated to other species (Eisler 1988a).

Among birds, LD_{50}s for arsenic compounds range from 17.4 to 3300 mg/kg bw (Eisler, 1988a). While no mortality was observed among mallard ducks fed a diet containing 100 ppm sodium arsenite for 128 days, 12% to 92% mortality was observed for ducks fed diets containing 250 to 1000 ppm arsenite (USFWS 1964). Camardese et al. (1990) and Whitworth et al. (1991) fed mallards diets containing 30, 100, or 300 ppm sodium arsenate. While no effects were observed on behavior, growth was reduced for male ducks consuming 300 ppm arsenic and for female ducks at all exposure levels.

Barium. The soluble salts of barium, an alkaline earth metal, are toxic in mammalian systems. At low doses, barium acts as a muscle stimulant and at higher doses affects the nervous system eventually leading to paralysis. The LD_{50} for rats is listed as 630 mg/kg for barium carbonate, 118 mg/kg for barium chloride, and 921 mg/kg for barium acetate (Lewis and Sweet 1984).

Schroeder and Mitchener (1975a, b) exposed rats and mice to 5 mg barium/L in drinking water for their lifetime. There was a slight but significant reduction in longevity of treated male mice when measured as the mean age at death of the last surviving 10% of animals. The overall average life span of the group, however, was about the same as the control group. In another study, Perry et al. (1983) exposed rats to 0, 1, 10, or 100 ppm barium for up to 16 months. A significant increase in average blood pressure was observed in the highest dose group; a slight but statistically significant increase was seen in the 10 ppm dose group. Information on developmental and reproductive toxicity of barium to mammals is not available.

The LD_{50} of barium to chickens is 623 mg/kg (Johnson et al. 1960). Johnson et al. (1960) report that while chickens will tolerate 1000 ppm barium in their diet without adverse effects, 2000 ppm reduces growth, 8000 ppm produces 50% mortality in 4 weeks, and diets containing 16,000 or 32,000 ppm barium are 100% lethal.

Cadmium. While there is little information to indicate that this relatively rare metal is biologically essential or beneficial, Cd has been suggested as the cause of various deleterious effects to wildlife (Eisler 1985a). Mammals and birds are comparatively resistant to the biocidal properties of Cd, which include growth retardation, anemia, and testicular damage. Cd tends to bioaccumulation the liver and kidney, eventually acting as a cumulative toxin. Cd residues of 2 ppm whole body fresh weight are evidence of Cd contamination, and residues >5 ppm whole animal fresh weight may be life-threatening (Eisler 1985a).

The lowest oral dose resulting in death for rats was 250 mg Cd/kg body weight (EPA 1980a). Weigel et al. (1987) fed rats 0.24, 0.85, or 2.25 mg/kg Cd in diet for 8 weeks. Concentrations ≥0.85 mg/kg resulted in reduced food intake, reduced body weights, and reduced enzyme activity, but no hematological effects were noted. Ma et al. (1991) determined that an average cadmium intake of 15 mg/kg/day corresponded with critical renal metal loads of 120 mg/kg, a level indicative of adverse health effects. Rats on a diet with 5 ppm Cd suffered shortened lifespans (Schroeder et al. 1965). Cd at 50 ppm in the diet depleted iron from rat livers (Whanger 1973). Rats eating diets with

7.15 ppm Cd (as CdO) exhibited growth reductions, but those consuming a diet with 2.80 ppm Cd did not (Weigel et al. 1987). In a 3 generation reproductive study, the population of mice exposed to 1 ppm $CdCl_2$ in their drinking water died out after the second generation (Schroeder and Mitchner 1971). Rats receiving >6 mg Cd/kg body weight daily during pregnancy gave birth to malformed fetuses (Ferm and Layton 1981).

No mortality was observed among adult mallard ducks fed diets containing 0, 2, 20, and 200 ppm Cd, however egg production was significantly reduced in the group consuming 200 ppm Cd (White and Finley 1978). In addition, the testes of males in the 200 ppm Cd group atrophied and the spermatogenic process was disrupted (White et al. 1978). Among mallard ducklings, 20 ppm Cd in the diet produces mild to severe kidney lesions, reduces packed cell volume and hemoglobin concentrations in the blood (Cain et al. 1983). Avoidance behavior of black ducklings is impaired by diets containing 40 ppm Cd (Heinz and Haseltine 1983).

Copper. Copper occurs naturally in elemental form and as a component of many minerals. It is an essential nutrient that is normally present in a wide variety of tissues (ATSDR 1990; EPA 1987). Because of its high electrical and thermal conductivity, it is widely used in the manufacture of electrical equipment. Common copper salts, such as the sulfate, carbonate, cyanide, oxide, and sulfide are used as fungicides, as components of ceramics and pyrotechnics, for electroplating, and for numerous other industrial applications (ACGIH 1986). The largest anthropogenic releases of copper to the environment result from mining operations, agriculture, solid waste, and sludge from sewage treatment plants. Natural discharges to air and water, such as windblown dust and volcanic eruptions, may be significant (ATSDR 1990).

Copper is a component of a number of metalloenzymes such as catalase, peroxidases, and cytochrome oxidase and is essential for the utilization of iron (Goyer 1991; Stokinger 1981a). Although most copper salts occur in two valence states, as cuprous (Cu^{+}) or cupric (Cu^{2+}) ions, the biological availability and toxicity of copper is most likely associated with the divalent state (ATSDR 1990). Copper sulfate is the most common copper salt. Copper is soluble in nitric acid and hot sulfuric acid, very slightly soluble in hydrochloric acid and ammonia, and insoluble in water (Stokinger 1981a).

The metabolism of copper involves mainly its transfer to and from various organic ligands, most notably sulfhydryl and imidazole groups on amino acids and proteins (ATSDR 1990). The liver is one of the main organs involved in the storage and metabolism of copper. Absorption of ingested copper occurs primarily in the upper gastrointestinal tract (EPA 1987). Soluble copper compounds (oxides, hydroxides, citrates) are readily absorbed but water-insoluble compounds (sulfides) are poorly absorbed (Venugopal and Luckey 1978). Zinc, molybdenum, and other metals may decrease dietary copper absorption (USAF 1990).

In animal studies, oral exposure to copper caused hepatic and renal accumulation of copper, liver and kidney necrosis at doses of ≥100 mg/kg/day, and hematological effects at doses of 40 mg/kg/day (EPA 1986; Haywood 1985; Rana and Kumar 1978; Gopinath et al. 1974; Kline et al. 1971). Oral or intravenous administration of copper sulfate can increase fetal mortality and developmental abnormalities in experimental animals (Lecyk 1980; Ferm and Hanlon 1974). Rat oral LD_{50} values for various copper compounds are 140 mg/kg for copper chloride ($CuCl_2$); 470 mg/kg for copper oxide (Cu_2O); 940 mg/kg for copper nitrate ($Cu(NO_3)_2 \cdot 3H_2O$); and 960 mg/kg for copper sulfate ($CuSO_4 \cdot 5\ H_2O$) (Stokinger 1981a). Deaths in animals given lethal doses of copper have been attributed to extensive hepatic centrilobular necrosis (USAF 1990).

In a 90-day subchronic study with copper cyanide (CuCN), high mortality, attributed to hemolytic anemia, was seen in both male and female rats receiving 50 mg/kg/day by gavage, but not in those receiving $\leq$ 5 mg/kg/day (EPA 1986). In general, male rats appeared to be more sensitive to the effects of CuCN than female rats. Rats receiving 500 ppm copper in their diet (about 5 mg/day) appeared normal, while rats receiving 1000 ppm exhibited depressed growth, those at 2000 ppm hardly grew at all, and those on a 4000 ppm diet lost weight rapidly and died (Boyden et al. 1938). Salt licks containing 5–9% copper sulfate caused anorexia, hemolytic anemia, icterus, and hemoglobinuria, followed by death within 2 days in sheep using the licks (Gopinath et al. 1974). The estimated ingested dose was 40–49 g over a 25- to 86-day period. Lecyk (1980) observed reduced litter size, decreased fetal weights, and skeletal abnormalities in the offspring of mice fed diets supplemented with 3000 or 4000 ppm copper sulfate (155 or 207 mg copper/kg/day, respectively) for one month prior to gestation and on days 0–19 of gestation.

Aulerich et al. (1982) reported an increased mortality rate in the offspring of minks fed a diet supplemented with >3 mg copper/kg/day as copper sulfate for 50 weeks. Although kit mortality was greater and litter mass was reduced relative to controls, reproductive performance of mink fed diets supplemented with up to 200 ppm copper for 357 days was within the normal range for the species (Aulerich et al. 1982). Lifetime exposure to 42.4 mg copper/kg/day (as copper gluconate) in drinking water caused a 12.8% decrease in the maximal lifespan in mice (Massie and Aiello 1984).

Domestic chicks on diets $\geq$324 ppm copper grew slowly; mortality increased with dietary copper concentrations of 1270 ppm (Mayo et al. 1956). Arthur et al. (1958) observed no ill effects in chicks fed $\leq$500 ppm copper in diet up to 8 weeks of age. Dietary copper levels from 588–1176 ppm for 10 weeks exerted a toxic effect on chick growth; the minimum toxic level of copper appeared to be about 500 ppm (Mehring et al. 1960). Turkey poults tolerated 676 ppm copper in starter diets for 21 days with no deleterious effects, but copper was definitely toxic at levels >1620 ppm (Vohra and Kratzer 1968). Chickens given a daily dose of >70 mg/kg of $CuCO_3$ died while those receiving <60 mg/kg exhibited slight symptoms of copper poisoning but survived (Pullar 1940). No symptoms of copper poisoning were observed in domestic mallards ingesting $\leq$29 mg/kg/day of $CuCO_3$, but daily intakes $\geq$55 mg/kg/day were toxic (Pullar 1940).

Chromium. Chromium occurs as either chromium (III) or chromium (VI). Trivalent chromium is an essential metal in man and wildlife, playing an important role in insulin metabolism (Larngard and Norseth 1979). Hexavalent chromium is more toxic than chromium (III) because of its high oxidation potential and the ease with which it penetrates biological membranes (Steven et al. 1976; Taylor and Parr 1978). However, it is unlikely that all chromium in soil would be chromium (VI) because it is a highly oxidizing chemical species which is usually reduced by soil organic matter to chromium (III). Chromium (III) solubility decreases with increasing pH, and it is completely precipitated at pH above 5.5. In most soils, chromium is primarily present as precipitated chromium (III) and is not bioavailable. Most chromium in soil and sediments is unavailable to living organisms, and there is little evidence of chromium biomagnifying through food chains in its inorganic form (Eisler 1986a). Concentrations of total chromium >4.0 mg/kg dry weight should be viewed as presumptive evidence of chromium contamination (Eisler 1986a).

At high concentrations, chromium is a mutagen, teratogen and carcinogen (Eisler 1986a). The LD_{50} for chromium (III) in mice is 260 mg/kg bw and 5 mg/kg bw for chromium (VI) (Steven et al. 1976). Rats fed chromium (VI) reached a toxic threshold at 1000 ppm (Steven et al. 1976). Pregnant hamsters injected with 5 to 15 mg CrO_3 [chromium (VI)]/kg bw displayed a dose-dependent increase in the number of resorbed and malformed fetuses (Gale, 1978). Guinea pigs fed

50 ppm chromium (III) for 21 weeks showed no adverse effects (Preston et al. 1976). Similar results were observed among rats consuming water containing 25 ppm chromium (VI) for 1 year (Mackenzie et al. 1958).

Injection of 0.002 to 0.05 mg CrO_3 [chromium (VI)]/chicken egg produced a dose-dependent decrease in egg viability and increased frequency of malformed embryos (Gilani and Marano, 1979). In contrast, adult black ducks fed a diet containing 0, 10, or 50 ppm chromium (III) for 10 months displayed normal growth and reproduction (Haseltine et al., unpublished manuscript). While no malformations were observed among ducklings from treated birds, growth and survivorship was reduced. Heinz and Haseltine (1981) observed no effects on avoidance behavior of black ducklings fed a diet containing 20 or 200 ppm chromium (III).

DDT. DDT (1,1,1-trichloro-2,2-bis(*p*-chlorophenyl)ethane) is an organochlorine insecticide that was banned for use in the United States in 1972. DDT, and its metabolites, DDE and DDD, are highly persistent. The half-life of DDT in soil is reported to range from 2 to 15 years (ATSDR 1993). DDT and it's metabolites are also highly lipophilic and have a high bioaccumulation potential. A bioconcentration factor for rainbow trout is reported to be 12000 (ATSDR 1993). Braune and Norstrom (1989) found DDE concentrations in herring gills to be 85 times higher than fish in their diet.

Acute oral toxicity of DDT and its metabolites is relatively low. Mammalian oral LD_{50} values range from 87 mg/kg for rats to >5000 mg/kg for hamsters (EPA 1993). Avian oral LD_{50} values range from 595 mg/kg for California quail to >4000 mg/kg for rock doves (Hudson et al. 1984). Hill and Camardese (1986) report 5-day dietary LC_{50}s for DDT and DDE to be 416 mg/kg and 859 mg/kg, respectively.

Despite low acute toxicity, chronic exposure to low levels of DDT in food has adverse effects of reproduction in wildlife. The primary adverse effect among birds is eggshell thinning and decreased reproductive success (Ratcliffe 1967). Anderson et al. (1975) studied the reproductive success of pelicans from 1969 through 1974. During this time, DDT residues in anchovies, their primary food, declined from 4.27 ppm (wet weight) to 0.15 ppm (wet weight). While reproductive success improved from 1969 to 1974, in 1974 the fledgling rate was still 30% below that needed to maintain a stable population. Because this study was long-term and considered reproductive effects in a wildlife species, EPA (1993) judged this study to be the most appropriate to evaluate DDT effects to avian wildlife. Therefore the 0.15 ppm DDT value was considered to be a chronic LOAEL.

In a study of the effects of DDT on reproduction in mammals, Fitzhugh (1948) exposed rats to 10, 50, 100, or 600 ppm DDT in their diet for two years. While consumption of 50 ppm or more DDT in the diet reduced the number of young produced, no adverse effects were observed at the 10 ppm DDT dose level. Because the study considered exposure throughout 2 years and reproduction, the 10 and 50 ppm DDT doses were considered to be chronic NOAELs and LOAELs, respectively.

Lead. Lead is a comparatively rare metal, averaging 16 ppm in the earth's crust, that is neither essential nor beneficial in living organisms (Eisler 1988b). Lead has adverse effects on survival, growth, reproduction, development, behavior, learning, and metabolism. In general, organic lead compounds are more toxic than inorganic compounds, biomagnification of lead is minimal, and younger organisms are more susceptible to lead toxicity (Eisler 1988b).

Acute oral doses of 5–108 mg lead/kg bw reduced rat survival (Eisler 1988b), and rats fed diets with 5 ppm lead had shortened life spans (Schroeder et al. 1965). An acute LD_{50} based on a single oral dose of 12 mg tetraethyllead/kg body weight was reported by Branica and Konrad (1980). Rats fed 0.5, 5, 25, or 250 ppm inorganic lead in diets over two generations exhibited no substantial developmental effects (Kimmel et al. 1980). In another study, Azar et al. (1973) fed rats a diet containing 0, 10, 50, 100, 1000, or 2000 ppm lead acetate for three generations. While the number of litters and young/litter was not affected by any dose level, growth was reduced and kidney histopathologies were observed among offspring in the 1000 and 2000 ppm treatments. Frequency of pregnancy was reduced in mice ingesting 3 mg/kg body weight tetraethyllead daily, and daily ingestion of 1.5 mg/kg tetraethyllead chloride resulted in a reduction in the success of implanted ova (Clark 1979).

Anemia and other hematological effects were induced among pigeons orally dosed with 6.25 mg lead/kg bw/day (Anders et al. 1982). Kendall and Scanlon (1981) exposed ring doves to drinking water containing 0 or 100 ppm lead and observed no effects on time to produce eggs, egg production, or fertility. However, testes weight and sperm count was decreased among lead-exposed males. Grandjean (1976) correlated eggshell thickness and eggshell lead levels in European kestrels (*Falco tinnunculus*), suggesting that lead may cause eggshell thinning. Among American kestrels (*Falco sparvarius*) fed diets containing 0, 10, or 50 ppm lead, no adverse effects survival, egg-laying, initiation of incubation, egg fertility, or eggshell thickness were observed (Pattee 1984).

Mercury. Mercury has no known biological function and is potentially toxic to fish and wildlife. Mercury is a mutagen, teratogen, and carcinogen that adversely affects the central nervous, renal, and reproductive systems of wildlife (Eisler 1987). Inorganic mercury compounds in aquatic systems are readily converted to organomercury by microbial action (Berlin 1979), with organomercury compounds being more toxic than inorganic mercury compounds. Biota bioconcentrate mercury compounds which can be further biomagnified through food chains (Wren, 1986).

Daily doses of 0.1–0.5 mg/kg bw/day and dietary concentrations of 1.0–5.0 ppm are lethal to sensitive mammals (Eisler 1987). Central nervous system toxicity, weight loss, and mortality were observed among rats fed a diet containing 250 ppm methyl mercury (MeHg) for 2 weeks (Verschuuren et al. 1976a). Rats consuming 2.5 ppm MeHg in the diet for 2 years displayed reduced growth, increased kidney weight, and altered kidney histochemistry (Verschuuren et al. 1976b). To study effects on reproduction, Verschuuren et al. (1976c) fed rats a diet containing 0, 0.1, 0.5, and 2.5 ppm MeHg for three generations. While no effects were observed among rats fed 0.1 or 0.5 ppm MeHg, offspring viability was reduced among rats in the 2.5 ppm treatment. Among mink, 93-day consumption of diets containing 1.8 to 15.0 ppm MeHg produced mortality, ataxia, anorexia, and paralysis (Wobeser et al. 1976), with the highest exposures showing the greatest effects.

The LD_{50} for MeHg for *Coturnix* quail ranges from 14.4 to 33.7 mg/kg bw (Eisler 1987). Growth was decreased and mortality increased among leghorn cockerels fed diets containing 6 to 18 ppm MeHg (Fimreite 1970). Ring-necked pheasants fed diets of MeHg-treated grains displayed reduced egg production and hatchability and laid more shell-less eggs than controls (Fimreite 1971). Heinz (1979) fed mallard ducks a diet containing 0.5 ppm MeHg for three generations. While MeHg consumption did not affect adult weights or weight change during the reproductive season, MeHg-exposed females laid fewer eggs (with more eggs outside the nest box), produced fewer young, and displayed slightly thinner eggshells. Young of MeHg-treated adults were less responsive to maternal calls and hyper-responsive to fright stimuli.

Nickel. Nickel is a naturally occurring element that may exist in various mineral forms. It forms 0.008% of the earth's crust (NAS 1980). Soil and sediment are the primary receptacles for nickel, but mobilization may occur depending on physico-chemical characteristics of the soil (ATSDR 1988; USAF 1990). Nickel is used in a wide variety of applications including metallurgical processes and electrical components, such as batteries (ATSDR 1988; USAF 1990). There is some evidence that nickel may be an essential trace element for mammals.

Nickel occurs in nature in the nonionic and divalent states; other valence states occur very infrequently (Mastromatteo 1986).

The absorption of nickel is dependent on its physico-chemical form, with water soluble forms being more readily absorbed. Soluble nickel compounds tend to be more toxic than insoluble compounds (Goyer 1991). The metabolism of nickel involves conversion to various chemical forms and binding to various ligands (ATSDR 1988). Nickel is excreted in the urine and feces with relative amounts for each route being dependent on the route of exposure and chemical form. Most nickel enters the body via food and water consumption.

Oral LD_{50} values for rats range from 67 mg nickel/kg (nickel sulfate hexahydrate) to >9000 mg nickel/kg (nickel powder) (ATSDR 1988). The Food and Drug Research Laboratories, Inc. (1984) reported an acute oral LD_{50} of 175 mg/kg for female rats exposed to nickel dioxide hexahydrate; acute oral LD_{50}s for 11 other nickel compounds ranged from 275 to >9000 mg/kg. Toxic effects of oral exposure to nickel usually involve the kidneys with some evidence from animal studies showing a possible developmental/reproductive toxicity effect (ATSDR 1988; Goyer 1991).

Inorganic nickel compounds are well-tolerated when taken orally by rodents in doses up to 500 mg/kg (Mastromatteo 1986). Rats continually fed a 250 ppm nickel diet for 16 months suffered no deleterious effects and were considered in excellent condition (Phatak and Patwardhan 1952). Progressive accumulation of nickel was not observed in the tissues assayed. In a three-generation study of rats, Ambrose et al. (1976) reported a no-observed-adverse-effects level (NOAEL) and lowest-observed-adverse-effects level (LOAEL) of 5 mg/kg/day and 50 mg/kg/day, respectively. Doses of 24.15 mg/kg-day administered as nickel sulfate in the diet had no adverse effects on reproduction of the rats. Growth in dogs was depressed by dietary concentrations of 2500 ppm nickel sulfate hexahydrate; in the rats, growth was depressed at dietary concentrations >1000 ppm (Ambrose et al. 1976).

Weber and Reid (1968) fed a basal diet of up to 1300 ppm nickel sulfate or nickel acetate to domestic chicks for 4 weeks. Growth of chicks was significantly depressed at 700 ppm nickel and above. Doses of 21.4 mg/kg-day administered as nickel sulfate in the diet had no adverse effects on weight gain after 4 weeks. Mallard ducklings on diets with ≥800 ppm nickel would be adversely affected (Cain and Pafford 1981).

PCBs. Polychlorinated biphenyls (PCBs) are a family of man-made chemicals consisting of 209 individual compounds with varying toxicity (ATSDR 1989a). Aroclor is the trade name for PCBs made by Monsanto. Because of their insulating and nonflammable properties, PCBs were widely used in industrial applications such as coolants and lubricants in transformers, capacitors, and electrical equipment (ATSDR 1989a). The United States stopped manufacturing PCBs in 1977 due to evidence that they accumulate in the environment. PCBs have become widespread environmental contaminants.

Most exposures to PCBs are oral. Absorption of PCBs following oral exposure is often >90% (ATSDR 1989a). PCBs are preferentially stored in adipose tissues in animals. They may cross the placenta or be transferred to offspring through milk. PCBs with higher chlorine content (the last 2 digits of the Aroclor designation indicate the percent Cl content of the compound) tend to persist in the environment longer than those with lower Cl content, and PCBs are known to bioaccumulate and biomagnify to toxic concentrations in animals (Eisler 1986b; ATSDR 1989a). Chronic exposures are of particular concern. PCBs with high K_{ow} values and high numbers of chlorines in adjacent positions are generally the most toxic. Although relatively insoluble in water, PCBs are generally freely soluble in nonpolar organic solvents and in biological lipids (EPA 1980).

Sixty percent of mice fed diets containing 1,000 ppm Aroclor 1254 for 14 days died within 15 days, but none of the mice fed diets with only 250 ppm Aroclor for 14 days died (Sanders et al. 1974). These diets translate to doses of 130 and 32.5 mg/kg/day, respectively (ATSDR 1989a). White-footed mice fed 10 ppm Aroclor 1254 for 18 months had fewer offspring produced and a longer time between litters than control mice (Linzey 1987).

Feeding studies suggest a total intake of 500-2,000 mg/kg of Aroclor 1254 obtained through the diet over 1 to 7 weeks is lethal in rats (Hudson et al. 1984). Male rats consuming diets containing 0-100 ppm Aroclor 1254 for 104 weeks suffered dose-related reduced survival (NCI 1978); however, there was no effect on similarly treated female rats. Dietary concentrations of ≥20 ppm Aroclor 1254 reduced litter sizes in one- and two-generation reproduction studies with rats; concentrations <5 ppm had no effect (Linder et al. 1974).

Mink are one of the most susceptible mammals; dietary levels as low as 0.1 ppm fresh weight have caused death and reproductive toxicity (Eisler 1986b). Diets containing 20 ppm Aroclor 1242 were lethal to mink in a 247-day experiment. The LC_{50} for chronic exposures is 6.65 ppm Aroclor 1254 for mink over a 8 month period (Ringer et al. 1981). Diets containing 5 ppm Aroclor 1242 caused complete reproductive failure (Bleavins et al. 1980). Exposure for 160 days to 3.57 ppm Aroclor 1254 resulted in 100% mortality of adult mink (Platonow and Karstad 1973).

A chronic study was conducted over 4.5 months exposing mink to 1, 5 and 15 ppm Aroclor 1254 in the diet. There was a significant reduction in the number of offspring born alive at the 5 and 15 mg/kg exposures (Aulerich and Ringer 1977). Mink fed carp containing 1.5 ppm Aroclor 1254 for 6 months produced no offspring that survived to 24 hours (Hornshaw et al. 1983). No effects were observed in mink fed 0.64 ppm Aroclor 1254 for 160 days (Platonow and Karstad 1973). Exposure of mink for 6 months to 1 ppm Aroclor 1254 resulted in no significant difference from controls in number of offspring, or offspring mortality (Wren et al. 1987). Therefore, the 1 ppm dose was considered to be a chronic NOAEL.

A dietary dose of 25 ppm Aroclor 1254 fed for at lease a month before egg-laying in mallard ducks had no detrimental effect on reproductive success (Custer and Heinz 1980). Dietary exposure of 5 ppm Aroclor 1254 for 39 weeks to laying hens and roosters resulted in reduced egg production, although hatchability of fertile eggs was not affected (Platonow and Reinhart 1973). Screech owls fed 3 ppm Aroclor 1248 through two breeding seasons did not have significantly different reproductive success, relative to controls (McLane and Hughes 1980). Exposure of pheasants to 12.5 mg/bird/week (1.8 mg/kg/d) of Aroclor 1254 for 17 weeks resulted in significantly reduced egg hatchability (Dahlgren et al. 1972). Because this study considered exposure throughout a critical lifestage (reproduction), the 12.5 mg/bird/week dose was considered to be a chronic LOAEL.

Selenium. While selenium is an essential nutrient that interacts with Vitamin E and maintains muscle integrity, t has a very narrow tolerance range; in humans, while 0.04-0.1 ppm is required in diet, 4 ppm may produce toxic effects (Eisler 1985b). In mammals, chronic selenium poisoning is induced by diets containing 1–44 ppm selenium (Harr 1978). Symptoms include liver cirrhosis, lameness, loss of hair, emaciation, reduced conception, and increased fetal resorption. Plants convert inorganic selenium to organic selenium compounds, thereby increasing their biological availability (Lo and Sandi 1980).

To evaluate the effects of selenium on reproduction, Schroeder and Mitchner (1971) exposed mice to 3 ppm selenate in drinking water for three generations. This dosage level increased juvenile mortality, number of runts, and resulted in reproductive failure by the third generation. In another study, exposure to 3 ppm selenate or selenite in water for a lifetime had no effect on mouse longevity and no tumorigenicity was observed (Schroeder and Mitchner 1972).

Selenium is both embryotoxic and teratogenic to birds, with organic selenium (selenomethionine) being more toxic than inorganic selenium (Hoffman and Heinz 1988). Mallard ducks were fed diets containing 1, 5, 10, 25, or 100 ppm selenite (Heinz et al. 1987) or 1, 2, 4, 8, or 16 ppm selenomethionine (Heinz et al. 1989) for about 10 weeks. Exposure to 1, 5, or 10 ppm selenite or 1, 2, or 4 ppm selenomethionine in the diet had no effect on survival, growth, or reproductive success of adults. The diet containing 100 ppm selenite killed 11 of 12 adults. While only one adult receiving the 25 ppm diet died, time to laying, interval between eggs was increased, and duckling survivorship was reduced in this treatment (Heinz et al. 1987). Diets containing 8 and 16 ppm selenomethionine resulted in 6.8% and 67.9% malformed embryos, respectively. In addition, duckling survival was significantly reduced (Heinz et al. 1989).

The most visible incident of environmental selenium toxicity occurred at the Kesterson National Wildlife Refuge in California. Agricultural wastewater containing approximately 0.3 ppm selenium was used for marsh management at the refuge (Ohlendorf et al. 1986). Mean selenium concentrations in plants, invertebrates, and fish at the site were 22–175 ppm (dry weight). As a result, reproductive success among water birds was poor, and the incidence of embryo mortality and developmental abnormalities was dramatically increased. Raccoons on the refuge were found to bioaccumulate selenium (Clark et al. 1989). While peak births at the refuge was 2 months later than reported at other locations, no adverse effects on raccoon reproduction were observed.

Metabolism of selenium may be significantly modified through interactions with heavy metals, and selenium may provide some protection from adverse effects associated with various metals, including cadmium and mercury (Eisler 1985b). Arsenite inhibits methylation of selenium but increases fecal excretion of selenite (Venugopal and Luckey 1978).

Thallium. Thallium is a widely distributed metal, occurring at concentrations of approximately 1 ppm in the earths crust (Kazantzis 1979). Principal systems affected by Tl exposure include nervous and digestive; renal damage and hair loss have also been observed. Thallium sulfate, which has been widely used as a rodenticide, has an acute oral LD_{50} of 16 mg/kg (Ware 1978). In chronic studies, rats tolerated a dose of 10 mg Tl acetate/ kg, while 30 mg/kg was lethal to males by 15 weeks. All rats fed a daily dose of 0.45 mg Tl/kg died after 4 months (Kazantzis 1979). Rats exposed to 10 ppm Tl in drinking water for 2 mo accumulated Tl in testis and exhibited signs of testicular toxicity including reduced sperm motility (Formigli et al. 1986).

Bean and Hudson (1976) orally dosed 3 golden eagles with 60 and 120 mg Tl_2SO_4/kg bw; the bird receiving 60 mg Tl_2SO_4/kg survived while the two dosed with 120 mg Tl_2SO_4/kg died, suggesting an LD_{50} between the doses. Oral LD_{50}'s for quail, geese, and ducks are 12, 15, and 30 mg/kg respectively (Shaw 1933). No long-term studies of thallium toxicity to birds are currently available.

Uranium. Uranium is an element used as a nuclear fuel, in nuclear weapons production, and in its natural or depleted form as counterweights for airplanes and as shielding material (Burkart 1991). Its average concentration in the earth's crust is approximately 3–4 ppm (Merritt 1971).

Except for their radioactivity, metallic uranium and particles of insoluble uranium compounds are biologically inert. The chemical toxicity of uranium is exerted only by its aqueous ions (Durbin and Wrenn 1975). Aqueous ions have been identified for uranium (III), uranium (IV), uranium (V), and uranium (VI), but only uranium (IV) and uranium (VI) are stable in solution. In a solution of low acidity, uranium (IV) hydrolyzes to form insoluble hydroxides (Durbin and Wrenn 1975). Uranium (VI) is the most frequently encountered oxidation state in nuclear fuel cycles. Uranyl nitrate and uranyl fluoride are 1.4–2 times more toxic than UCl_5, UCl_4, UO_3, or $NO_2U_2O_7$ and 3 times more toxic than $(NH_4)_2U_2O_7$ (Durbin and Wrenn 1975). Uranium-235 is the most radioactive of the uranium isotopes. Other uranium isotopes including uranium-233, -234, and -238 have low specific activities, long half-lives, and have lower potential to cause radiation induced diseases (ATSDR 1990).

The absorption level of uranium compounds following oral exposure is generally considered to be quite low. In animals, once uranium has been absorbed following inhalation exposures, it leaves the blood very quickly for distribution to body tissues (ATSDR 1990). Some of the uranium reacts with the protein surface of the columnular cells lining the renal tubule and injures or kills these cells. With small or moderate doses, the distal portion of the proximal convoluted tubule receives the severest injury. If death ensues, it follows a typical uremia caused by kidney dysfunction. If the animal survives, cellular regeneration restores much of the kidney tissue and function (NAS 1980). Most of the absorbed uranium is excreted in the urine, and renal clearance of uranium (VI) in cats, dogs, humans, and rabbits is high (Durbin and Wrenn 1975). About 60% is excreted as a soluble bicarbonate complex, whereas the remainder is bound to plasma protein. Sixty percent is excreted in the urine within 24 hours. About 25% may be fixed in the bone (Chen et al. 1961).

The toxicity of uranium compounds depends on the degree of solubility, transport across cellular barriers, and absorption into blood. Toxicological effects from the ingestion of uranium are the result of the action of uranium as a metal and its radioactive properties. For humans and animals, uranium and its salts are highly toxic. Dermatitis, renal damage, and acute arterial lesions may occur. Acute intoxication may lead to irreversible damage and to death due to renal dysfunction (Burkart 1991). The primary toxic chemical effect of uranium is seen in kidney damage, but bone is considered the critical tissue for long-term radiation effects (ICRP 1959). Studies in rabbits, mice, and dogs showed kidney damage in a dose-related effect. Fetal skeletal abnormalities and fetal death were found in pregnant mice exposed to 6 mg/kg of uranyl acetate dihydrate (ATSDR 1990). Uranium toxicity is dependent upon and modified by many factors and most of the reported studies have been conducted with laboratory animals, primarily mice (NAS 1980). Herbivores may be highly sensitive because of the acidity of their urine (Dounce, 1951).

The acute LD_{50} for natural uranium injected in mice varies with strain and sex from 6–25 mg uranium/kg (Dounce et al. 1951; Tannenbaum and Silverstone 1951). It is somewhat lower for $^{233}UO_2(NO_3)_2$: 4.5 mg ^{233}U/kg (Durbin and Wrenn 1975). The toxicity benchmark for mammals is based on a 30-day study involving rabbits (Maynard and Hodge 1949). Doses of 2.8 mg/kg-day administered as uranium soluble salts in the diet had adverse effects on the kidneys of the rats. However, a dietary level of 400 ppm uranium appears to be safe for rats, even when the uranium is in a soluble form (NAS 1980).

Inhalation of uranium dioxide dust by rats, dogs, and monkeys at a concentration of 5 mg uranium/m^3 for up to 5 years produced accumulation in the lungs and tracheobronchial lymph nodes that accounted for 90% of the body burden. No evidence of toxicity was observed despite the long duration of observation (Leach et al. 1970). Doses up to 10 mg uranium/m^3 failed to cause excess mortality in dogs subjected to one year of continual inhalation (36 hrs/wk) (Durbin and Wrenn 1975). Following inhalation of the insoluble uranium salts, retention by the lungs is prolonged (Goyer 1991).

In a 6-week study of black ducks fed 0–1600 ppm powdered uranium in their feed, Haseltine and Sileo (1983) found no alterations in kidney or liver weights, no significant lesions, and no increase in mortality relative to controls. Doses of 86 mg/kg-day administered as depleted metallic uranium in the diet caused no adverse effects on the liver, kidney, or mortality rates of the ducks.

Vanadium. Vanadium is a metallic element that occurs in six oxidation states and numerous inorganic compounds. The toxicity of vanadium depends on its physico-chemical state, particularly on its valence state and solubility. Based on acute toxicity, pentavalent NH_4VO_3 has been reported to be more than twice as toxic as trivalent VCl_3 and more than 6 times as toxic as divalent VI_2. Pentavalent V_2O_5 has been reported to be more than 5 times as toxic as trivalent V_2O_3 (Roshchin 1967). In animals, acutely toxic oral doses cause vasoconstriction, diffuse desquamative enteritis, congestion and fatty degeneration of the liver, congestion and focal hemorrhages in the lungs and adrenal cortex (Gosselin et al. 1984). Minimal effects seen after subchronic oral exposures to animals include diarrhea, altered renal function, and decreases in erythrocyte counts, hemoglobin, and hematocrit (Domingo et al. 1985; Zaporowska and Wasilewski 1991).

A vanadyl sulfate concentration of 5 µg/mL in drinking water, plus a vanadium level of 3.2 µg/g in the diet (4.1 mg V/kg total) of mice, was reported to cause no adverse effects over a lifetime exposure period (Schroeder and Balassa 1967). In similar lifetime studies, rats and mice exhibited no adverse effects when exposed to 5 ppm vanadium (as vanadyl sulfate) in drinking water (Schroeder et al. 1970; Schroeder and Mitchner 1975b). The estimated dose levels were 0.7 mg V/kg/day for rats and 0.9 mg V/kg/day for mice. Vanadium pentoxide in the diet of rats at levels of 10 and 100 ppm for their entire lifetime resulted in no significant toxicological effects except for a reduction in hair cystine content (Stokinger 1981b).

White and Dieter (1978) observed no mortality among mallard ducks fed diets containing 1, 10, or 100 ppm vanadyl sulfate for 12 weeks. Altered lipid metabolism was observed among birds fed 100 ppm vanadium; no other effects were observed. Among chickens, 200 to 400 ppm $Ca_2(VO_4)_2$ in the diet produced 100% mortality; weight gain decreased among chicks fed 20 to 40 ppm $Ca_2(VO_4)_2$ (Romoser et al. 1961).

Zinc. Zinc makes up about 0.002% of the earth's crust (NAS 1980). Zinc is an essential trace element in all living organisms; it assures the stability of biological molecules and structures such as DNA, membranes, and ribosomes (Eisler 1993). It is used commercially primarily in galvanized metals and metal alloys, but zinc compounds also have wide applications as chemical intermediates, catalysts, pigments, vulcanization activators and accelerators in the rubber industry, UV stabilizers, and supplements in animal feeds and fertilizers. Zinc compounds are also used in rayon manufacture, smoke bombs, soldering fluxes, mordants for printing and dyeing, wood preservatives, mildew inhibitors, deodorants, antiseptics, and astringents (Lloyd 1984; ATSDR 1989b). In addition, zinc phosphide is used as a rodenticide.

Zinc occurs in nature as a sulfide, oxide, or carbonate (Eisler 1993). It is divalent in solution. In freshwater with pH >4 and <7 it exists almost exclusively as the aquo ion $(Zn(H_2O)_6)^{2+}$ (Campbell and Stokes 1985). Zinc interacts with many chemicals, and it may diminish the toxic effects of cadmium and protects against lead toxicosis in terrestrial animals (Eisler 1993). Background concentrations seldom exceed 0.040 mg/L in water or 200 mg/kg in soil or sediment (Eisler 1993).

Although it is essential for normal growth and reproduction (Prasad 1979; Stahl et al. 1989) and important to central nervous system function (Eisler 1993), the primary toxic effect of zinc is on zinc-dependent enzymes that regulate RNA and DNA. It is most harmful to aquatic life in conditions of low pH, low alkalinity, low dissolved oxygen, and elevated temperature. Zinc is relatively nontoxic in mammals, but excessive intake can cause a variety of effects. It is not known to be carcinogenic by normal exposure routes (Eisler 1993).

Gastrointestinal absorption of zinc is variable (20–80%) and depends on the chemical compound as well as on zinc levels in the body and on dietary concentrations of other nutrients (EPA 1984). Information on pulmonary absorption is limited and complicated by the potential for gastrointestinal absorption due to mucociliary clearance from the respiratory tract and subsequent swallowing. Pulmonary inflammation and changes in lung function have been observed in inhalation studies on animals (Amur et al. 1982; Lam et al. 1985; Drinker and Drinker 1928). Zinc is present in all tissues with the highest concentrations in the prostate, kidney, liver, heart, and pancreas. Zinc is a vital component of many metalloenzymes such as carbonic anhydrase, which regulates CO_2 exchange (Stokinger 1981).

In animals, gastrointestinal and hepatic lesions (Allen et al. 1983; Brink et al. 1959), pancreatic lesions (Maita et al. 1981; Drinker et al. 1927), anemia (ATSDR 1989b; Fox and Jacobs 1986; Maita et al. 1981), and diffuse nephrosis (Maita et al. 1981; Allen et al. 1983) have been observed following subchronic oral exposures. Anemia and pancreatitis were the major adverse effects observed in chronic animal studies (Aughey et al. 1977; Drinker et al. 1927; Walters and Roe 1965; Sutton and Nelson 1937). Teratogenic effects have not been seen in animals exposed to zinc; however, high oral doses can affect reproduction and fetal growth (Ketcheson et al. 1969; Schlicker and Cox 1967, 1968; Sutton and Nelson 1937).

Livestock and small mammals are tolerant of extended dietary loadings >100 times the minimum recommended daily zinc requirement (Eisler 1993). No adverse effects on general health or reproduction were observed in dairy cows fed 1310 mg zinc/kg food (Miller et al., 1989). A diet of 4000–5000 mg zinc/kg food for 18 days resulted in fetotoxicity and poor reproduction in rats (NAS 1979). Acute oral LD_{50} doses of 350–800 mg zinc/kg body weight have been reported for rats (Eisler 1993). Wlostowski et al. (1988) recommended 30 mg zinc/kg in the diet of bank voles.

Dogs on diets with up to 1000 mg zinc/kg of food for up to one year showed no measurable signs of damage (NAS 1979). Horses ingesting >90 mg zinc/kg body weight daily in the vicinity of a lead-zinc smelter exhibited decreased growth and death (NAS 1979). No effects were observed in mice fed <682 mg zinc/kg food (<109 mg zinc/kg body weight daily) for 13 weeks, but at 6820 mg zinc/kg food adverse effects on growth and survival were documented (Maita et al. 1981). In a 37-day study involving rats, doses of 97 mg/kg-day administered as zinc carbonate in the diet had no adverse effects on the reproductivity of rats (Kinnamon 1963). European ferrets (*Mustela putorius furo*) fed up to 500 mg zinc/kg for up to 197 days all survived with no significant histopathologies, but those fed 1500 or 3000 mg/kg diet died within 21 days (Straube et al. 1980; Reece et al. 1986). Reproduction ceased entirely in female rats ingesting a diet with 500 mg zinc/kg/day (Sutton and Nelson 1937), possibly a result of zinc-induced anemia.

Mallards (*Anas platyrhynchos*) fed diets containing >3000 mg zinc/kg for 30 or 60 days suffered leg paralysis, decreased food consumption, and high mortality (Gasaway and Buss 1972; NAS 1979). Egg production in Japanese quail (*Coturnix coturnix japonica*) hens fed 15,000 mg zinc (as ZnO)/kg feed for 7 days decreased to near zero within 3 days (Hussein et al. 1988). Seven percent of 14-day old quail fed 600 mg zinc (as zinc phosphide)/kg feed over 5 days died, 53% of those fed 990 mg/kg died, and 93% of those fed 1634 mg/kg died (Hill and Camardese, 1986). Domestic chicken pullets and hens on a diet with 20,000 mg zinc/kg feed for 5 days were lighter weight by day 5 and produced significantly fewer eggs for 4 weeks following treatment (Palafox and Ho-A 1980). Eggs collected 14–28 days post-treatment had reduced fertility and hatchability. However, normal growth, egg production, fertility, and hatchability was observed 4–12 weeks post-treatment. Acute oral LD_{50} values for zinc phosphide, a rodenticide, were between 16 and 47 mg/kg body weight in ring-necked pheasants (*Phasianus colchicus*), golden eagles (*Aquila chrysaetos*), mallards, and horned larks (*Eremophila alpestris*) (Hudson et al. 1984), but much of the biocidal action is attributed to the phosphide rather than the zinc (Eisler 1993).

Diets containing 28, 48, 228, or 2028 mg zinc/kg for 12–44 weeks had no effect on overall egg production by domestic chickens although zinc levels were elevated in hens on the highest zinc diet (Stahl et al. 1990). All day-old chicks fed diets containing 16,000 mg zinc/kg feed for 5 weeks and 80% of those fed 8000 mg/kg died; those on a 4000 mg zinc/kg diet showed no significant reductions in growth or survival (Oh et al. 1979). In a 60-day study, doses of 170 mg/kg-day administered as zinc carbonate in the diet caused increased mortality and altered blood chemistry in mallards (Gasaway and Buss 1972).

In chickens, adverse effects associated with zinc deficiency have been observed at <38 mg zinc/kg dry weight feed (Blamberg et al. 1960; Westmoreland and Hoekstra 1969; Stahl et al., 1989), but concentrations of 93–120 mg/kg are suggested as adequate in the diet (Blamberg et al. 1960; Westmoreland and Hoekstra 1969). Greater than 178 mg/kg dry weight feed is considered excessive (Stahl et al. 1989), and dietary concentrations >2000 mg/kg dry weight feed are considered toxic (NAS 1979; Oh et al. 1979; Stahl et al. 1990). Turkey poults tolerated zinc levels up to 2000 ppm in starter diets for 21 days with no deleterious effects, but levels ≥4000 ppm resulted in marked growth depression (Vohra and Kratzer 1968). No mortality was observed in poults on a diet containing 10,000 ppm zinc (Vohra and Kratzer, 1968), but increased mortality has been observed for chickens on diets with 3000 ppm zinc (Roberson and Schaible 1960).

Appendix E

REPRODUCTIVE PERFORMANCE OF MINK

REPRODUCTIVE PERFORMANCE OF MINK

Richard S. Halbrook
Cooperative Wildlife Research Laboratory
Southern Illinois University

1. INTRODUCTION

Plant operations and waste disposal at the Oak Ridge National Laboratory (ORNL), the Gaseous Diffusion Plant (ORGDP), and the Weapons Plant (Y-12) have introduced an assortment of potentially harmful contaminants into the surrounding environment (Ashwood et al. 1986, Suter 1990). The potential for off-reservation transport of contaminants by streams on the Oak Ridge Reservation (ORR) that empty into the Clinch and Tennessee River systems is a concern.

Contaminants of special concern include mercury (Hg) and polychlorinated biphenyls (PCB's) (Suter 1990). Elevated concentrations of Hg and PCB's have been found in fish collected from East Fork Poplar Creek (EFPC) and Bear Creek, and elevated concentrations of PCB's also have been found in fish from White Oak Creek (Loar 1990). East Fork Poplar Creek and Bear Creek originate within the Y-12 Plant and flow into Poplar Creek north of the K-25 Plant and White Oak Creek flows through ORNL. Both creeks empty into the Clinch River on the upper reach of Watts Bar Lake. In the Screening Level Risk Assessment for the Off-Site Ecological Effects in Surface Waters Downstream from the U.S. Department of Energy Oak Ridge Reservation, Suter (1990) indicated that piscivorous wildlife along the Clinch River are at risk.

Mink (*Mustela vison*) have been shown to be among the most sensitive, if not the single most sensitive, mammalian species to polychlorinated biphenyl (PCB) toxicity (Aulerich and Ringer 1977). Feeding studies conducted by Aulerich *et al.* (1971, 1973), Hornshaw *et al.* (1983), and Heaton (1992) have demonstrated the extreme sensitivity of mink to chlorinated hydrocarbon contaminants, especially PCBs, contained in fish taken from the Great Lakes. Additional studies have shown this species also to be sensitive to other halogenated hydrocarbons, including polybrominated biphenyls (Aulerich and Ringer 1979), hexachlorobenzene (Bleavins *et al.* 1988) and mercury (Hg) (Aulerich et al. 1974, Wobeser and Swift 1976, Wobeser et al. 1976). Numerous other toxicological studies with mink have been reported in the literature (Scientifur 1987, Sundqvist 1989, Leonards et al. 1994) and summarized by Calabrese *et al.* (1992). In addition, mink have been recommended as an indicator species for the goal of virtual elimination of persistent toxic substances in the Great Lakes by the International Joint Commission Virtual Elimination Task Force Biomarker Workshop (personal communication from Glen Fox, Environment Canada, Ottawa, Ontario).

Because mink are sensitive to PCB and Hg toxicity and inhabit wetland areas, they are potentially good indicators of environmental effects of these chemicals in aquatic habitats. However, mink are secretive and population densities tend to be low (male home ranges average 2,600 m in stream length, Dunstone 1993), making assessment of environmental contaminant effects in natural populations difficult. Since it is known that fish inhabiting aquatic systems downstream from the Oak Ridge Reservation (ORR) contain elevated concentrations of PCBs and Hg (Sect. 3.5.1), and that fish are a major food item of mink, the objectives of this study were to compare biological accumulation of environmental contaminants and reproductive effects in mink fed fish collected on the ORR to accumulation and effects in mink fed fish collected from the Clinch River above the ORR, or from the ocean.

2. MATERIALS AND METHODS

2.1 Fish Collection and Diet Preparation

Fish used in mink diets were collected from the reach of Poplar Creek between East Fork Poplar Creek and the confluence of Poplar Creek with the Clinch River (on the ORR) and from the Clinch River above Melton Hill Dam near Bull Run Power Plant (above the ORR), or were ocean fish (mackerel) obtain from a commercial supplier. Fish collected on the ORR and above the ORR were identified, weighted, placed in labeled plastic bags, frozen and shipped on dry ice for overnight delivery to the Michigan State University (MSU) Experimental Fur Farm. Ocean fish were frozen and shipped directly to MSU by a commercial supplier. At MSU, fish collected from the same location were ground through a 3/8 inch plate and mixed in a paddle mixer. This process was repeated until all fish from the same location were ground and mixed together so that a homogeneous mixture was obtained. Ten aliquots of the homogeneous mixture were placed in whirlpac bags, labelled, and frozen for contaminant analyses. This process was repeated for fish collected from each source.

Five diets, each composed of 75% fish and 25% normal ranch mink chow, were prepared. Appropriate proportions of homogenized fish from prescribed locations were blended with components of normal mink diet (eggs, liver, vitamin and mineral premix, d-biotin, and cereal). The fish portion of 2 diets (A and B) contained 75% ocean fish and 75% fish collected above the ORR (Clinch River above Melton Hill Dam), respectively. These served as reference diets for this study. The fish portion of the remaining 3 diets (C, D, and E) contained 25, 50 and 75% fish collected on the ORR and 50, 25, and 0% ocean fish, respectively. All diets were formulated to meet the nutrient requirements of the mink (NRC, 1982). Diet proximate analyses were determined by MSU. Ten aliquots of each diet were placed in whirlpac bags, labelled, and frozen for contaminant analyses.

2.2 Mink Feeding Experiment

Fifty adult, natural dark mink from the MSU Experimental Fur Farm, Michigan State University (MSU), East Lansing, Michigan were uniquely identified and randomly divided into 5 groups of 2 males and 8 females per group. Mink were housed individually in wire cages (61 x 76 x 46 cm) with attached nest boxes (38 x 28 x 27 cm). Cages were suspended above the ground in open-sided sheds. Throughout the study, mink were provided food and drinking water *at libitum* and exposed to ambient temperature and photoperiod. Mink were immunized against canine distemper, virus enteritis, infectious pneumonia, and botulism, and provided thiamine daily to prevent thiamine deficiency resulting form thiaminase in fish. Mink were acclimated to the test facilities for at least one week prior to the definitive test.

Each mink group was fed one of the prepared diets from December 1, 1993 (approximately 3 months prior to breeding) through approximately June 30, 1993 (6 weeks postpartum). Mink were weighed at the beginning of the feeding trials and at monthly intervals thereafter (except during the gestation period). They were observed daily and any behavioral changes or clinical signs of toxicity recorded.

Mating began March 1, 1994 and was confined within the respective groups. Females were given an opportunity to mate every fourth day until a confirmed mating (presence of motile spermatozoa in vaginal aspirations) was obtained. The mated females were given an opportunity for a second mating the day following the initial mating or eight days later (a standard commercial mink ranch practice). The bred females were checked daily during gestation for evidence of whelping. The gestation period of mink averages 51 days but is highly variable (42 to 65 days) due to delayed implantation. Whelped kits were counted, sexed, and weighed on the day of birth and at three and six weeks of age. Mink kits begin to consume solid feed at 21 to 24 days of age and are weaned at 6 weeks. Thus, kit body weight at 3 weeks of age provides a good indication of the lactational performance of the female. Reproductive indices measured included: number of females mated; number of females whelping; length of gestation; number of kits whelped (alive, dead); kit sex ratio; average kit body weight at birth, 3, and 6 weeks of age; and kit survival to 3 and 6 weeks of age.

Adult mink with > 30 % decrease in original body weight and all adults at the termination of the study were euthanized (CO_2). All adult mink were necropsied, organ (brain, liver, kidneys, heart, lungs, gonads, and adrenal glands) weights were recorded and samples of adipose, liver, kidney, and hair collected for residue analysis. At 6 weeks of age, 3 kits each from 3 randomly selected females from dietary groups A, B, C, and E were euthanized, liver, spleen, and kidneys weighed, and samples (liver, kidney, and remaining carcass) collected for residue analyses. Tissue samples (brain, liver, kidney, heart, lungs, and adrenal gland) also were collected from adult mink and preserved in 10% formalin for histopathologic examination.

Ten aliquots, each, of homogenized fish and mink diets, and collected mink tissues were shipped frozen to the Southwest Research Institute, San Antonio, TX for PCB (Aroclors), CB (congeners) and mercury concentration determination. Adult mink liver and fat tissues and kidney, liver, and hair tissues were analyzed for Aroclor and CB concentrations, and mercury concentration, respectively. Liver tissue also was analyzed for ethoxyresorufin-o-deethylase (EROD) activity. Kit whole carcass and liver tissue, and whole carcass and kidney tissues were analyzed for PCB and CB concentrations, and mercury concentration, respectively. Lipid concentration (% lipid) was determined for all samples analyzed for PCBs

PCB Aroclor and congener results were adjusted for lipid concentration (tissue concentrations divided by the % lipid) prior to statistical analysis. Results of contaminant analyses, physiological measurements, and reproductive parameters were statistically evaluated for differences among diet groups and between diet groups A or B and E using non-parametric (Wilcoxon or Kruskel-Wallis) and gausian (t-test or ANOVA) tests.

3. RESULTS

The species composition of fish collected from the ORR and the Clinch River above Melton Hill Dam were similar and consisted mostly of benthic species (Table E.1). Mean mercury concentrations were significantly different among fish collected from the ORR, Clinch River, or ocean (Table E.2). Mean mercury concentrations in mink diets increased progressively from diet A through diet E (Table E.2). Correspondingly, mercury concentrations in liver, kidney, and hair of adult female mink increased progressively in mink fed diets A through E (Table E.3). Mercury concentrations in kit kidney tissue and homogenized carcass were not significantly different in offspring of mink fed diets A, B, or C, but were significantly greater ($P < 0.05$) in offspring of mink fed diet E (Table E.3).

3.1 PCB and Congener Profiles in Fish and Mink Diets

Aroclor 1260 was the dominant Aroclor detected in aliquots of homogenized fish, mink diets, and tissues of adult mink and kits, although Aroclor 1254 also was quantified in several tissue samples. Aroclor 1260 was quantified in aliquots of all diets except for diet A (75% ocean fish), in fat tissue from mink in all diet groups except diet group C, and in liver tissue of mink from diet groups D and E. Twenty-three specific congeners, including 8 coplanar congeners (non-ortho or mono-ortho congeners), were evaluated in homogenized fish, diets, liver and fat tissues of adult mink, and liver tissue and carcass of kits. Ninety-six percent of congener concentrations were significantly different among ocean, ORR, and Clinch River homogenized fish, including all but one coplanar congeners (Table E.4). In all cases where significant differences existed in homogenized fish congener concentrations among collection sites, the greatest concentrations were in fish collected from the ORR. Aroclor 1260 and 87% of the congener evaluated also were quantified in mink diets (Table E.5). Mean Aroclor 1260 concentration was significantly greater ($P < 0.01$) in diet E compared to concentrations other diets. Coplanar CBs 126 and 189 were not detected in any diets, CB 156 was detected in low concentrations in diets B, C, and D, and CBs 77 and 81 were quantified in low concentrations in diets C, D, and E, while CB 167 was only quantified in diets D and E. Concentrations of coplanar CB 118 were significantly greater ($P < 0.01$) in aliquots of diet E compared to aliquots of the other diets. Mean concentrations of CB 123 progressively increased from diet C to D, however, quantified concentrations in diet E were surprisingly lower than concentrations in diet C. Low concentrations of this CB in diet E are thought to result from matrix interference in this diet. Similarly, lower than expected concentrations were quantified for CBs 99, 101, 156, and 171 in diet E. The remaining non-plainer congener concentrations were generally greatest in aliquots from diet E (Table E.5).

3.2 PCB and Congener Profile in Mink Tissues

Mean Aroclor 1260 concentration was significantly greater in liver tissue of female mink fed diet E (Table E.6). Coplanar CB 189 was quantified at low concentrations (<21 ppb) in liver tissue from all mink fed diet E, 50% of those fed diet D, and less than 10% of those fed diets A, B, or C. Liver concentrations of CB 126 were significantly greater ($P < 0.01$) in samples collected from female mink fed diet E. Low concentrations (<32 ppb) of CB 126 also were quantified in liver tissue from female mink fed diets B and D. Mean liver concentrations of coplanar CBs 77 and 81 were ≤ 6 ppb in all female mink regardless of diet. Mean concentrations of CBs 156 and 167 increased progressive in liver tissue from female mink fed diets A - E and were significantly greater ($P < 0.01$) in mink fed diet E compared to those fed diets A or B. Mean concentration of coplanar CBs 118 and 123 were significantly greater in liver tissue from female mink on diet E compared to concentrations in liver tissue from mink fed diets A or B. There were significant differences ($P < 0.05$) in all female mink liver tissue non-planar congener concentrations among diet groups. For all non-planar congener in female liver tissue, concentrations were significantly greater ($P < 0.05$) in tissues from diet E mink compared to diet A mink, except for concentrations of CBs 195 and 196 which were not significantly different. Similarly, mean female mink liver concentrations of all non-planar congeners were significantly greater in female mink liver from diet group E mink compared to diet group B mink, except for CBs 146, 153, 170, 180, 183, and 201 which were not significantly different between these diet groups.

Mean Aroclor 1260 concentration in fat tissue from female mink fed diet E were significantly greater than mean concentrations from female mink fed diets A or B (Table E.7). Mean concentrations of all coplanar CBs were significantly greater ($P < 0.05$) in fat tissue from female mink fed diet E compared to mean concentrations in mink fed diets A or B, except that there was no difference in CB 126 fat concentration between female mink fed diets E and B. Non-planar CB mean concentrations were significantly greater ($P < 0.05$) in fat tissue from female mink fed diet E compared to mean concentrations in mink fed diets A or B, except CBs 170, 194, and 195. There was no difference between CB 170 or 194 mean fat concentrations between female mink fed diets B or E, and mean fat concentration of CB 195 in female mink was significantly greater ($P < 0.05$) in female mink fed diet B compared to diet E.

Concentrations of coplanar CBs 77, 81, 123, 156, and 189 were < 20 ppb in liver tissue from kits in all diet groups (Table E.8). Concentrations of coplanar CBs 118, 126, and 167 were significantly greater ($P < 0.05$) in liver from diet E kits compared to those from diets A, B, or C. Concentrations of non-planar CBs 101, 151, 171, and 195 were < 15 ppb in liver tissue from kits in all diet groups. Concentrations of the remaining non-planar CBs quantified were greater in liver tissue of diet E kits.

The pattern of concentrations of coplanar CBs in kit carcass homogenates from the various diets were similar to those observed in kit liver tissue (Table E.9). Except, the concentration of coplanar CB 126 was < 25 ppb in kit carcass homogenates and the concentration of CB 156 was significantly greater ($P < 0.05$) in kit carcass homogenates from diet group E compared to other diet groups. Concentration patterns of non-planar CBs in the various diet groups also were similar in carcass homogenates compared to concentrations in liver tissue. Except concentrations of CBs 151 and 196 were the only CBs with concentrations < 25 ppb. Concentrations of all other CBs quantified were greater in homogenized carcasses of kits from diet group E.

3.3 Physiological and Reproductive Effects

Two mink from diet group A, one male and one female, died during the experimental period. The male died on March 18, 1994 from hemorrhagic and necrotizing cystitis and the female died on April 24, 1994 due to complications during parturition. In addition to these adult mink, kits from one female in diet group B developed staph infections and all but one diet prior to 6 weeks of age.

One, 2, and 4 females did not whelp in diet groups A and B, D, and C, respectively (Table E.10) . Two females that did not whelp (1 from diet group A and 1 from diet group C) had cyst in the reproductive tracts that probably interfered with normal reproduction. Two females that did not whelp (1 from diet group C and 1 from diet group D) had no placental scars in the uterus and therefore probably were not pregnant. The reason the remaining 4 females did not whelp is unknown.

Mean whole body weights of female mink were not significantly different among diet groups at the beginning of the experimental period, however, mean weights of females in diet group E were significantly less ($P=0.03$) than mean weights of females in diet group A at the end of the experimental period (Table E.10). Mean female relative organ weights (organ weights/body weight) were not significantly different among diet groups. At 6 weeks of age, mean whole body weights were significantly lower ($P=0.004$) in male kits from diet group E compared to those from diet group A. A similar trend was observed in 6 week old female kits, although differences were not statistically significant. Mean relative kidney weights were significantly lower ($P=0.003$) in kits from diet group B ($\bar{x} = 1.0$ g) compared to those from diet group E ($\bar{x} = 1.3$ g). Kit mean relative liver and spleen weights were not significantly different among diet groups. No histological lesions were attributed to diets.

Mean litter size was significantly reduced (P=0.01) in diet group E compared to diet groups A, B, and C but not diet group D (Table E.10). Liver EROD activity was significantly increased in adult female mink from diet groups D and E compared to those from diet group A (Table E.10).

Although concentrations of mercury and PCBs were greater in fish collected from streams located on the ORR and these contaminants were higher in diets fed to mink with increasing percentage of ORR fish, reproductive effects were only noted in mink fed 75% ORR fish. Liver EROD activity, a sensitive biomarker of exposure to PCBs increased in mink fed diets containing 50% and 75% fish collected from the ORR.

Although fish are a major food item in the diet of wild mink, the proportion of fish in their diets normally does not exceed 40-60%. However, in addition to fish, concentrations of contaminants in other food items (crayfish, frogs, muskrat, ducks, and reodents) need to be evaluated in assessing effects of contaminants on mink living on the ORR.

Table E.1. Percent by weight of the most common fish species collected from the ORR and Clinch River above Melton Hill Dam

Common name	ORR %	Weight kg	Clinch River %	Weight kg
Sucker	17	280	3	12
Carp	20	330	24	97
Catfish	15	248	13	53
Shad	7	116	6	24
Buffalo	17	280	42	170
Other species	24	396	12	49
TOTALS	100	1,650	100	405

Table E.2. Mean mercury concentrations (ppm, wet wt) in homogenized fish[1] collected on the ORR[2], Clinch River above the ORR[3], and from the ocean[4] and diets fed to mink

	N[5]	MEAN[6]	SE	MIN	MAX
LOCATION					
On the ORR	10	0.35[a]	0.03	0.17	0.43
Clinch River	10	0.07[b]	0.00	0.05	0.09
Ocean	10	0.03[c]	0.00	0.02	0.04
DIET					
A[7]	10	0.02[a]	0.00	0.02	0.03
B[8]	10	0.05[b]	0.00	0.04	0.06
C[9]	10	0.09[c]	0.00	0.08	0.11
D[10]	10	0.15[d]	0.01	0.12	0.18
E[11]	10	0.22[e]	0.01	0.16	0.24

[1]Various fish species.
[2]Poplar Creek between East Fork Poplar Creek and confluence with the Clinch River.
[3]Above Melton Hill Dam near Bull Run Power Plant.
[4]Mackerel purchased from commercial supplier.
[5]Number of aliquots analyzed.
[6]Means followed by different letters are significantly different, $P<0.05$.
[7]75% ocean fish, 25% ranch mink diet.
[8]75% fish collected from the Clinch River above the Oak Ridge Reservation (ORR), 25% ranch mink diet.
[9]25% fish collected from Poplar Creek on the ORR, 50% ocean fish, 25% ranch mink diet.
[10]50% fish collected from Poplar Creek on the ORR, 25% ocean fish, 25% ranch mink diet.
[11]75% fish collected from Poplar Creek on the ORR, 25% ranch mink diet.

Table E.3. Mercury concentration (ppm, wet wt) in tissues from female mink fed (n=8/diet) various diets[1] and their 6-week-old kits

		Diet A	Diet B	Diet C	Diet D	Diet E
ADULT FEMALE MINK						
Liver Hg	Mean[2]	0.41[a]	0.61[a]	1.06[a]	1.93[b]	3.67[c]
	SE	0.07	0.06	0.10	0.15	0.32
	Range	0.17-0.8	0.47-0.87	0.74-1.49	1.26-2.47	2.52-5.20
Kidney	Mean	0.84[a]	1.25[ab]	2.22[bc]	3.47[cd]	4.35[d]
	SE	0.13	0.18	0.35	0.52	0.34
	Range	0.25-1.46	0.53-1.96	1.24-4.22	2.38-7.00	3.33-6.25
Hair Hg	Mean	3.79[a]	7.43[b]	7.71[b]	13.44[c]	19.03[d]
	SE	0.26	0.55	0.63	0.79	0.57
	Range	2.20-4.61	5.05-9.70	4.38-9.62	10.2-15.6	16.8-21.4
KITS						
Carcass	Mean	0.02[a]	0.03[a]	0.05[a]		0.20[b]
	SE	0.004	0.003	0.003		0.02
	Range	0.01-0.05	0.02-0.05	0.04-0.06		0.10-0.30
	N	9	9	8		9
Kidney	Mean	0.03[a]	0.03[a]	0.06[a]		0.19[b]
	SE	0.001	0.003	0.003		0.02
	Range	0.02-0.04	0.02-0.04	0.05-0.07		0.11-0.31
	N	9	9	8		9

[1]Diet A = 75% ocean fish, Diet B = 75% fish collected above the Oak Ridge Reservation, Diet C = 25% fish collected on the Oak Ridge Reservation and 50% ocean fish, Diet D = 50% fish collected on the Oak Ridge Reservation and 25% ocean fish, Diet E = 75% fish collected on the Oak Ridge Reservation.

[2]Means with different superscripts are significantly different, $P<0.05$.

Table E.4. Mean[1] ±SE lipid adjusted Aroclor 1260 and PCB congener concentrations (ppm, wet wt) in homogenized fish[2] collected on the ORR[3], Clinch River above the ORR[4], and from the ocean[5]

	Ocean	Clinch River	ORR
CB 77	0.022^{a}±0.000 (10)	0.039^{b}±0.001 (10)	0.190^{c}±0.004 (10)
CB 81	0.053^{a}±0.001 (10)	0.592^{b}±0.062 (10)	1.419^{c}±0.262 (9)
CB 99	0.022^{a}±0.000 (10)	0.076^{b}±0.011 (10)	0.894^{c}±0.015 (10)
CB 101	0.022^{a}±0.000 (10)	0.142^{b}±0.022 (10)	0.609^{c}±0.010 (10)
CB 118	0.022^{a}±0.000 (10)	0.468^{ab}±0.219 (10)	1.150^{b}±0.030 (9)
CB 123	0.022^{a}±0.000 (10)	0.039^{ab}±0.001 (10)	0.051^{b}±0.010 (10)
CB 126	0.022^{a}±0.000 (10)	0.039^{b}±0.001 (10)	0.041^{b}±0.001 (10)
CB 128	0.022^{a}±0.000 (10)	0.178^{b}±0.003 (10)	0.636^{c}±0.012 (10)
CB 138	0.022^{a}±0.000 (10)	0.706^{b}±0.014 (10)	1.611^{c}±0.052 (9)
CB 146	0.022^{a}±0.000 (10)	0.388^{b}±0.007 (10)	0.822^{c}±0.023 (10)
CB 151	0.039^{a}±0.002 (10)	0.496^{b}±0.008 (10)	1.731^{c}±0.048 (10)
CB 153	0.074^{a}±0.002 (10)	2.813^{b}±0.082 (10)	4.733^{c}±0.123 (9)
CB 156	0.022^{a}±0.000 (10)	0.039^{b}±0.001 (10)	0.078^{b}±0.037 (10)
CB 167	0.022^{a}±0.000 (10)	0.044^{b}±0.003 (10)	0.193^{c}±0.003 (10)
CB 170	0.022^{a}±0.000 (10)	0.455^{b}±0.010 (10)	1.315^{c}±0.025 (10)
CB 171	0.022^{a}±0.000 (10)	0.039^{b}±0.001 (10)	0.041^{b}±0.001 (10)
CB 180	0.022^{a}±0.000 (10)	3.021^{b}±0.099 (10)	3.592^{c}±0.088 (10)
CB 183	0.022^{a}±0.000 (10)	0.690^{b}±0.012 (10)	1.000^{c}±0.016 (10)
CB 189	0.022^{a}±0.000 (10)	0.039^{b}±0.001 (10)	0.041^{b}±0.001 (10)
CB 194	0.022^{a}±0.000 (10)	0.376^{b}±0.009 (10)	0.430^{c}±0.006 (10)
CB 195	0.022^{a}±0.000 (10)	0.042^{b}±0.002 (10)	0.043^{b}±0.002 (10)
CB 196	0.022^{a}±0.000 (10)	0.570^{b}±0.014 (10)	1.660^{c}±0.041 (10)
CB 201	0.022^{a}±0.000 (10)	0.486^{b}±0.009 (10)	0.605^{c}±0.008 (10)
Aroclor 1260	0.379^{a}±0.008 (10)	21.917^{b}±0.681 (10)	28.997^{c}±0.659 (10)

[1]Means with different superscripts are significantly different, $P<0.05$.
[2]Various fish species.
[3]Poplar Creek between East Fork Poplar Creek and confluence with the Clinch River.
[4]Above Melton Hill Dam near Bull Run Power Plant.
[5]Mackerel purchased from commercial supplier.

Table E.5. Mean ±SE lipid adjusted Aroclor 1260 and PCB congener concentrations (ppm, wet wt) in mink diets[1] (n=10/diet)

	Diet A	Diet B	Diet C	Diet D	Diet E
CB 77	0.025±0.000	0.037±0.001	0.046±0.003	0.102±0.002	0.116±0.005
CB 81	0.027±0.002	0.337±0.051	0.507±0.011	0.873±0.022	1.158±0.033
CB 99	0.025±0.000	0.037±0.001	0.276±0.011	0.531±0.014	0.520±0.013
CB 101	0.031±0.004	0.239±0.032	0.288±0.009	0.585±0.012	0.396±0.020
CB 118	0.025±0.000	0.117±0.010	0.192±0.007	0.405±0.007	0.668±0.021
CB 123	0.025±0.000	0.037±0.001	0.212±0.008	0.446±0.008	0.076±0.003
CB 126	0.025±0.000	0.037±0.001	0.027±0.001	0.038±0.003	0.033±0.001
CB 128	0.025±0.000	0.085±0.003	0.104±0.004	0.228±0.005	0.351±0.013
CB 138	0.080±0.002	0.791±0.087	0.331±0.011	0.690±0.009	1.048±0.020
CB 146	0.025±0.000	0.037±0.001	0.141±0.006	0.335±0.007	0.501±0.015
CB 151	0.025±0.000	0.314±0.010	0.254±0.009	0.555±0.009	1.058±0.039
CB 153	0.025±0.000	1.862±0.025	0.766±0.029	1.772±0.026	3.126±0.056
CB 156	0.025±0.000	0.139±0.013	0.065±0.002	0.094±0.015	0.033±0.001
CB 167	0.025±0.000	0.037±0.001	0.027±0.001	0.061±0.003	0.103±0.004
CB 170	0.025±0.000	1.847±0.964	0.154±0.007	0.346±0.008	0.798±0.016
CB 171	0.025±0.000	0.037±0.001	0.061±0.002	0.127±0.003	0.033±0.001
CB 180	0.025±0.000	1.011±0.266	0.507±0.019	1.091±0.018	2.292±0.040
CB 183	0.025±0.000	0.276±0.053	0.170±0.006	0.355±0.007	0.573±0.019
CB 189	0.025±0.000	0.037±0.001	0.027±0.001	0.031±0.000	0.033±0.001
CB 194	0.025±0.000	0.058±0.022	0.072±0.008	0.149±0.020	0.245±0.009
CB 195	0.025±0.000	0.039±0.003	0.027±0.001	0.033±0.002	0.033±0.001
CB 196	0.025±0.000	1.081±0.084	0.184±0.008	0.415±0.008	1.071±0.024
CB 201	0.025±0.000	0.230±0.034	0.060±0.002	0.131±0.003	0.338±0.010
Aroclor 1260	0.169±0.002	11.440±0.327	4.697±0.174	10.405±0.250	20.670±0.458

[1]Diet A = 75% ocean fish, Diet B = 75% fish collected above the Oak Ridge Reservation, Diet C = 25% fish collected on the Oak Ridge Reservation and 50% ocean fish, Diet D = 50% fish collected on the Oak Ridge Reservation and 25% ocean fish, Diet E = 75% fish collected on the Oak Ridge Reservation.

Table E.6. Mean ±SE lipid adjusted Aroclor 1260 and PCB congener concentrations (ppm, wet wt) in liver tissue from female mink (n=8/diet) fed various diets[1]

	Diet A	Diet B	Diet C	Diet D	Diet E
CB 77	0.048±0.016	0.081±0.010	0.033±0.004	0.095±0.040	0.028±0.005
CB 81	0.048±0.016	0.054±0.010	0.033±0.004	0.095±0.040	0.197±0.117
CB 99	0.048±0.016	0.117±0.014	0.420±0.061	0.962±0.123	0.823±0.215
CB 101	0.048±0.016	0.053±0.011	0.033±0.004	0.145±0.019	0.154±0.015
CB 118	0.141±0.008	0.590±0.040	1.066±0.153	2.157±0.406	1.656±0.332
CB 123	0.048±0.016	0.041±0.006	0.033±0.004	0.095±0.040	1.598±0.228
CB 126	0.048±0.016	0.224±0.023	0.033±0.004	0.095±0.040	1.703±0.251
CB 128	0.048±0.016	0.174±0.023	0.151±0.024	0.353±0.054	0.691±0.097
CB 138	0.136±0.023	2.063±0.479	2.083±0.224	4.816±0.915	5.649±0.465
CB 146	0.059±0.015	0.627±0.051	0.545±0.055	1.188±0.113	0.604±0.111
CB 153	0.206±0.020	5.075±0.445	3.858±0.365	8.063±1.195	7.242±1.658
CB 156	0.048±0.016	0.228±0.074	0.193±0.037	0.480±0.102	0.648±0.102
CB 167	0.048±0.016	0.125±0.013	0.166±0.020	0.244±0.077	0.776±0.100
CB 170	0.057±0.015	2.249±0.219	0.774±0.144	1.971±0.444	1.878±0.194
CB 171	0.048±0.016	0.041±0.006	0.093±0.013	0.217±0.027	0.774±0.065
CB 180	0.131±0.015	6.576±0.772	3.117±0.390	6.980±1.296	7.752±0.815
CB 183	0.048±0.016	0.412±0.032	0.229±0.024	0.479±0.097	0.527±0.086
CB 189	0.048±0.016	0.044±0.007	0.042±0.007	0.137±0.038	0.106±0.013
CB 194	0.050±0.016	1.887±0.208	0.803±0.086	1.795±0.202	1.218±0.174
CB 195	0.048±0.016	0.041±0.006	0.192±0.018	0.457±0.035	0.115±0.015
CB 196	0.068±0.015	2.998±0.302	0.033±0.004	0.095±0.040	1.863±0.985
CB 201	0.048±0.016	2.085±0.261	0.245±0.084	1.448±0.459	2.794±0.356
Aroclor 1260	0.344±0.132	0.270±0.039	0.230±0.021	0.723±0.329	79.486±8.112

[1]Diet A = 75% ocean fish, Diet B = 75% fish collected above the Oak Ridge Reservation, Diet C = 25% fish collected on the Oak Ridge Reservation and 50% ocean fish, Diet D = 50% fish collected on the Oak Ridge Reservation and 25% ocean fish, Diet E = 75% fish collected on the Oak Ridge Reservation.

Table E.7. Mean ±SE Aroclor 1260 and PCB congener concentrations (ppm, wet wt) in fat tissue from female mink (n=8/diet) fed various diets[1]

	Diet A	Diet B	Diet C	Diet D	Diet E
CB 77	0.011±0.005	0.035±0.006	0.046±0.006	0.083±0.019	0.138±0.011
CB 81	0.120±0.042	0.339±0.061	0.280±0.052	0.429±0.023	0.696±0.078
CB 99	0.050±0.018	0.169±0.029	0.786±0.168	1.447±0.265	1.708±0.272
CB 101	0.016±0.006	0.098±0.020	0.107±0.018	0.263±0.029	0.311±0.037
CB 118	0.163±0.066	0.464±0.089	1.461±0.276	2.943±0.388	3.175±0.299
CB 123	0.130±0.036	0.458±0.088	0.033±0.006	0.063±0.006	2.375±0.330
CB 126	0.064±0.029	1.171±0.212	0.196±0.032	0.481±0.035	1.511±0.160
CB 128	0.033±0.020	0.299±0.048	0.352±0.059	0.781±0.080	1.210±0.097
CB 138	0.267±0.135	2.800±0.609	3.464±0.638	9.543±1.036	9.925±0.833
CB 146	0.041±0.015	0.500±0.104	0.600±0.097	1.421±0.111	1.771±0.179
CB 153	0.405±0.230	5.538±1.069	5.195±0.988	15.714±1.686	15.375±1.349
CB 156	0.009±0.003	0.469±0.084	0.409±0.073	0.914±0.086	1.188±0.077
CB 167	0.040±0.019	0.350±0.055	0.621±0.109	1.347±0.126	1.500±0.125
CB 170	0.093±0.051	2.278±0.471	0.800±0.157	2.043±0.238	3.013±0.168
CB 171	0.035±0.017	0.521±0.093	0.488±0.086	1.083±0.100	1.393±0.084
CB 180	0.290±0.188	7.175±1.544	5.264±1.034	14.571±1.325	14.750±1.161
CB 183	0.019±0.012	0.559±0.102	0.368±0.069	0.899±0.073	1.114±0.143
CB 189	0.005±0.001	0.090±0.019	0.041±0.006	0.130±0.015	0.186±0.018
CB 194	0.060±0.035	2.103±0.475	0.918±0.174	2.386±0.201	2.688±0.351
CB 195	0.011±0.007	0.419±0.078	0.033±0.006	0.063±0.006	0.133±0.021
CB 196	0.021±0.014	0.778±0.163	0.426±0.091	1.064±0.105	1.645±0.295
CB 201	0.031±0.019	0.889±0.151	0.477±0.080	1.226±0.101	1.813±0.178
Aroclor 1260	3.169±1.849	61.250±12.560	0.261±0.044	105.86±11.26	128.63±7.73

[1]Diet A = 75% ocean fish, Diet B = 75% fish collected above the Oak Ridge Reservation, Diet C = 25% fish collected on the Oak Ridge Reservation and 50% ocean fish, Diet D = 50% fish collected on the Oak Ridge Reservation and 25% ocean fish, Diet E = 75% fish collected on the Oak Ridge Reservation.

Table E.8. Mean[1] ±SE Aroclor 1260 and PCB congener concentrations (ppm, wet wt) in liver tissue from 6-week-old mink kits from dams fed diets of fish collected from various sources[2]

	Diet A	Diet B	Diet C	Diet E
CB 77	0.003±0.000 (9)	0.006±0.001 (9)	0.007±0.001 (8)	0.006±0.001 (9)
CB 81	0.004±0.000 (9)	0.006±0.001 (9)	0.007±0.001 (8)	0.007±0.001 (9)
CB 99	0.003^{a}±0.000 (9)	0.006^{a}±0.001 (9)	0.016^{a}±0.005 (8)	0.049^{b}±0.012 (9)
CB 101	0.004±0.000 (9)	0.006±0.001 (9)	0.007±0.001 (8)	0.006±0.001 (9)
CB 118	0.012^{a}±0.001 (9)	0.012^{a}±0.002 (9)	0.068^{b}±0.014 (8)	0.138^{c}±0.025 (9)
CB 123	0.008±0.001 (9)	0.007±0.000 (9)	0.007±0.001 (8)	0.006±0.001 (9)
CB 126	0.003^{a}±0.000 (9)	0.007^{a}±0.001 (9)	0.007^{a}±0.001 (8)	0.014^{b}±0.003 (9)
CB 128	0.003^{a}±0.000 (9)	0.006^{a}±0.001 (9)	0.020^{a}±0.005 (8)	0.092^{b}±0.034 (9)
CB 138	0.015^{a}±0.002 (9)	0.058^{a}±0.011 (9)	0.141^{a}±0.033 (8)	0.547^{b}±0.200 (9)
CB 146	0.004^{a}±0.000 (9)	0.011^{a}±0.002 (9)	0.033^{a}±0.006 (8)	0.143^{b}±0.042 (9)
CB 151	0.004±0.000 (9)	0.006±0.001 (9)	0.007±0.001 (8)	0.006±0.001 (9)
CB 153	0.011^{a}±0.002 (9)	0.065^{a}±0.010 (9)	0.157^{a}±0.039 (8)	0.509^{b}±0.137 (9)
CB 156	0.003±0.000 (9)	0.008±0.001 (9)	0.009±0.001 (8)	0.006±0.001 (9)
CB 167	0.004^{a}±0.000 (9)	0.007^{a}±0.001 (9)	0.009^{a}±0.002 (8)	0.028^{b}±0.007 (9)
CB 170	0.004^{a}±0.000 (9)	0.054^{a}±0.009 (9)	0.078^{b}±0.014 (8)	0.294^{b}±0.118 (9)
CB 171	0.003±0.000 (9)	0.008±0.001 (9)	0.007±0.001 (8)	0.006±0.001 (9)
CB 180	0.006^{a}±0.001 (9)	0.109^{a}±0.018 (9)	0.194^{b}±0.040 (8)	0.629^{b}±0.235 (9)
CB 183	0.004^{a}±0.000 (9)	0.007^{a}±0.000 (9)	0.013^{a}±0.004 (8)	0.035^{b}±0.009 (9)
CB 189	0.003±0.000 (9)	0.006±0.001 (9)	0.007±0.001 (8)	0.008±0.002 (9)
CB 194	0.004^{a}±0.000 (9)	0.019^{a}±0.003 (9)	0.041^{b}±0.008 (8)	0.146^{b}±0.055 (9)
CB 195	0.003±0.000 (9)	0.006±0.001 (9)	0.007±0.001 (8)	0.006±0.001 (9)
CB 196	0.004^{a}±0.000 (9)	0.052^{a}±0.011 (9)	0.084^{b}±0.015 (8)	0.319^{b}±0.128 (9)
CB 201	0.003^{a}±0.000 (9)	0.014^{a}±0.002 (9)	0.027^{a}±0.005 (8)	0.142^{b}±0.032 (9)
Aroclor 1260	0.099±0.016 (9)	0.151±0.099 (9)	0.058±0.009 (8)	0.048±0.008 (9)

[1]Means with different superscripts are significantly different, $P \leq 0.05$.
[2]Diet A = 75% ocean fish, Diet B = 75% fish collected above the Oak Ridge Reservation, Diet C = 25% fish collected on the Oak Ridge Reservation and 50% ocean fish, Diet E = 75% fish collected on the Oak Ridge Reservation.

Table E.9. Mean[1] ±SE Aroclor 1260 and PCB congener concentrations (ppm, wet wt) in carcass[2] of 6-week-old mink kits from dams fed diets of fish collected from various sources[3]

	Diet A	Diet B	Diet C	Diet E
CB 77	0.003±0.000 (9)	0.003±0.000 (9)	0.003±0.000 (8)	0.003±0.000 (9)
CB 81	0.003±0.000 (9)	0.003±0.000 (9)	0.003±0.000 (8)	0.005±0.001 (9)
CB 99	0.003[a]±0.000 (9)	0.009[a]±0.003 (9)	0.017[a]±0.003 (8)	0.096[b]±0.023 (9)
CB 101	0.003[a]±0.000 (9)	0.004[a]±0.001 (9)	0.006[a]±0.001 (8)	0.017[b]±0.002 (9)
CB 118	0.008[a]±0.001 (9)	0.030[a]±0.009 (9)	0.071[a]±0.018 (7)	0.245[b]±0.036 (9)
CB 123	0.003±0.000 (9)	0.011±0.005 (9)	0.003±0.000 (8)	0.008±0.001 (9)
CB 126	0.003±0.000 (9)	0.011±0.001 (9)	0.005±0.001 (8)	0.003±0.000 (9)
CB 128	0.003[a]±0.000 (9)	0.011[a]±0.004 (9)	0.012[a]±0.002 (8)	0.054[b]±0.007 (9)
CB 138	0.008[a]±0.001 (9)	0.112[a]±0.016 (9)	0.106[a]±0.021 (7)	0.634[b]±0.110 (9)
CB 146	0.003[a]±0.000 (9)	0.013[a]±0.002 (9)	0.019[a]±0.003 (8)	0.103[b]±0.017 (9)
CB 151	0.003±0.000 (9)	0.003±0.000 (9)	0.003±0.000 (8)	0.005±0.001 (9)
CB 153	0.009[a]±0.001 (9)	0.141[a]±0.024 (9)	0.119[a]±0.025 (7)	0.619[b]±0.096 (9)
CB 156	0.003[a]±0.000 (9)	0.017[ab]±0.003 (9)	0.022[b]±0.003 (8)	0.058[c]±0.008 (9)
CB 167	0.003[a]±0.000 (9)	0.014[bc]±0.002 (9)	0.010[ab]±0.002 (8)	0.022[c]±0.003 (9)
CB 170	0.003[a]±0.000 (9)	0.073[a]±0.012 (9)	0.047[a]±0.007 (8)	0.238[b]±0.036 (9)
CB 171	0.003[a]±0.000 (9)	0.021[a]±0.003 (9)	0.008[a]±0.004 (8)	0.017[b]±0.002 (9)
CB 180	0.004[a]±0.000 (9)	0.203[a]±0.026 (9)	0.121[a]±0.019 (7)	0.611[b]±0.080 (9)
CB 183	0.003[a]±0.000 (9)	0.011[a]±0.001 (9)	0.007[a]±0.002 (8)	0.031[b]±0.005 (9)
CB 189	0.003±0.000 (9)	0.003±0.000 (9)	0.003±0.000 (8)	0.008±0.001 (9)
CB 194	0.003[a]±0.000 (9)	0.025[a]±0.003 (9)	0.019[a]±0.004 (8)	0.089[b]±0.010 (9)
CB 195	0.003[a]±0.000 (9)	0.003[a]±0.000 (9)	0.004[a]±0.001 (8)	0.023[b]±0.003 (9)
CB 196	0.003±0.000 (9)	0.014±0.002 (9)	0.005±0.002 (8)	0.005±0.001 (9)
CB 201	0.003[a]±0.000 (9)	0.013[a]±0.002 (9)	0.012[a]±0.002 (8)	0.050[b]±0.009 (9)
Aroclor 1260	0.082±0.005 (9)	1.791±0.282 (9)	0.353±0.245 (8)	0.049±0.006 (9)

[1]Means with different superscripts are significantly different, $P<0.05$. Diet groups were separated based on lipid adjusted concentrations.
[2]Whole body minus liver tissue.
[3]Diet A = 75% ocean fish, Diet B = 75% fish collected above the Oak Ridge Reservation, Diet C = 25% fish collected on the Oak Ridge Reservation and 50% ocean fish, Diet E = 75% fish collected on the Oak Ridge Reservation.

Table E.10. Reproductive performance of female mink fed diets of 75% fish from various sources[1]

	Diet A	Diet B	Diet C	Diet D	Diet E
Females whelping	6	7	4	6	8
Female weights					
December[2]	1269±64[3]	1245±63	1374±64	1258±64	1230±64
June[4]	1168±84[a]	1016±81	1134±81	1020±81	935±81[b]
Gestation (days)	44.6	46.4	44.3	47.5	44.9
Kit wts (6 wks)	328±14	311±10	333±20	307±12	295±11
Females	296±38				268±37
Males	376±42[a]				312±44[b]
Litter size[5]	6.9[a]	7.3[a]	7.8[a]	6.0[ab]	4.3[b]
EROD[6]	51±13[a]	134±26[ab]	124±32[ab]	276±33[b]	262.54±31[b]

[1]Diet A = 75% ocean fish, Diet B = 75% fish collected above the Oak Ridge Reservation, Diet C = 25% fish collected on the Oak Ridge Reservation and 50% ocean fish, Diet D = 50% fish collected on the Oak Ridge Reservation and 25% ocean fish, Diet E = 75% fish collected on the Oak Ridge Reservation.
[2]Beginning of study.
[3]Means followed by different superscripts are significantly different, $P<0.05$.
[4]End of study.
[5]Kits/female.
[6]Ethoxyresorufin-o-deethylase, pmoles/mg protein/min.

Appendix F

CONTAMINANT ACCUMULATION AND EFFECTS IN GREAT BLUE HERON

CONTAMINANT ACCUMULATION AND EFFECTS IN GREAT BLUE HERON

Richard S. Halbrook
Cooperative Wildlife Research Laboratory
Southern Illinois University

1. INTRODUCTION

Plant operations and waste disposal at the Oak Ridge National Laboratory (ORNL), Gaseous Diffusion Plant (ORGDP), and Weapons Plant (Y-12) have introduced an assortment of harmful contaminants into the surrounding environment (Ashwood et al. 1986, Suter 1990). The potential exist for off-reservation transport of contaminants by streams on the Oak Ridge Reservation (ORR) that empty into the Clinch River. Elevated levels of Hg and PCB's have been found in fish collected from East Fork Poplar Creek (EFPC) and from Bear Creek, and elevated levels of PCB's have been found in fish from the White Oak Creek area (Loar 1990). East Fork Poplar Creek and Bear Creek originate within the Y-12 Plant and flow into Poplar Creek north of the K-25 Plant and White Oak Creek flows through ORNL. Both empty into the Clinch River at upper Watts Bar Lake. In the Screening Level Risk Assessment for the Off-Site Ecological Effects in Surface Waters Downstream from the U.S. Department of Energy Oak Ridge Reservation, Suter (1990) identified piscivorous wildlife along the Clinch River as being at risk.

In response to this assessment, monitoring of great blue heron (*Ardea herodias*) was begun in 1991. The great blue heron was chosen as an indicator species because it (1) is predominantly piscivorous foraging along the major waterways on and downstream of the ORR, (2) is at the top of the aquatic food chain, (3) has been suggested to be a good indicator of aquatic health, (3) is well represented in the scientific literature, including toxicological literature, and, (4) satisfies necessary logistical sampling considerations. Important logistical considerations were the presence of study and reference colonies on or in close proximity to ORR and population densities to meet sampling requirements. In addition, great blue heron are highly visible, facilitating direct observation and site location.

This ongoing study seeks to assess the general health and fecundity of the ORR great blue heron population and document any contaminant-induced effects, particularly with respect to Hg and PCB exposure. Reproductive health is of particular concern, and the potential for off-site transportation of contaminants through heron body burdens is addressed.

2. STUDY SITES

Four colonies have been utilized for heron chick and egg collection. Two colonies (K25 and Melton Hill colonies) are located within 3 km of ORR and herons utilizing these colonies are potentially exposed to contaminants occurring on the reservation. The remaining two colonies (Long Island and Looney Island colonies) are located >10 Km from the ORR and heron utilizing these colonies are assumed not to be exposed to contaminants that occur on the ORR. In general, there has been an increase in heron colonies in eastern Tennessee resulting from recent range expansion of the great blue heron in the upper Tennessee Valley (Pullin, 1990).

The K-25 colony is located within the boundaries of Oak Ridge Gaseous Diffusion Plant adjacent to Poplar Creek, which flows through this facility. The colony is located on the west bank of Poplar Creek approximately 2 km from the confluence of Poplar Creek and the Clinch River. Fluctuation of the creek water level is dependent on operations at Watts Bar Dam. Areal surveys by the Tennessee Valley Authority (TVA) established nesting activity at K-25 in 1986 and an estimated 31 nests were active in 1988 (Pullin 1990). The number of nest at this colony have remained at 25 - 50 during the 4 years of this study.

The second colony is located among three small islands in Melton Hill Lake approximately 2 km above Melton Hill Dam. This colony has been active for at least four years (personal communication, Jim Evans, TWRA, Oak Ridge National Laboratory). This colony is composed of approximately 40 active nest.

Colonies on Long Island and Looney Island served as off-site reference locations each greater than 10 km from ORR. Long Island is approximately 3 km from the confluence of the Tennessee and Clinch Rivers in the Tennessee River arm of Watts Bar Lake. The colony has been active since at least 1983 and 141 great blue heron nests were active in 1988 (Pullin 1990). Approximately 200 active nests have been observed during each year of the current study.

Looney Island is located in the Tennessee River approximately 30 km upstream of Long Island in upper Fort Loudon Reservoir. The colony has been active since at least 1992 and an estimated 100 active great blue heron nests were observed on the island during the 1993 and 1994 nesting seasons. Black-crowned night herons also were found nesting on this island during both seasons.

3. METHODS

During March - June 1992 - 1994 eggs and chicks were collected from great blue heron colonies. Nest were accessed by climbing trees using ropes and ascenders or using tree climbing spikes.

Egg collection and processing

Collected eggs were individually marked at both ends and transported to the laboratory in styrofoam containers. In the laboratory, egg length, width or circumference, and weights were recorded. Eggs were opened by etching the shell along the greatest circumference of the longitudinal axes using a small tooth file. Contents were transferred to acid washed glass containers and examined for embryonic development. Following examination, egg contents were homogenized using a Waring Blender and 2 approximately 20 g aliquots were collected in scintillation vials for metal and PCB analyses. Vials were individually labeled and frozen prior to analyses. Egg shells were dried for >3 days at room temperature and shell weight (±0.1 g) was recorded. Shell thickness (±0.001 mm) was recorded as the average of 6 shell thickness measurements taken at 3 locations on each shell half using a digametic micrometer.

Mercury concentrations in homogenized egg samples collected in 1992 were analyzed by the Analytical Chemistry Division, Oak Ridge National Laboratory, Oak Ridge, TN. Mercury concentration in homogenized egg samples collected in 1993 and 1994 and PCB concentration in homogenized egg samples collected in 1992, 1993, and 1994 was determined by Southwest Research Institute, San Antonio, TX.

Chick collection and necropsy

Collected chicks were lowered to the ground using backpacks. On the ground, a uniquely numbered tag was attached to the leg of each chick. Collected chicks were transported to the laboratory in ventilated turkey boxes prior to weighing, euthanasia, and necropsy. When possible, U.S. Fish and Wildlife bands and ORNL numbered and color coded bands were attached to chicks that were not collected.

In the laboratory, total weight (± 0.1 kg) was measured using a 5 kg spring scale and 3 hematocrit tubes of blood were taken from wing veins followed by euthanasia by asphyxiation with CO_2. Total length (from bill tip to end of tail feathers), bill length (from tip to base along dorsal ridge), wing length (from wrist to end of last primary), and tarsometatarsus length (± 1 mm) were recorded. Feathers along the dorsal feather tracts were removed and stored in zip lock plastic bags or aluminum foil prior to metal analysis. An incision was made along the abdomen and the liver, spleen, and heart were removed and weighed (± 0.01 g). Two 1 g liver samples were taken for enzyme and DNA analysis and the remaining liver was divided into two samples, approximately 20 g each, for Hg and PCB analysis. Abdominal fat samples (5 - 10 g) were collected for PCB analysis and 2 approximately 20 g muscle samples were collected from along the tibiotarsus bone for Hg and PCB analysis. All collected tissues were wrapped in aluminum foil, quick frozen in liquid N_2, and stored in permanent liquid N_2 storage containers or in -80°C freezers. Hematocrits were determined by averaging the pack cell volume of the 3 hematocrit tubes collected from each chick after centrifugation for 15 min.

To assess heron food preference and availability, fish regurgitated from chicks or found beneath nests were collected and crop contents were examined. Recognizable fish samples were archived prior to PCB and Hg analysis. Abnormalities were noted and organ somatic indices were computed.

Results of contaminant analyses, physiological measurements, and reproductive parameters were statistically evaluated for differences between colonies located on and off the ORR. Aroclor 1260 and individual congener differences were evaluated when concentrations in at least one location (on or off ORR) were greater than 30 ppb. For congeners that were evaluated, any concentrations below detection limits were assigned a value equal to half the detection limit. Differences between locations were evaluated using a Student's t-test and, when appropriate, differences among colonies were evaluated using an ANOVA or Kruskal-Wallis test.

4. RESULTS

Mercury and chromium concentrations were significantly greater in fish collected from colonies located on the ORR compared to colonies located off the ORR (Table F.1). Although Aroclor 1260 concentrations were quantified in collected fish, no significant differences existed between on and off ORR colonies and all congener concentrations were < 20 ppb.

Egg and Chick Metal concentrations

Thirty-three and 34 eggs and 38 and 35 chicks, respectively, were collected from heron colonies on and off the ORR from 1992 - 1994. Extreme Hg concentrations were quantified in one egg from the Melton Hill colony (KE022, Hg concentration = 0.601 ppm) and one egg from the Long Island colony (LE513, Hg concentration = 0.596 ppm). The egg from the Melton Hill colony was collected from a nest with 2 chicks approximately 2 weeks of age and this egg did not show signs of development. Egg LE513 was collected from a nest that contained 3 eggs and was in an early stage of development. Both concentrations were rejected as outliers by the Dixon and Grubbs test for outlying observations and were eliminated from the data set (Taylor 1987).

No difference existed between mean mercury concentrations in eggs collected from the Long Island and Looney Island colonies (Table F.2), therefore, data from both colonies were used in calculating differences between on and off ORR mercury concentrations in eggs. However, mean mercury concentration in eggs collected from the K25 colony ($\bar{x} \pm SE = 0.17 \pm 0.02$, ppm) was significantly greater ($P < 0.001$) than the mean concentration in eggs collected from the Melton Hill colony ($\bar{x} \pm SE = 0.07 \pm 0.01$, ppm). Therefore, only mercury data from eggs collected from the K25 colony was used in statistical test for differences between on and off ORR mercury concentrations in eggs.

Mean mercury concentration in eggs collected on the ORR was significantly greater than the mean concentration in eggs collected off the ORR (Table F.2). Mean concentrations were greatest in eggs collected from the K25 colony followed in decreasing order in eggs collected from the Long Island ($\bar{x} = 0.12$ ppm) and Looney Island ($\bar{x} = 0.12$ ppm) colonies, and the Melton Hill colony ($\bar{x}$ = 0.0.07 ppm).

Mean chromium concentration in eggs collected on the ORR was significantly greater ($P = 0.046$) than the mean concentration in eggs collected off the ORR (Table F.2). Concentrations were greatest in eggs collected from the Melton Hill colony ($\bar{x} = 0.22$ ppm) followed in decreasing order by concentrations in the K25 ($\bar{x} = 0.15$ ppm), Long Island ($\bar{x} = 0.11$ ppm), and Looney Island ($\bar{x} = 0.11$ ppm) colonies. Arsenic was quantified in only one egg and the concentration was below the contract required detection limit.

Mean mercury concentrations were significantly greater ($P < 0.05$) in feathers and liver tissue of chicks collected on the ORR compared to those collected off the ORR (Table F.3). Mean feather mercury concentration was significantly greater in chicks collected from the K25 colony ($\bar{x} = 2.02$ ppm) compared to feathers from chicks collected from the Melton Hill ($\bar{x} = 1.02$ ppm), Looney Island ($\bar{x} = 0.97$ ppm), and Long Island ($\bar{x} = 0.87$ ppm) colonies. Mean liver mercury concentration was not significantly different between chicks collected from the K25 colony ($\bar{x} = 0.29$ ppm) and the Looney Island colony ($\bar{x} = 0.25$ ppm). However, mean liver mercury concentration was significantly greater in chicks collected from the K25 colony compared to chicks collected from the Melton Hill ($\bar{x} = 0.15$ ppm) and Long Island ($\bar{x} = 0.12$ ppm) colonies. No significant differences existed between muscle liver concentrations between colonies located on or off the ORR. Mean muscle mercury concentration was significantly greater in chicks collected from the K25 colony ($\bar{x} = 0.09$ ppm) compared to chicks collected from the Melton Hill colony ($\bar{x} = 0.05$ ppm). No significant differences in mean liver, muscle, or feather concentrations of arsenic or chromium were detected between chick collected on and off ORR, or among colonies (Table F.3).

<u>Egg and Chick PCB and Congener concentrations</u>

Mean concentrations of Aroclor 1260 and 76% of the quantified congeners were significantly greater ($P < 0.05$) in eggs collected from the K25 colony compared to those collected from the Melton Hill colony, while, no significant differences were detected in Aroclor 1260 or congener concentrations between Long Island and Looney Island eggs. Therefore, for statistical analysis between on and off ORR colonies, PCB concentrations in K25 eggs were compared to concentrations in Long Island and Looney Island eggs combined. Mean concentrations of Aroclor 1260 and 10 congeners were significantly greater in eggs collected on the ORR compared to concentrations in eggs collected off the ORR (Table F.4). Concentrations of 47% of the 30 congeners evaluated in egg homogenates were below 30 ppb. Concentrations of congeners 123 and 167 were the only coplanar congeners that differed between eggs from colonies located on and off the ORR.

Aroclor 1260 and a majority of congener concentrations were significantly greater ($P < 0.05$) in fat, liver, and muscle tissue from heron chicks collected from the K25 colony compared to those collected from the Melton Hill colony, while no differences existed between chicks collected from the Long Island and Looney Island colonies. Therefore, comparison of PCB results between on and off ORR was between the K25 colony, and Long Island and Looney Island colonies combined. Aroclor 1260 concentration was significantly greater ($P < 0.05$) in fat, liver, and muscle tissue from chicks collected on the ORR compared to concentrations in chicks collected off the ORR. Although concentrations of all congeners were greater in fat tissue from chicks collected on the ORR, this difference was significant in only 30% of the congeners quantified (Table F.5). Congener 156 was the only coplanar congener that was significantly different in fat tissue between on and off ORR colonies.

Of the 30 congeners evaluated, 77 and 73% of the concentrations in chick muscle and liver tissue, respectively, were below 30 ppb. In chick liver tissue, concentrations of congeners 110, 118, 151, 153 and 180 differed significantly between on and off ORR colonies (Table F.6). In chick muscle tissue, concentrations of congeners 110, 118, 138, 153, and 180 differed significantly between on and off ORR colonies (Table F.7). Congener 110 and 118 were the only coplanar congener that differed between on and off ORR colonies in liver and muscle tissue, although concentrations of coplanar congeners ranged from below detection to 18 ppm in chick fat tissue.

<u>Physiological and Reproductive Effects</u>

No significant differences were observed in the number of eggs or chicks per nest between on and off ORR colonies (Table F.8). The mean weight of eggs collected from colonies on the ORR were significantly heavier than eggs collected off the ORR, however, there was no difference in shell thickness.

Chick weight/length ratios, liver somatic indexes, and hematocrit measurements were not different in chicks collected on and off the ORR. However, liver EROD activity and DNA F values (fraction of double stranded DNA) were significantly greater ($P < 0.05$) in chicks collected from colonies off the ORR compared to those collected on the ORR (Table F.8).

Although herons occupying the K25 colony have elevated body burdens of mercury and PCBs compared to herons occupying colonies off the ORR, the contaminant levels in tissues do not appear to effect the number of eggs laid or survival of chicks to fledging. Effects on chick survival from fledging to reproductive maturity is yet to be determined. Contaminant data from one adult heron collected on the ORR in August 1992 suggest that body burdens are much greater in adults than in chicks. Mercury concentration in muscle tissue and feathers of this adult were 1.48 and 18.2 ppm, respectively, which is greater than the maximum found in chicks collected during this study (maximum chick muscle Hg = 0.68 ppm; maximum chick feather Hg = 6.35 ppm). Similarly, Aroclor 1260 concentration in muscle tissue of this adult (89 and 38 ppm, respectively) was greater than concentrations detected in chicks (maximum chick muscle Aroclor 1260 = 4.0 ppm). Congener concentrations in this adult also were greater than concentrations found in chicks. Muscle concentrations of coplanar congeners 77, 81, 110, 118, and 123 were 1.0, 2.0, 5.0, 5.0, and 3.8, respectively, which are at least one order of magnitude greater than the maximum concentrations detected in chick muscle tissue (0.07, 0.36, 0.29, 0.21, and 0.15, respectively). This suggests that some individuals may continue to feed on the ORR after fledging, however, it is not know if the chicks that are born on the ORR return to their birth colony to reproduce. Concentrations of mercury and PCBs in eggs collected on the ORR were greater than concentrations in eggs collected off the ORR, which suggest that at least some adults are exposed prior to egg laying. Monitoring movements of chicks after fledging as well as observations for bands placed on chicks during 1993 and 1994 will provide additional data from addressing this issue.

Table F.1. Mean ±SE (N) concentrations (ppm, wet wt) of elements and Aroclor 1260[1] from homogenized fish[2] collected from great blue heron colonies located on[3] and off[4] the ORR

	ON ORR	OFF ORR	P[5]
Mercury	0.06±0.02 (13)	0.02±0.00 (15)	0.030
Arsenic	0.30±0.05 (13)	0.23±0.03 (15)	0.238
Chromium	1.52±0.54 (12)	0.37±0.08 (15)	0.030
Aroclor 1260	0.20±0.04 (13)	0.15±0.03 (15)	0.269

[1]All congeners concentration were <20 ppb.
[2]Various fish species collected from active nest or stomachs of collected great blue heron chicks.
[3]Includes the K25 and Melton Hill colonies.
[4]Includes the Long Island and Looney Island colonies.
[5]T-test P value.

Table F.2. Metal[1] concentrations (ppm, wet wt) detected in great blue heron eggs from colonies located on[2] and off[3] the ORR during 1992-1994

	ON ORR	OFF ORR	P[4]
Mercury			
Mean	0.17	0.12	0.009
SE	0.02	0.02	
Min	0.04	0.04	
Max	0.31	0.29	
N	24	34	
Chromium			
Mean	0.18	0.11	0.046
SE	0.03	0.01	
Min	0.05	0.06	
Max	0.84	0.21	
N	25	26	

[1]Arsenic was quantified in one egg at a concentration below the contract required detection limit.
[2]Includes K25 colony.
[3]Includes Long Island and Looney Island colonies.
[4]T-test P value.

Table F.3. Metal concentrations (Mean±SE) detected in tissues collected from great blue heron chicks from colonies located on[1] (N=38) and off[2] (N=35) the ORR during 1992-1994

	ON ORR	OFF ORR	P[3]
Mercury			
Feather	1.71±0.21	0.91±0.08	0.001
Liver	0.24±0.03	0.16±0.02	0.028
Muscle	0.08±0.01	0.09±0.02	0.66
Chromium			
Feather	0.96±0.17	1.16±0.19	0.429
Liver	1.49±0.48	1.26±0.49	0.739
Muscle	1.86±0.56	2.84±0.81	0.322
Arsenic			
Feather	0.10±0.01	0.10±0.01	0.977
Liver	0.13±0.03	0.12±0.02	0.771
Muscle	0.15±0.05	0.15±0.04	0.938

[1]Includes K25 and Melton Hill colonies.
[2]Includes Long Island and Looney Island colonies.
[3]T-test P value.

Table F.4. Mean ±SE (N) Aroclor 1260 and congener concentrations[1] (ppm, wet wt) in great blue heron eggs collected from colonies located on[2] and off[3] the ORR

	ON ORR	OFF ORR	P[4]
Aroclor 1260	1.68±0.48 (24)	0.27±0.08 (34)	0.008
CB 81	0.13±0.04 (16)	0.08±0.02 (26)	0.365
CB 99	0.09±0.03 (16)	0.02±0.01 (26)	0.030
CB 101	0.04±0.02 (16)	0.00±0.00 (26)	0.018
CB 118	0.17±0.04 (16)	0.08±0.02 (26)	0.062
CB 123	0.11±0.04 (16)	0.01±0.00 (26)	0.015
CB 138	0.29±0.05 (16)	0.14±0.03 (26)	0.025
CB 146	0.09±0.03 (16)	0.03±0.01 (26)	0.036
CB 149	0.09±0.05 (8)	0.03±0.01 (14)	0.288
CB 153	0.37±0.07 (16)	0.16±0.04 (26)	0.019
CB 158	0.04±0.02 (16)	0.06±0.02 (26)	0.128
CB 167	0.05±0.01 (16)	0.01±0.00 (26)	0.008
CB 170	0.09±0.02 (16)	0.04±0.01 (26)	0.012
CB 180	0.27±0.06 (16)	0.11±0.02 (26)	0.021
CB 183	0.06±0.01 (16)	0.02±0.00 (26)	0.020
CB 194	0.04±0.01 (16)	0.02±0.00 (26)	0.076
CB 196	0.07±0.02 (16)	0.03±0.01 (26)	0.059

[1]Concentrations of CBs 66, 76, 77, 95, 105, 110, 114, 126, 128, 132, 151, 156, 171, and 201 were <30 ppb and are not included.
[2]Includes the K25 colony.
[3]Includes the Long Island and Looney Island colonies.
[4]T-test P value.

Table F.5. Mean ±SE (N) Aroclor 1260 and congener concentrations (ppm, wet wt) in abdominal fat from great blue heron chicks collected from colonies located on[1] and off[2] the ORR

	ON ORR	OFF ORR	P[3]
Aroclor 1260	48.63±11.71 (16)	15.70±2.64 (24)	0.014
CB 66	1.21±0.75 (16)	0.23±0.03 (24)	0.210
CB 76	0.78±0.55 (16)	0.12±0.02 (24)	0.250
CB 77	0.27± 0.10 (16)	0.20±0.04 (24)	0.556
CB 81	1.54±0.44 (16)	1.28±0.30 (24)	0.761
CB 95	0.84±0.54 (16)	0.14±0.04 (24)	0.216
CB 99	2.70±1.36 (16)	0.56±0.15 (24)	0.138
CB 101	2.65±1.37 (16)	0.47±0.15 (24)	0.134
CB 105	0.73±0.36 (16)	0.13±0.02 (24)	0.115
CB 110	2.40±1.16 (16)	0.49±0.10 (24)	0.122
CB 114	0.07±0.04 (16)	0.00±0.00 (24)	0.999
CB 118	1.95±0.82 (16)	0.79±0.11 (24)	0.182
CB 123	2.53±1.09 (16)	0.63±0.11 (24)	0.102
CB 126	0.54±0.13 (16)	0.33±0.08 (24)	0.195
CB 128	0.95±0.37 (16)	0.19±0.02 (24)	0.058
CB 132	0.76±0.41 (16)	0.14±0.02 (24)	0.146
CB 138	5.13±1.44 (16)	1.70±0.23 (24)	0.032
CB 146	1.70±0.37 (16)	0.75±0.11 (24)	0.024
CB 149	2.76±0.54 (7)	1.04±0.24 (12)	0.018
CB 151	0.98±0.35 (16)	0.33±0.06 (24)	0.084
CB 153	6.24±1.35 (16)	2.47±0.45 (24)	0.016
CB 156	0.31±0.09 (16)	0.12±0.02 (24)	0.043
CB 158	0.19±0.14 (16)	0.21±0.08 (24)	0.905

Table F.5 (continued)

	ON ORR	OFF ORR	P[3]
CB 167	0.86±0.30 (16)	0.29±0.04 (24)	0.078
CB 170	1.57±0.34 (16)	0.54±0.07 (24)	0.010
CB 171	0.22±0.09 (16)	0.17±0.05 (24)	0.621
CB 180	4.27±0.95 (16)	1.37±0.25 (24)	0.009
CB 183	0.88±0.25 (16)	0.35±0.05 (24)	0.054
CB 194	0.63±0.12 (16)	0.38±0.05 (31)	0.078
CB 196	0.93±0.21 (16)	0.37±0.06 (24)	0.018
CB 201	0.53±0.11 (16)	0.22±0.03 (24)	0.012

[1]Includes the K25 colony.
[2]Includes the Long Island and Looney Island colonies.
[3]T-test P value.

Table F.6. Mean ±SE (N) Aroclor 1260 and congener concentrations[1] (ppm, wet wt) in liver tissue from great blue heron chicks collected from colonies located on[2] and off[3] the ORR

	ON ORR	OFF ORR	P[4]
Aroclor 1260	0.77±0.23 (18)	0.23±0.03 (22)	0.029
CB 110	0.06±0.02 (18)	0.02±0.00 (22)	0.050
CB 118	0.05±0.02 (18)	0.01±0.00 (22)	0.049
CB 138	0.07±0.03 (18)	0.02±0.00 (22)	0.077
CB 149	0.06±0.03 (8)	0.02±0.00 (10)	0.209
CB 151	0.04±0.02 (18)	0.01±0.00 (22)	0.048
CB 153	0.10±0.03 (18)	0.03±0.00 (22)	0.017
CB 180	0.07±0.02 (18)	0.02±0.00 (22)	0.021

[1]Concentrations of CBs 66, 76, 77, 95, 99, 101, 105, 114, 123, 126, 128, 132, 146, 156, 158, 167, 170, 171, 183, 194, 196, and 201 were <30 ppb and are not included.
[2]Includes the K25 colony.
[3]Includes the Long Island and Looney Island colonies.
[4]T-test P value.

Table F.7. Mean ±SE (N) Aroclor 1260 and congener concentrations[1] (ppm, wet wt) in muscle tissue from great blue heron chicks collected from colonies located on[2] and off[3] the ORR

	ON ORR	OFF ORR	P[4]
Aroclor 1260	1.05±0.25 (18)	0.35±0.08 (24)	0.015
CB 81	0.04±0.01 (18)	0.04±0.02 (24)	0.795
CB 110	0.06±0.02 (18)	0.01±0.00 (24)	0.027
CB 118	0.06±0.01 (18)	0.02±0.01 (24)	0.015
CB 138	0.09±0.02 (18)	0.04±0.01 (24)	0.033
CB 149	0.09±0.03 (8)	0.03±0.01 (12)	0.086
CB 153	0.16±0.03 (18)	0.05±0.01 (24)	0.009
CB 180	0.10±0.02 (18)	0.03±0.01 (24)	0.008

[1]Concentrations of CBs 66, 76, 77, 95, 99, 101, 105, 114, 123, 126, 128, 132, 146, 151, 156, 167, 170, 171, 183, 194, 196, and 201 were <30 ppb and are not included.
[2]Includes the K25 colony.
[3]Includes the Long Island and Looney Island colonies.
[4]T-test P value, based on lipid adjusted concentrations.

Table F.8. Reproductive, physiological, and biomarker measurements [Mean±SE (N)] in great blue heron from colonies located on[1] and off[2] the ORR during 1992-1994

	ON ORR	OFF ORR
Mean eggs/nest	3.5±0.2 (26)	3.2±0.2 (27)
Egg shell thickness (mm)	0.427±0.01 (33)	0.410±0.01 (34)
Egg weight (g)[3]	69.16±0.97 (33)	66.36±0.97 (34)
Mean chicks/nest	2.7±0.1 (55)	2.7±0.2 (30)
Chick weight/length ratio	2.06±0.05 (38)	2.12±0.06 (35)
Liver somatic index	4.50±0.16 (38)	4.64±0.23 (35)
Liver EROD activity[4]	31.9±2.7 (12)	41.3±3.2 (12)
DNA double-strandedness (F)[5]	73±0.03 (26)	84±0.02 (27)
Hematocuit	32±0.8 (38)	31±0.7 (26)

[1]Includes K25 and Melton Hill colonies.
[2]Includes Long Island and Looney Island colonies.
[3]Means significantly different (T-test, P=0.048).
[4]1994 data; ethoxyresorufin-o-deethylase activity (pmole/mq protein/min); means significantly different (T-test, P=0.033).
[5]Means signficantly different (T-test, P=0.006), F = fraction of double-stranded DNA.

Appendix G

TABLES AND FIGURES FOR CHAPTER 5: ASSESSMENT OF RISK TO VERMIVORES AND HERBIVORES ON THE OAK RIDGE RESERVATION

Table G.1. Life history parameters for the white-tailed deer (*Odocoileus virginianus*)

Parameter	Value[a]	Comments	Reference
Body weight	68 kg (♂) 45 kg (♀) 56.5 kg (mean♂+♀)		Smith 1991
Food consumption rate	1.74 kg/d		Mautz et al. 1976
Water consumption rate	3.7 L/d	estimated using allometric equation[b] assuming 56.5 kg bw	
Soil consumption rate	<2%		Beyer et al. 1994
	0.0348 kg/d	assuming 2% soil and 1.74 kg/d food consumption rates	
Diet composition	exclusively herbivorous diet diverse and variable, depends on availability.		Zim et al. 1951
	major foods: - buds and twigs of trees and shrubs - grasses and forbs (summer) - mast and fruits (fall)		Smith 1991
Home range	59 - 520 ha		Marchinton and Hirth 1984
Habitat requirements	uses a wide variety of habitats; favors forest-field-farmland mosaic; population density directly related to number and distribution of forest openings		Smith 1991

Table G.1 (continued)

Parameter	Value[a]	Comments	Reference
Population density	0.06 /ha	eastern mixed deciduous forest - Tennessee	Barber 1984
	0.39 - 0.78 /ha	oak-hickory forest - midwest	Torgerson and Porath 1984
	0.1704/ha (calculated based on 2000 deer on ORR and available habitat)	Oak Ridge Reservation	personal communication, Jim Evans 1995
Behavior	generally crepuscular		Smith 1991
	active year-round; does not hibernate		

[a] Suggested values for use in exposure assessment are in bold.

[b]Allometric equation for estimation of water consumption for deer is:

$$WIR = 0.099(BW)^{0.90}$$

where:

WIR= water ingestion rate (L water/individual/day).

Table G.2. Life history parameters for the wild turkey (*Meleagris gallopavo*)

Parameter	Value[a]	Comments	Reference
Body weight	7.400 kg (♂) 4.222 kg (♀) **5.8 kg** (mean♂+♀)		Dunning 1984
Food consumption rate	13.6 g/lb bw/d **0.174** kg/d	 assuming 5.8 kg bw	Korschgen 1967
Water consumption rate	**0.19** L/d	estimated using allometric equation[c] assuming 5.8 kg bw	
Soil consumption rate	9.3 % **0.0162** kg/d	 assuming 0.174 kg/d food consumption rates	Beyer et al. 1994
Diet composition	plant material (mast, fruit, seeds, some foliage) - 90.3% animal material (insects, crayfish, snails, salamanders) - 9.7 %		Korschgen 1967
Home range	150 - 190 ha		Pough 1951[b]
Habitat requirements	mast-producing woodlands with associated fields and abundant water		Schorger 1966[b]
Population density	0.03 /ha 0.06 - 0.076 /ha **0.0426 /ha** (calculated based on @ 500 turkey observed on ORR and suitable habitat)	West Virginia in 'ideal' habitat Oak Ridge Reservation	Uhling 1950[b] Pough 1951[b] Personal Communication, Jim Evans 1995
Behavior	forage primarily on the ground roost in trees at night year-round resident; does not migrate		National Geographic Society 1987

[a] Suggested values for use in exposure assessment are in bold.
[b] Cited in DeGraaf et al. 1981.
[c] Allometric equation for estimation of water consumption for birds is:

$$WIR = 0.059(BW)^{0.67}$$

where:
WIR= water ingestion rate (L water/individual/day).

Table G.3. Life history parameters for the short-tailed shrew (*Blarina brevicauda*)

Parameter	Value[a]	Comments	Reference
Body weight	**0.015** ± 0.00078 kg	New Hampshire (field)	Schlessinger and Potter 1974
Food consumption rate	0.01 kg/d	larch sawfly diet (lab)	Buckner 1964
	0.00795 ± 0.00017 kg/d	mealworm diet (lab)	Barrett and Stueck 1976
	mean = **0.009** kg/d		
Water consumption rate	0.223 ml/g bw/d		Chew 1951
	0.033 L/d	assuming a 0.015 kg bw	
Soil consumption rate	13% of diet		Talmage and Walton 1993
	0.00117 kg/d	assuming diet of 0.009 kg/d	
Diet composition	earthworms 31.4% slugs/snails 27.1% soil/litter invert 13.2% fungi 8.4% misc. animals 8.1% coleoptera 5.9% vegetation 5.4%	percent volume in diet in summer in New York	Whitaker and Ferraro 1963
Home range	**0.39** ± 0.036 ha	Manitoba bog	Buckner 1966
Habitat requirements	broad and variable but requires >50% herbaceous cover		Miller and Getz 1977
	forest, wetlands, and grasslands. most abundant in hardwood forests with deep litter and humus.		van Zyll de Jong 1983
Population density	2.3 /ha - winter 5.2 /ha - spring 9.3 /ha -summer 8.1 /ha - fall	Illinois - alfalfa, tallgrass, and bluegrass; means derived from graph.	Getz 1989
	2.5-45 /ha (median= **23 /ha**)	range depending on the habitat	

Table G.3 (continued)

Parameter	Value[a]	Comments	Reference
Behavior	nocturnal, semifossorial, spends little time above surface		George et al. 1986
	active year-round - does not hibernate		EPA 1993a
Other	appear to be unpalatable to most predators due to lateral gland		van Zyll de Jong 1983

[a] Suggested values for use in exposure assessment are in bold.

Table G.4. Life history parameters for the American woodcock (*Scolopax minor*)

Parameter	Value[a]	Comments	Reference
Body weight	0.176 kg (♂) 0.219 kg (♀) **0.198** kg (mean♂+♀)		Dunning 1984
Food consumption rate	**0.15** kg/d		Sheldon 1971
Water consumption rate	**0.02** L/d	estimated using allometric equation[b] assuming 0.198 kg bw	
Soil consumption rate	10.4% **0.0156** kg/d	 assuming diet of 0.15 kg/d	Beyer et al. 1994
Diet composition	primarily earthworms (58 % - ~99 %) plus other ground-dwelling invertebrates		Sperry 1940 Krohn 1970 Miller and Causey 1985 Stribling and Doerr 1985
Home range	10.5 ha (singing ♂) 73.6 ha (active ♂) 3.1 ha (inactive ♂)	Pennsylvania - mixed forest fields	Hudgins et al. 1985
Habitat requirements	Breeding: moist early successional woodlands, swamps, river bottoms, alder thickets feeding: moist open pasture, cultivated fields, stream banks		DeGraaf et al. 1981
Population density	 3.4 /ha 0.2 /ha 0.034 /ha 0.21 nests/ha **0.28 /ha**	North Carolina - winter untilled soy stubble untilled corn stubble rebedded corn Pennsylvania - mixed pine hardwoods based on 5.6 males/40 ha; assuming 1:1 sex ration	Connors and Doerr 1982 Coon et al. 1982 Stewart and Robbins 1958

Table G.4 (continued)

Parameter	Value[a]	Comments	Reference
Behavior	migrate from northern breeding range to wintering range in south Atlantic and gulf coast states. early migrants; leave wintering grounds in February, arrive at northern breeding grounds lat March.		Sheldon 1971

[a] Suggested values for use in exposure assessment are in bold.
[b] Allometric equation for estimation of water consumption for birds is:

$$WIR = 0.059(BW)^{0.67}$$

where:

WIR= water ingestion rate (L water/individual/day).

Table G.5. Life history parameters for red fox (*Vulpes fulva*)

Parameter	Value[a]	Comments	Reference
Body Weight	5.25 ± 0.18 kg (♂) 4.13 ± 0.11 kg (♀)	Illinois	Storm et al. 1976
	4.82 ± 0.081 kg (♂) 3.94 ± 0.079 kg (♀)	Iowa	
	4.5 kg	mean ♂+♀ for both Illinois and Iowa	
Food Consumption Rate	0.596 kg/d	see calculation below[b]	Vogtsberger and Barret 1973
	0.31 kg/d	0.069 g/g/d for nonbreeding adult times 4.5 kg bw	Sargent 1978
	0.45 kg/d	mean of both estimates	
Water Consumption Rate	**0.38 L/d**	Estimated using allometric equation[c]; assuming 4.5 kg bw	
Soil Consumption Rate	2.8%		Beyer et al. 1994
	0.0126 kg/d	assuming diet of 0.45 kg/d	
Diet Composition	mammals - 68.8% birds - 12.0% plants - 10.4% insects - 0.9% misc. - 5.5%	Maryland, Appalachian region	Hockman and Chapman 1983
Home Range	699 ± 137 ha (♀ spring)	Minnesota - forest, field, swamp	Sargent 1972
	717 ha (♂ all year) 96 ha (♀ all year)	Wisconsin - multiple habitats	Ables 1969
Habitat Requirements	wide and diverse - occur in many habitats		EPA 1993b
	prefer mixture of forest and open habitat		Burt and Grossenheider 1976
Population Density	0.046 - 0.077 /ha	"good fox range" in North America	EPA 1993b
Behavior	active year round - does not hibernate		EPA 1993b

[a] Suggested values for use in exposure assessment are in bold.

[b] The following parameters were presented by Vogtsberger and Barret (1973):

food ingestion = 223 kcal/kg bw/d   energy content of vertebrate food = 5.606 kcal/g dry wt.

wet-dry weight conversion = 1 g wet wt = 0.3 g dry wt

therefore: 223 kcal/kg bw/d x 4.5 kg bw = 1003.5 kcal/d

1003.5 kcal/d x 1g dry wt./5.606 kcal = 179 g dry/d

179 g dry/d x 1 g wet/0.3 g dry (wet-dry conversion) = 596 g/d

[c] Allometric equation for estimation of water consumption by mammals is $W=0.099(bw)^{0.90}$

where: W = water consumption (L/d)   bw = body weight (kg)

Table G.6. Life history parameters for red-tailed hawks (*Buteo jamaicensis*)

Parameter	Value[a]	Comments	Reference
Body Weight	1.028 kg (♂) 1.224 kg (♀) 1.126 kg (mean♂+♀)		Dunning 1984
Food Consumption Rate	0.109 kg/d		Craighead and Craighead 1969
Water Consumption Rate	0.064 L/d	Estimated using allometric equation[b]; assuming 1.126 kg bw	
Soil Consumption Rate	while some soil attached to prey may be ingested, amount is assumed to negligible		
Diet Composition	predominantly small mammals		EPA 1993b
	small mammal - 78.5 % bird - 8.5 % snake - 13.0 %	Oregon - pasture and wheat fields	Janes 1984
Home Range	233 ha	Oregon - pasture and wheat fields	Janes 1984
	1936 ha (957 - 2465 ha range)	Colorado - prairie-pinyon/juniper woodland; mean of 4 birds; 95% ellipse and systematic relocation	Anderson and Rongstad 1989
Habitat Requirements	use wide range of habitats. prefer landscapes containing mixture of oldfields, wetlands and pasture for foraging with trees interspersed for perching and nesting		EPA 1993b DeGraaf et al. 1981
Population Density	0.03 - >0.005 pairs/ha		EPA 1993b

Table G.6 (continued)

Parameter	Value[a]	Comments	Reference
Behavior	territorial throughout year		Brown and Amadon 1968[b]
	northerly populations migrate; those in the south do not		National Geographic Society 1987

[a] Suggested values for use in exposure assessment are in bold.
[a] Allometric equation for estimation of water consumption by birds is:

$$W=0.059(bw)^{0.67}$$

where: W = water consumption (L/d)
bw = body weight (kg)

Table G.7. Contaminant Concentrations in Soil (mg/kg) on the Oak Ridge Reservation

Location	Analyte	Obs	# Det	# Nondet	Mean[a]	Standard Error	Min	Max	95% UCB
BC OU 2	1,1-Dichlorethene	9	9	0	0.0077	0.0002	0.0070	0.0090	0.0081
BC OU 2	1,1,1-trichlorethane	9	9	0	0.0077	0.0002	0.0070	0.0090	0.0081
BC OU 2	1,2-Dichlorethane	9	9	0	0.0077	0.0002	0.0070	0.0090	0.0081
BC OU 2	1,2-Dichlorethene	9	9	0	0.0077	0.0002	0.0070	0.0090	0.0081
BC OU 2	4,4-DDD	9	9	0	0.0052	0.0002	0.0044	0.0070	0.0056
BC OU 2	4,4-DDE	9	9	0	0.0052	0.0002	0.0044	0.0070	0.0056
BC OU 2	4,4-DDT	9	9	0	0.0052	0.0002	0.0044	0.0070	0.0056
BC OU 2	Acetone	9	9	0	0.0514	0.0288	0.0130	0.2800	0.1051
BC OU 2	Aldrin	9	9	0	0.0026	0.0001	0.0022	0.0030	0.0028
BC OU 2	Alpha-BHC	9	9	0	0.0026	0.0001	0.0022	0.0030	0.0028
BC OU 2	Alpha-chlordane	9	9	0	0.0026	0.0001	0.0022	0.0030	0.0028
BC OU 2	Aluminum	13	13	0	26143.8462	5485.3630	6840.0000	63900.0000	35920.3400
BC OU 2	Antimony	9	9	0	0.3089	0.0259	0.2300	0.4900	0.3570
BC OU 2	Arsenic	13	9	4	33.3692	2.6757	15.6000	50.3000	35.0930
BC OU 2	Barium	13	13	0	101.4000	29.5003	17.9000	340.0000	153.9779
BC OU 2	Benzene	9	9	0	0.0077	0.0002	0.0070	0.0090	0.0081
BC OU 2	Benzo(a)pyrene	9	9	0	0.4989	0.0162	0.4300	0.6000	0.5290
BC OU 2	Beryllium	13	13	0	1.0246	0.1631	0.2900	2.0000	1.3154
BC OU 2	Beta-BHC	9	9	0	0.0026	0.0001	0.0022	0.0030	0.0028
BC OU 2	Bis(2-ethylhexyl)Phthalate	9	9	0	0.4989	0.0162	0.4300	0.6000	0.5290
BC OU 2	Boron	4	4	0	65.5000	5.9090	50.0000	78.0000	79.4061
BC OU 2	Cadmium	13	9	4	1.2469	0.4118	0.1100	3.5000	0.8571
BC OU 2	Carbon tetrachloride	9	9	0	0.0077	0.0002	0.0070	0.0090	0.0081
BC OU 2	Chloroform	9	9	0	0.0077	0.0002	0.0070	0.0090	0.0081
BC OU 2	Chromium	13	13	0	37.3308	3.8723	16.5000	60.0000	44.2323
BC OU 2	Copper	13	13	0	39.2231	10.1792	10.3000	131.0000	57.3653
BC OU 2	Delta-BHC	9	9	0	0.0026	0.0001	0.0022	0.0030	0.0028
BC OU 2	Dibenzofuran	9	9	0	0.4989	0.0162	0.4300	0.6000	0.5290

Table G.7 (continued)

Location	Analyte	Obs	# Det	# Nondet	Mean[a]	Standard Error	Min	Max	95% UCB
BC OU 2	Dieldrin	9	9	0	0.0052	0.0002	0.0044	0.0070	0.0056
BC OU 2	Diethylphthalate	9	9	0	0.4989	0.0162	0.4300	0.6000	0.5290
BC OU 2	Di-n-butlyphthalate	9	9	0	0.4989	0.0162	0.4300	0.6000	0.5290
BC OU 2	Endosulfan I	9	9	0	0.0026	0.0001	0.0022	0.0030	0.0028
BC OU 2	Endosulfan II	9	9	0	0.0052	0.0002	0.0044	0.0070	0.0056
BC OU 2	Endrin	9	9	0	0.0052	0.0002	0.0044	0.0070	0.0056
BC OU 2	Gamma-chlordane	9	9	0	0.0026	0.0001	0.0022	0.0030	0.0028
BC OU 2	Heptachlor	9	9	0	0.0026	0.0001	0.0022	0.0030	0.0028
BC OU 2	Lead	13	12	1	81.0154	25.6587	18.3000	370.0000	126.8223
BC OU 2	Lindane	9	9	0	0.0026	0.0001	0.0022	0.0030	0.0028
BC OU 2	Lithium	4	4	0	39.2500	3.3758	33.0000	48.0000	47.1944
BC OU 2	Manganese	13	13	0	1021.5231	425208.0000	55.8000	6060.0000	1779.3673
BC OU 2	Mercury	24	24	0	49.0188	15775.0000	0.1000	300.0000	76.0554
BC OU 2	Methoxychlor	9	9	0	0.0261	0.0012	0.0220	0.0330	0.0284
BC OU 2	Methylene chloride	9	9	0	0.0161	0.0010	0.0130	0.0230	0.0179
BC OU 2	Nickel	13	13	0	32.6000	9.9436	5.8000	147.0000	50.3224
BC OU 2	Niobium	4	1	3	9.8500	0.4699	8.7000	11.0000	NA[b]
BC OU 2	PCB-1016	9	9	0	0.0521	0.0023	0.0440	0.0650	0.0565
BC OU 2	PCB-1221	9	9	0	0.1040	0.0045	0.0880	0.1300	0.1124
BC OU 2	PCB-1232	9	9	0	0.0521	0.0023	0.0440	0.0650	0.0565
BC OU 2	PCB-1242	9	9	0	0.0521	0.0023	0.0440	0.0650	0.0565
BC OU 2	PCB-1248	9	9	0	0.0521	0.0023	0.0440	0.0650	0.0565
BC OU 2	PCB-1254	9	9	0	0.0521	0.0023	0.0440	0.0650	0.0565
BC OU 2	PCB-1260	9	9	0	0.0416	0.0032	0.0210	0.0500	0.0475
BC OU 2	Pentachlorophenol	9	9	0	1.2111	0.0455	1.0000	1.5000	1.2957
BC OU 2	Selenium	9	9	0	1.0944	0.3730	0.2400	3.3000	1.7881
BC OU 2	Strontium	4	4	0	109.9250	10.1746	82.7000	126.0000	133.8695
BC OU 2	Tetrachloroethene	9	9	0	0.0074	0.0002	0.0070	0.0080	0.0078
BC OU 2	Thallium	9	9	0	0.3144	0.0269	0.2100	0.4400	0.3644

Table G.7 (continued)

Location	Analyte	Obs	# Det	# Nondet	Mean[a]	Standard Error	Min	Max	95% UCB
BC OU 2	Toluene	9	9	0	0.0077	0.0002	0.0070	0.0090	0.0081
BC OU 2	Toxaphene	9	9	0	0.2611	0.0122	0.2200	0.3300	0.2838
BC OU 2	Trichloroethene	9	9	0	0.0077	0.0002	0.0070	0.0090	0.0081
BC OU 2	Uranium	20	20	0	2.0408	0.2752	0.5200	5.2900	2.5166
BC OU 2	Vanadium	13	13	0	54.8385	4.3422	33.0000	82.5000	62.5775
BC OU 2	Vinyl chloride	9	9	0	0.0153	0.0005	0.0130	0.0180	0.0162
BC OU 2	Zinc	13	13	0	113.2077	20.3168	41.0000	302.0000	149.4180
BC OU 2	Zirconium	4	4	0	59.2500	6.4727	46.0000	77.0000	74.4826
K-1407 OU	1,1,1-trichlorethane	37	1	36	0.0155	0.0005	0.0010	0.0200	NA
K-1407 OU	1,2-Dichlorethene	37	3	34	0.0171	0.0007	0.0120	0.0330	0.0277
K-1407 OU	Acetone	37	11	26	0.0285	0.0015	0.0080	0.0420	0.0188
K-1407 OU	Aluminum	81	81	0	26562.9630	1298.3185	7600.0000	69000.0000	28723.5270
K-1407 OU	Antimony	81	1	80	7.1506	0.7359	4.8000	50.0000	NA
K-1407 OU	Arsenic	81	35	46	12.4333	1.1038	5.0000	50.0000	13.0681
K-1407 OU	Barium	81	81	0	110.4938	8.8823	25.0000	600.0000	125.2752
K-1407 OU	Beryllium	81	81	0	1.0159	0.0667	0.2500	4.9000	1.1269
K-1407 OU	Boron	81	38	43	6.4191	1.1358	0.4000	59.0000	8.3996
K-1407 OU	Cadmium	81	70	11	1.8799	0.1743	0.3000	8.5000	2.1492
K-1407 OU	Chloroform	37	4	33	0.0156	0.0004	0.0060	0.0240	0.0119
K-1407 OU	Chromium	81	81	0	61.0370	5.3044	18.0000	240.0000	69.8642
K-1407 OU	Copper	81	79	2	40.8537	4.6847	0.5100	190.0000	48.6398
K-1407 OU	Di-n-butylphthalate	6	6	0	0.0172	0.0007	0.0160	0.0200	0.0185
K-1407 OU	Lead	81	78	3	30.6753	1.5668	5.8000	72.0000	32.9964
K-1407 OU	Manganese	81	81	0	1184.7778	102.4519	86.0000	3900.0000	1355.2705
K-1407 OU	Mercury	64	28	36	4.7250	0.9668	1.0000	40.0000	6.3965
K-1407 OU	Methylene chloride	37	37	0	0.0175	0.0022	0.0030	0.0360	0.0212
K-1407 OU	Molybdenum	81	28	53	1.8006	0.1551	0.9600	10.0000	1.5498
K-1407 OU	Nickel	81	81	0	192.1790	35.4005	5.0000	1500.0000	251.0899
K-1407 OU	Selenium	81	1	80	7.1519	0.7359	4.8000	50.0000	NA

Table G.7 (continued)

Location	Analyte	Obs	# Det	# Nondet	Mean[a]	Standard Error	Min	Max	95% UCB
K-1407 OU	Strontium	81	81	0	18.1420	1.5188	1.8000	64.0000	20.6695
K-1407 OU	Tetrachloroethene	37	8	29	0.0232	0.0046	0.0050	0.1700	0.0243
K-1407 OU	Toluene	37	11	26	0.0115	0.0012	0.0009	0.0200	0.0010
K-1407 OU	Trichloroethene	37	11	26	0.0246	0.0040	0.0090	0.1300	0.0281
K-1407 OU	Uranium	386	353	33	143.6944	68.1672	0.1080	26190.0000	255.8501
K-1407 OU	Vanadium	81	81	0	38.9753	1.4213	14.0000	75.0000	41.3405
K-1407 OU	Zinc	81	81	0	59.7778	2.8203	11.0000	140.0000	64.4711
K-1414	Acetone	2	1	1	0.0310	0.0190	0.0120	0.0500	NA
K-1414	Benzo(a)pyrene	2	1	1	0.2870	0.1930	0.0940	0.4800	NA
K-1414	Bis(2-ethylhexyl)phthalate	2	1	1	0.2235	0.1665	0.0570	0.3900	NA
K-1414	Di-n-butlyphthalate	2	2	0	0.7400	0.2600	0.4800	1.0000	2.3816
K-1414	Methylene chloride	2	2	0	0.0380	0.0190	0.0190	0.0570	0.1580
K-1414	Tetrachloroethene	2	1	1	0.0040	0.0020	0.0020	0.0060	NA
K-1420 OU	1,2-Dichlorethane	5	3	2	0.0054	0.0012	0.0020	0.0090	0.0074
K-1420 OU	Acetone	5	3	2	0.0190	0.0028	0.0120	0.0250	0.0249
K-1420 OU	Aldrin	4	1	3	0.0114	0.0012	0.0096	0.0150	NA
K-1420 OU	Aluminum	2	2	0	19950.0000	4650.0000	15300.0000	24600.0000	49308945.0000
K-1420 OU	Arsenic	4	4	0	18.4700	3.6054	8.3800	25.5000	26.9549
K-1420 OU	Barium	2	2	0	31.8500	8.2500	23.6000	40.1000	83.9384
K-1420 OU	Benzo(a)pyrene	5	2	3	0.3780	0.0659	0.1200	0.4800	0.3862
K-1420 OU	Beryllium	2	2	0	0.3750	0.1450	0.2300	0.5200	1.2905
K-1420 OU	Beta-BHC	4	1	3	0.0137	0.0035	0.0096	0.0240	NA
K-1420 OU	Bis(2-ethylhexyl)phthalate	5	4	1	0.2150	0.0637	0.0750	0.4000	0.2892
K-1420 OU	Boron	2	1	1	2.7000	1.4000	1.3000	4.1000	NA
K-1420 OU	Chromium	3	2	1	15.2000	7.4505	0.4000	24.1000	25.4717
K-1420 OU	Copper	2	2	0	26.2000	3.3000	22.9000	29.5000	47.0354
K-1420 OU	Fluoride	4	2	2	40.0150	23.0854	0.0300	80.0000	0.0300
K-1420 OU	Lead	4	4	0	66.2500	10.3119	48.2000	93.2000	90.5177
K-1420 OU	Lithium	2	2	0	52.2000	27.9000	24.3000	80.1000	228.3537

Table G.7 (continued)

Location	Analyte	Obs	# Det	# Nondet	Mean[a]	Standard Error	Min	Max	95% UCB
K-1420 OU	Manganese	2	2	0	470.0000	236.0000	234.0000	706.0000	1960.0454
K-1420 OU	Mercury	4	3	1	0.2025	0.0936	0.0300	0.4500	0.4301
K-1420 OU	Methylene chloride	5	4	1	0.0070	0.0011	0.0040	0.0100	0.0093
K-1420 OU	Nickel	2	2	0	24.0500	1.5500	22.5000	25.6000	33.8363
K-1420 OU	Nitrate	4	2	2	20.0075	11.5427	0.0100	40.0000	0.0268
K-1420 OU	PCB-1254	4	3	1	0.6625	0.4128	0.2200	1.9000	1.6934
K-1420 OU	Pentachlorophenol	5	1	4	2.1060	0.6458	0.1300	4.2000	NA
K-1420 OU	Strontium	2	2	0	38.2500	34.4500	3.8000	72.7000	255.7587
K-1420 OU	Tetrachloroethene	5	1	4	0.0060	0.0003	0.0050	0.0070	NA
K-1420 OU	Thallium	2	1	1	0.7200	0.2800	0.4400	1.0000	NA
K-1420 OU	Trichloroethene	5	1	4	0.0410	0.0348	0.0060	0.1800	NA
K-1420 OU	Uranium	12	12	0	139.1092	79.8794	1.9800	929.0000	282.5634
K-1420 OU	Vanadium	2	2	0	48.9000	14.6000	34.3000	63.5000	141.0808
K-1420 OU	Zinc	2	2	0	84.3500	11.0500	73.3000	95.4000	154.1170
LEFPC	4,4-DDD	115	6	109	0.0166	0.0023	0.0001	0.2200	0.0006
LEFPC	4,4-DDE	114	36	78	0.0154	0.0023	0.0002	0.2200	228.0000
LEFPC	4,4-DDT	115	5	110	0.0168	0.0023	0.0002	0.2200	0.0014
LEFPC	Acetone	12	12	0	0.2536	0.1800	0.0030	2.2000	0.5768
LEFPC	Aldrin	115	11	104	0.0083	0.0012	0.0001	0.1100	0.0004
LEFPC	Alpha-chlordane	115	39	76	0.0730	0.0121	0.0001	1.1000	0.0025
LEFPC	Aluminum	150	150	0	12605.6667	377.0456	0.0000	27900.0000	13229.7310
LEFPC	Antimony	1590	1316	274	1.2837	0.0656	0.1300	53.9000	0.7872
LEFPC	Arsenic	1289	1275	14	7.7788	0.1166	1.1000	77.3000	7.9621
LEFPC	Barium	150	150	0	121.3567	5.2507	33.7000	454.0000	130.0473
LEFPC	Benzo(a)Pyrene	113	70	43	0.4917	0.0476	0.0500	3.5000	0.4838
LEFPC	Beryllium	150	146	4	0.9165	0.0383	0.2500	4.6000	0.9781
LEFPC	Bis(2-ethylhexyl)Phthalate	113	62	51	0.3343	0.0229	0.0450	1.3000	0.2007
LEFPC	Cadmium	150	100	50	4.0894	0.3975	0.7300	41.3000	4.6446
LEFPC	Chromium	1698	1698	0	64.6076	0.5609	6.9000	217.0000	65.5307

Table G.7 (continued)

Location	Analyte	Obs	# Det	# Nondet	Mean[a]	Standard Error	Min	Max	95% UCB
LEFPC	Copper	150	150	0	78.0333	7.0314	2.6000	397.0000	89.6714
LEFPC	Cyanide	36	22	14	3.0242	1.7695	0.0000	62.6000	5.8240
LEFPC	Delta-BHC	115	5	110	0.0084	0.0012	0.0001	0.1100	0.0003
LEFPC	Dibenzofuran	113	9	104	0.4390	0.0158	0.0520	1.3000	0.1178
LEFPC	Dieldrin	115	9	106	0.0169	0.0023	0.0002	0.2200	0.0015
LEFPC	DiethylPhthalate	113	2	111	0.4612	0.0134	0.1600	1.3000	0.1733
LEFPC	Di-n-butlyPhthalate	113	33	80	0.4212	0.0190	0.0450	1.3000	0.1841
LEFPC	Endosulfan I	115	3	112	0.0084	0.0012	0.0001	0.1100	0.0009
LEFPC	Endosulfan II	115	5	110	0.0167	0.0023	0.0003	0.2200	0.0010
LEFPC	Endrin	115	9	106	0.0166	0.0023	0.0001	0.2200	0.0007
LEFPC	Gamma-chlordane	115	33	82	0.0727	0.0121	0.0001	1.1000	0.0014
LEFPC	Heptachlor	115	19	96	0.0081	0.0012	0.0001	0.1100	0.0002
LEFPC	Lead	148	148	0	53.7993	4.6434	5.2000	625.0000	61.4855
LEFPC	Lindane	115	4	111	0.0085	0.0012	0.0002	0.1100	0.0007
LEFPC	Manganese	150	150	0	1110.0367	51.1151	25.6000	4270.0000	1194.6395
LEFPC	Mercury	1720	589	1131	38.4880	3.0932	0.1100	1870.0000	41.6088
LEFPC	Methoxychlor	115	12	103	0.0835	0.0117	0.0003	1.1000	0.0059
LEFPC	Methylene chloride	12	12	0	0.0373	0.0087	0.0100	0.1100	0.0529
LEFPC	Nickel	150	146	4	34.3673	2.1702	3.7000	174.0000	37.9061
LEFPC	PCB-1016	146	9	137	0.0896	0.0092	0.0330	1.1000	0.0499
LEFPC	PCB-1221	146	9	137	0.1201	0.0098	0.0670	1.1000	0.1005
LEFPC	PCB-1232	146	9	137	0.0896	0.0092	0.0330	1.1000	0.0499
LEFPC	PCB-1242	146	9	137	0.0896	0.0092	0.0330	1.1000	0.0499
LEFPC	PCB-1248	146	9	137	0.0896	0.0092	0.0330	1.1000	0.0499
LEFPC	PCB-1254	146	23	123	0.2579	0.0412	0.0330	3.0000	0.2239
LEFPC	PCB-1260	145	91	54	0.4311	0.0587	0.0030	3.8000	0.4655
LEFPC	Pentachlorophenol	113	2	111	1.6920	0.0927	0.0670	6.4000	0.3767
LEFPC	Selenium	1716	439	1277	13.5663	0.2453	0.6100	110.0000	8.7045
LEFPC	Thallium	146	1	145	0.8092	0.1281	0.4300	19.3000	NA

Table G.7 (continued)

Location	Analyte	Obs	# Det	# Nondet	Mean[a]	Standard Error	Min	Max	95% UCB
LEFPC	Uranium	24	24	0	9.7083	1.2757	1.9800	25.5900	11.8948
LEFPC	Vanadium	150	150	0	26.8927	0.8537	9.6000	92.7000	28.3057
LEFPC	Zinc	1701	521	1180	179.9126	15.5480	14.0000	7640.0000	166.1992
SCF	1,1-Dichlorethene	154	9	145	10.4636	5.2994	0.0020	518.1000	19.6786
SCF	1,1,1-trichlorethane	84	13	71	0.4363	0.3034	0.0000	19.2100	0.9550
SCF	1,2-Dichlorethane	84	4	80	60.8926	42.2368	0.0100	2591.0000	157.2160
SCF	4,4-DDD	23	5	18	0.0045	0.0006	0.0001	0.0110	0.0015
SCF	4,4-DDE	23	13	10	0.0030	0.0006	0.0002	0.0140	0.0018
SCF	4,4-DDT	23	9	14	0.0058	0.0015	0.0002	0.0300	0.0065
SCF	Acetone	84	16	68	97.9546	67.5711	0.0110	4145.0000	212.9860
SCF	Aldrin	23	3	20	0.0026	0.0004	0.0001	0.0070	0.0004
SCF	Alpha-chlordane	23	5	18	0.0026	0.0004	0.0001	0.0070	0.0013
SCF	Aluminum	22	22	0	16294.0455	2471.5459	149.0000	47000.0000	20546.9410
SCF	Antimony	103	91	12	3.1252	0.7214	0.0940	38.0000	1.2148
SCF	Arsenic	113	111	2	12.7714	1.0468	0.8000	103.7000	14.5344
SCF	Barium	22	20	2	111.6045	15.9635	0.4000	322.0000	139.7386
SCF	Benzene	84	7	77	0.9165	0.6335	0.0003	38.8600	2.0400
SCF	Benzo(a)pyrene	22	7	15	0.4829	0.0640	0.0580	1.1000	0.3224
SCF	Beryllium	22	12	10	1.4800	0.1716	0.2500	3.9000	1.6114
SCF	Bis(2-ethylhexyl)phthalate	22	7	15	0.4390	0.0690	0.0500	1.1000	0.1756
SCF	Cadmium	113	91	22	6.1319	0.9122	0.0000	85.9900	7.4130
SCF	Carbon tetrachloride	84	6	78	0.0031	0.0009	0.0000	0.0420	0.0001
SCF	Chloroform	84	6	78	0.8859	0.6124	0.0003	37.5600	1.9872
SCF	Chromium	113	110	3	56.8916	2.4701	2.0000	204.7000	61.1572
SCF	Copper	22	18	4	20.5545	3.9385	3.0000	81.2000	27.8990
SCF	Delta-BHC	23	4	19	0.0026	0.0004	0.0001	0.0070	0.0004
SCF	Dibenzofuran	22	1	21	0.5218	0.0487	0.2900	1.1000	NA
SCF	Dieldrin	23	7	16	0.0041	0.0007	0.0002	0.0110	0.0013
SCF	Di-n-butlyphthalate	22	4	18	0.4705	0.0686	0.0610	1.4000	0.1183

Table G.7 (continued)

Location	Analyte	Obs	# Det	# Nondet	Mean[a]	Standard Error	Min	Max	95% UCB
SCF	Endosulfan I	23	1	22	0.0028	0.0003	0.0009	0.0070	NA
SCF	Endrin	23	4	19	0.0046	0.0006	0.0001	0.0110	0.0011
SCF	Gamma-chlordane	23	3	20	0.0027	0.0003	0.0005	0.0070	0.0010
SCF	Heptachlor	23	1	22	0.0028	0.0003	0.0005	0.0070	NA
SCF	Lead	22	22	0	41.5059	6.2219	0.4300	135.0000	52.2122
SCF	Manganese	22	21	1	1392.0923	265.3807	0.8000	4080.0000	1849.2636
SCF	Mercury	113	102	11	0.6817	0.1102	0.0000	6.6000	0.8542
SCF	Methoxychlor	23	3	20	0.0266	0.0030	0.0024	0.0710	0.0142
SCF	Methylene chloride	154	8	146	136.1755	68.9493	0.0110	6736.0000	281.1491
SCF	Nickel	22	15	7	18.4182	1.8591	5.6000	37.2000	20.3718
SCF	PCB-1254	23	3	20	0.0567	0.0064	0.0200	0.1400	0.0375
SCF	PCB-1260	23	4	19	0.0665	0.0126	0.0330	0.3100	0.0694
SCF	Pentachlorophenol	103	82	21	0.2657	0.0571	0.0000	2.7000	0.0052
SCF	Selenium	110	91	19	2.7963	0.1575	0.0387	7.9030	2.9646
SCF	Tetrachloroethene	155	10	145	0.5462	0.3456	0.0000	38.8600	1.1422
SCF	Toluene	84	7	77	0.9167	0.6335	0.0003	38.8600	2.0452
SCF	Trichloroethene	154	14	140	0.7824	0.4186	0.0001	44.0400	1.4930
SCF	Uranium	91	91	0	3.1277	0.1117	1.1902	6.0080	3.3133
SCF	Vanadium	20	18	2	31.4000	4.3587	2.0000	67.3000	38.9609
SCF	Zinc	113	111	2	114.1718	19.2046	1.9000	1524.0000	146.0309
UEFPC OU 2	Aluminum	2	2	0	29900.0000	5600.0000	24300.0000	35500.0000	65257.0090
UEFPC OU 2	Arsenic	2	2	0	1.4600	1.1400	0.3200	2.6000	8.6577
UEFPC OU 2	Barium	2	2	0	149.8500	66.1500	83.7000	216.0000	567.5047
UEFPC OU 2	Beryllium	2	2	0	1.2500	0.1500	1.1000	1.4000	2.1971
UEFPC OU 2	Chromium	2	2	0	39.7000	5.9000	33.8000	45.6000	76.9511
UEFPC OU 2	Copper	2	2	0	22.1000	5.2000	16.9000	27.3000	54.9315
UEFPC OU 2	Lead	2	2	0	36.6000	33.8000	2.8000	70.4000	250.0048
UEFPC OU 2	Lithium	2	2	0	22.7000	1.4000	21.3000	24.1000	31.5393
UEFPC OU 2	Manganese	2	2	0	484.0000	334.0000	150.0000	818.0000	2592.7930

Table G.7 (continued)

Location	Analyte	Obs	# Det	# Nondet	Mean[a]	Standard Error	Min	Max	95% UCB
UEFPC OU 2	Nickel	2	2	0	36.2000	3.3000	32.9000	39.5000	57.0354
UEFPC OU 2	Nitrate	2	2	0	0.5850	0.0850	0.5000	0.6700	1.1217
UEFPC OU 2	Strontium	2	2	0	21.1000	15.3000	5.8000	36.4000	117.7004
UEFPC OU 2	Uranium	2	2	0	1.5650	0.7350	0.8300	2.3000	6.2056
UEFPC OU 2	Vanadium	2	2	0	26.0000	1.4000	24.6000	27.4000	34.8393
UEFPC OU 2	Zinc	2	2	0	86.2000	31.8000	54.4000	118.0000	286.9773
WAG 1	1,1-Dichlorethene	168	2	166	0.0076	0.0004	0.0050	0.0340	0.0060
WAG 1	1,1,1-trichlorethane	168	12	156	0.0077	0.0005	0.0020	0.0340	0.0033
WAG 1	1,2-Dichlorethane	168	2	166	0.0076	0.0004	0.0050	0.0340	0.0060
WAG 1	1,2-Dichlorethene	168	4	164	0.0076	0.0004	0.0020	0.0340	0.0023
WAG 1	4,4-DDD	63	1	62	0.0214	0.0013	0.0170	0.0900	NA
WAG 1	4,4-DDE	63	1	62	0.0218	0.0014	0.0170	0.0900	NA
WAG 1	4,4-DDT	65	3	62	0.0211	0.0012	0.0076	0.0900	0.0101
WAG 1	Acetone	168	107	61	0.0278	0.0024	0.0020	0.2300	0.0293
WAG 1	Alpha-BHC	67	1	66	0.0118	0.0013	0.0083	0.0840	NA
WAG 1	Alpha-chlordane	67	1	66	0.1049	0.0060	0.0830	0.4500	NA
WAG 1	Aluminum	136	135	1	12152.1588	558.6427	13.6000	35200.0000	13085439.0000
WAG 1	Antimony	49	25	24	6.1265	0.3790	2.5000	17.4000	6.0617
WAG 1	Arsenic	136	132	4	9.0118	0.5659	1.2000	29.4000	9.7694
WAG 1	Barium	136	135	1	107.4636	4.7336	0.4500	410.0000	115.3482
WAG 1	Benzene	168	3	165	0.0076	0.0004	0.0030	0.0340	0.0031
WAG 1	Benzo(a)Pyrene	123	58	65	0.6776	0.1273	0.0390	12.0000	0.7257
WAG 1	Beryllium	137	131	6	0.9493	0.0369	0.1900	2.6000	1.0127
WAG 1	Bis(2-ethylhexyl)Phthalate	123	85	38	0.4584	0.0746	0.0220	8.5000	0.4414
WAG 1	Boron	40	37	3	1204.9650	329.8646	4.8000	7000.0000	1761.2341
WAG 1	Cadmium	137	66	71	1.7696	0.1478	0.2200	10.3000	1.9618
WAG 1	Carbon tetrachloride	168	2	166	0.0076	0.0004	0.0050	0.0340	0.0060
WAG 1	Chloroform	168	44	124	0.0098	0.0017	0.0010	0.2400	0.0090
WAG 1	Chromium	136	135	1	28.9507	2.4147	2.3000	189.0000	32.9578

Table G.7 (continued)

Location	Analyte	Obs	# Det	# Nondet	Mean[a]	Standard Error	Min	Max	95% UCB
WAG 1	Copper	136	132	4	19.6249	1.5910	0.7200	125.0000	22.2562
WAG 1	Cyanide	65	1	64	4.6813	0.3108	0.0001	8.0000	NA
WAG 1	Dibenzofuran	123	10	113	0.5403	0.0512	0.0290	5.5000	0.1746
WAG 1	Diethylphthalate	123	10	113	0.5785	0.0578	0.0220	5.5000	0.0481
WAG 1	Di-n-butlyphthalate	122	73	49	0.7199	0.0595	0.0440	2.9000	0.7003
WAG 1	Endrin	66	1	65	0.0210	0.0012	0.0028	0.0900	NA
WAG 1	Gamma-chlordane	67	1	66	0.1043	0.0060	0.0550	0.4500	NA
WAG 1	Heptachlor	67	1	66	0.0105	0.0006	0.0083	0.0450	NA
WAG 1	Lead	134	133	1	40.8739	3.3078	2.9000	337.0000	46.3236
WAG 1	Manganese	136	135	1	841.9415	40.8851	0.4500	2970.0000	909.9661
WAG 1	Mercury	93	49	44	1.3060	0.3266	0.1000	16.4000	1.8496
WAG 1	Methylene chloride	168	152	16	0.0310	0.0035	0.0010	0.3600	0.0366
WAG 1	Nickel	136	135	1	19.2610	0.7882	3.3000	47.7000	20.5598
WAG 1	PCB-1254	66	10	56	0.3505	0.0922	0.0800	5.8000	0.4403
WAG 1	PCB-1260	67	10	57	0.2473	0.0289	0.0880	1.9000	0.2270
WAG 1	Pentachlorophenol	123	5	118	2.9574	0.2817	0.0530	26.0000	0.2800
WAG 1	Selenium	102	48	54	14.5650	1.6571	0.3900	52.1000	16.8413
WAG 1	Tetrachloroethene	168	5	163	0.0076	0.0004	0.0020	0.0340	0.0043
WAG 1	Thallium	133	35	98	14.1675	2.1681	0.2200	127.0000	15.8509
WAG 1	Tin	40	40	0	50.7300	2.0604	31.8000	83.9000	54.2015
WAG 1	Toluene	168	41	127	0.0071	0.0004	0.0006	0.0340	0.0035
WAG 1	Trichloroethene	168	14	154	0.0074	0.0005	0.0010	0.0340	0.0023
WAG 1	Uranium	90	90	0	7.9570	3.9183	0.5200	323.0000	14.4699
WAG 1	Vanadium	137	136	1	21.5983	0.7594	0.4700	54.5000	22.8507
WAG 1	Vinyl chloride	168	2	166	0.0155	0.0009	0.0100	0.0680	0.0120
WAG 1	Zinc	136	135	1	91.9930	8.2040	0.4500	514.0000	105.6279
WAG 6	1,2-Dichlorethene	37	1	36	0.0068	0.0002	0.0060	0.0150	NA
WAG 6	1,4-Dioxane	4	2	2	6.6750	0.3198	6.2000	7.6000	7.5588
WAG 6	Acetone	37	23	14	0.0139	0.0010	0.0060	0.0440	0.0147

Table G.7 (continued)

Location	Analyte	Obs	# Det	# Nondet	Mean[a]	Standard Error	Min	Max	95% UCB
WAG 6	Aluminum	32	32	0	15837.8125	813.9395	7380.0000	24600.0000	17217862.0000
WAG 6	Arsenic	32	27	5	1.7666	0.1659	0.3700	4.2000	2.0874
WAG 6	Barium	32	32	0	132.8125	6.2860	70.6000	228.0000	143.4706
WAG 6	Beryllium	32	32	0	1.3834	0.0605	0.9700	2.4000	1.4859
WAG 6	Bis(2-ethylhexyl)phthalate	32	27	5	0.3983	0.0530	0.0660	1.7000	0.4624
WAG 6	Cadmium	32	28	4	2.5013	0.1860	0.5800	4.0000	2.8456
WAG 6	Chloroform	37	21	16	0.0114	0.0017	0.0020	0.0640	0.0128
WAG 6	Chromium	32	32	0	24.6031	1.0401	13.1000	34.8000	26.3667
WAG 6	Copper	32	32	0	16.5219	0.9470	7.1000	27.5000	18.1276
WAG 6	Cyanide	32	1	31	23.8172	13.0661	0.0100	250.0000	NA
WAG 6	Lead	31	30	1	15.4981	1.7097	0.5400	46.2000	18.4334
WAG 6	Manganese	32	32	0	1037.6594	116.8054	54.1000	3530.0000	1235.7050
WAG 6	Mercury	30	4	26	0.1007	0.0080	0.0000	0.1400	0.0374
WAG 6	Methylene chloride	37	37	0	0.0283	0.0057	0.0060	0.2000	0.0378
WAG 6	Nickel	32	32	0	38.2844	1.9707	18.7000	59.7000	41.6257
WAG 6	Tetrachloroethene	37	2	35	0.0063	0.0002	0.0020	0.0080	0.0033
WAG 6	Tin	4	4	0	55.0250	14.5400	25.7000	87.1000	89.2430
WAG 6	Toluene	37	17	20	0.0044	0.0004	0.0010	0.0080	0.0025
WAG 6	Trichloroethene	37	13	24	0.0055	0.0005	0.0010	0.0170	0.0036
WAG 6	Uranium	4	4	0	0.8183	0.0800	0.6870	1.0500	1.0065
WAG 6	Vanadium	32	32	0	17.1344	0.8968	5.7000	32.5000	18.6549
WAG 6	Zinc	32	32	0	57.4594	3.0367	23.5000	103.0000	62.6082

[a] Mean: In cases where only a single detected value was observed at that location, the single detected concentration is presented. The 95% UCB is designated with NA.

[b] NA= Not Available.

Table G.8. Contaminant concentrations in soil (mg/kg) on the ORR compared with background soil levels (ESD 1993)

LOCATION	FORMATION[a]	ANALYTE	BACKGROUND		OU SOIL		Retained[b]-Exceeds Background?
			95% UCB HIGH	95% UCB LOW	MEAN	95% UCB	
LEFPC	CHI	Aluminum	18600	NA	12605.6667	13229.7316	NO
LEFPC		Antimony	NA	NA	1.2837	0.7872	YES
LEFPC	CHI	Arsenic	9.73	NA	7.7788	7.9621	NO
LEFPC	CHI	Barium	99.6	NA	121.3567	130.0473	YES
LEFPC	CHI	Beryllium	1.120	NA	0.9165	0.9781	NO
LEFPC		Cadmium	NA	NA	4.0894	4.6446	YES
LEFPC	CHI	Chromium	38.5	NA	64.6076	65.5307	YES
LEFPC	CHI	Copper	14.50	NA	78.0333	89.6714	YES
LEFPC	CHI (DG[c])	Cyanide	.583	NA	3.0242	5.8240	YES
LEFPC	CHI	Lead	43.2	NA	53.7993	61.4855	YES
LEFPC	CHI	Manganese	2290	NA	1110.0367	1194.6395	NO
LEFPC	CHI	Mercury	0.5790	NA	38.4880	41.6088	YES
LEFPC	CHI	Nickel	21.30	NA	34.3673	37.9061	YES
LEFPC	CHI	Selenium	0.962	NA	13.5663	8.7045	YES
LEFPC		Thallium	NA	NA	0.8092	NA	YES
LEFPC	CHI	Vanadium	42.0	NA	26.8927	28.3057	NO
LEFPC	CHI	Zinc	56.9	NA	179.9126	166.1992	YES
K-1407 OU	CHI	Aluminum	18600	NA	26562.9630	28723.5267	YES

Table G.8 (continued)

LOCATION	FORMATION[a]	ANALYTE	BACKGROUND		OU SOIL		Retained[b]-Exceeds Background?
			95% UCB HIGH	95% UCB LOW	MEAN	95% UCB	
K-1407 OU	CHI	Antimony	NA	NA	7.1506	NA	YES
K-1407 OU	CHI	Arsenic	9.73	NA	12.4333	13.0681	YES
K-1407 OU	CHI	Barium	99.6	NA	110.4938	125.2752	YES
K-1407 OU	CHI	Beryllium	1.120	NA	1.0159	1.1269	YES
K-1407 OU	CHI	Boron	NA	NA	6.4191	8.3996	YES
K-1407 OU	CHI	Cadmium	NA	NA	1.8799	2.1492	YES
K-1407 OU	CHI	Chromium	38.5	NA	61.0370	69.8642	YES
K-1407 OU	CHI	Copper	14.50	NA	40.8537	48.6398	YES
K-1407 OU	CHI	Lead	43.2	NA	30.6753	32.9964	NO
K-1407 OU	CHI	Manganese	2290	NA	1184.7778	1355.2705	NO
K-1407 OU	CHI	Mercury	0.5790	NA	4.7250	6.3965	YES
K-1407 OU	CHI	Molybdenum	3.20	NA	1.8006	1.5498	NO
K-1407 OU	CHI	Nickel	21.30	NA	192.1790	251.0899	YES

Table G.8 (continued)

LOCATION	FORMATION[a]	ANALYTE	BACKGROUND		OU SOIL		Retained[b]- Exceeds Background?
			95% UCB HIGH	95% UCB LOW	MEAN	95% UCB	
K-1407 OU	CHI	Selenium	0.962	NA	7.1519	NA	YES
K-1407 OU	CHI	Strontium	16.000	NA	18.1420	20.6695	YES
K-1407 OU	CHI	Vanadium	42.0	NA	38.9753	41.3405	NO
K-1407 OU	CHI	Zinc	56.9	NA	59.7778	64.4711	YES
WAG 1	DG, NL	Aluminum	25000	232000	12152.1588	13085.4391	NO
WAG 1	NL	Antimony	0.485	NA	6.1265	6.0617	YES
WAG 1	DG, NL	Arsenic	8.18	7.97	9.0118	9.7694	YES
WAG 1	DG, NL	Barium	129.0	97.8	107.4636	115.3482	NO
WAG 1	DG, NL	Beryllium	0.964	0.957	0.9493	1.0127	YES
WAG 1	DG	Boron	22.70	NA	1204.9650	1761.2341	YES
WAG 1		Cadmium	NA	NA	1.7696	1.9618	YES
WAG 1	DG, NL	Chromium	34.0	29.2	28.9507	32.9578	YES
WAG 1	DG, NL	Copper	20.50	14.90	19.6249	22.2562	YES
WAG 1	DG	Cyanide	0.398	NA	4.6813	NA	YES
WAG 1	DG, NL	Lead	27.7	25.1	40.8739	46.3236	YES
WAG 1	DG, NL	Manganese	1370	895	841.9415	909.9661	NO
WAG 1	DG, NL	Mercury	0.3700	0.2170	1.3060	1.8496	YES

Table G.8 (continued)

LOCATION	FORMATION[a]	ANALYTE	BACKGROUND		OU SOIL		Retained[b]- Exceeds Background?
			95% UCB HIGH	95% UCB LOW	MEAN	95% UCB	
WAG 1	DG, NL	Nickel	21.40	16.70	19.2610	20.5598	NO
WAG 1	DG, NL	Selenium	0.931	0.718	14.5650	16.8413	YES
WAG 1	DG	Thallium	0.556	NA	14.1675	15.8509	YES
WAG 1	DG, NL	Vanadium	39.1	37.1	21.5983	22.8507	NO
WAG 1	DG, NL	Zinc	62.6	46.8	91.9930	105.6279	YES
WAG 6	DG, NL	Aluminum	25000	23200	15837.8125	17217.8622	NO
WAG 6	DG, NL	Arsenic	8.18	7.97	1.7666	2.0874	NO
WAG 6	DG, NL	Barium	129.0	97.8	132.8125	143.4706	YES
WAG 6	DG, NL	Beryllium	0.964	0.957	1.3834	1.4859	YES
WAG 6		Cadmium	NA	NA	2.5013	2.8456	YES
WAG 6	DG, NL	Chromium	34.0	29.2	24.6031	26.3667	NO
WAG 6	DG, NL	Copper	20.50	14.90	16.5219	18.1276	NO
WAG 6	DG, NL	Cyanide	0.281	NA	23.8172	NA	YES
WAG 6	DG, NL	Lead	27.7	25.1	15.4981	18.4334	NO
WAG 6	DG, NL	Manganese	1370	895	1037.6594	1235.7050	NO
WAG 6	DG, NL	Mercury	0.3700	0.2170	0.1007	0.0374	NO
WAG 6	DG, NL	Nickel	36.10	26.60	38.2844	41.6257	YES
WAG 6	DG, NL	Vanadium	39.1	37.1	17.1344	18.6549	NO
WAG 6	DG, NL	Zinc	62.6	46.8	57.4594	62.6082	NO

Table G.8 (continued)

LOCATION	FORMATION[a]	ANALYTE	BACKGROUND		OU SOIL		Retained[b]- Exceeds Background?
			95% UCB HIGH	95% UCB LOW	MEAN	95% UCB	
UEFPC OU 2	CHI	Aluminum	18600	NA	29900.0000	65257.0085	YES
UEFPC OU 2	CHI	Arsenic	9.73	NA	1.4600	8.6577	NO
UEFPC OU 2	CHI	Barium	99.6	NA	149.8500	567.5047	YES
UEFPC OU 2	CHI	Beryllium	1.120	NA	1.2500	2.1971	YES
UEFPC OU 2	CHI	Chromium	38.5	NA	39.7000	76.9511	YES
UEFPC OU 2	CHI	Copper	14.50	NA	22.1000	54.9315	YES
UEFPC OU 2	CHI	Lead	43.2	NA	36.6000	250.0048	YES
UEFPC OU 2	CHI	Lithium	17.40	NA	22.7000	31.5393	YES
UEFPC OU 2	CHI	Manganese	2290	NA	484.0000	2592.7930	YES
UEFPC OU 2	CHI	Nickel	21.30	NA	36.2000	57.0354	YES
UEFPC OU 2	CHI	Strontium	16.000	NA	21.1000	117.7004	YES
UEFPC OU 2	CHI	Vanadium	42.0	NA	26.0000	34.8393	NO
UEFPC OU 2	CHI	Zinc	56.9	NA	86.2000	286.9773	YES

Table G.8 (continued)

LOCATION	FORMATION[a]	ANALYTE	BACKGROUND		OU SOIL		Retained[b]-Exceeds Background?
			95% UCB HIGH	95% UCB LOW	MEAN	95% UCB	
BC OU 2	CR	Aluminum	11800	NA	26143.8462	35920.3403	YES
BC OU 2		Antimony	NA	NA	0.3089	0.3570	YES
BC OU 2	CR	Arsenic	30.70	NA	33.3692	35.0930	YES
BC OU 2	CR	Barium	93.2	NA	101.4000	153.9779	YES
BC OU 2	CR	Beryllium	0.634	NA	1.0246	1.3154	YES
BC OU 2	CR	Boron	NA	NA	65.5000	79.4061	YES
BC OU 2	CR	Cadmium	NA	NA	1.2469	0.8571	YES
BC OU 2	CR	Chromium	18.3	NA	37.3308	44.2323	YES
BC OU 2	CR	Copper	8.19	NA	39.2231	57.3653	YES
BC OU 2	CR	Lead	23.00	NA	81.0154	126.8223	YES
BC OU 2	CR	Lithium	3.48	NA	39.2500	47.1944	YES
BC OU 2	CR	Manganese	1460	NA	1021.5231	1779.3673	YES
BC OU 2	CR	Mercury	0.184	NA	49.0188	76.0554	YES
BC OU 2	CR	Nickel	9.71	NA	32.6000	50.3224	YES
BC OU 2	CR	Selenium	0.803	NA	1.0944	1.7881	YES
BC OU 2	CR	Strontium	4.810	NA	109.9250	133.8695	YES
BC OU 2	CR	Thallium	1.370	NA	0.3144	0.3644	NO
BC OU 2	CR	Vanadium	30.3	NA	54.8385	62.5775	YES
BC OU 2	CR	Zinc	43.2	NA	113.2077	149.4180	YES
SCF	CHI	Aluminum	18600	NA	16294.0455	20546.9405	YES

Table G.8 (continued)

LOCATION	FORMATION[a]	ANALYTE	BACKGROUND		OU SOIL		Retained[b]- Exceeds Background?
			95% UCB HIGH	95% UCB LOW	MEAN	95% UCB	
SCF	CHI	Antimony	NA	NA	3.1252	1.2148	YES
SCF	CHI	Arsenic	7.99	NA	12.7714	14.5344	YES
SCF	CHI	Barium	103.0	NA	111.6045	139.7386	YES
SCF	CHI	Beryllium	1.250	NA	1.4800	1.6114	YES
SCF	CHI	Cadmium	NA	NA	6.1319	7.4130	YES
SCF	CHI	Chromium	40.2	NA	56.8916	61.1572	YES
SCF	CHI	Copper	20.60	NA	20.5545	27.8990	YES
SCF	CHI	Lead	51.1	NA	41.5059	52.2122	YES
SCF	CHI	Manganese	1440	NA	1392.0923	1849.2636	YES
SCF	CHI	Mercury	0.1880	NA	0.6817	0.8542	YES
SCF	CHI	Nickel	16.70	NA	18.4182	20.3718	YES
SCF	CHI	Selenium	0.931	NA	2.7963	2.9646	YES
SCF	CHI	Vanadium	41.9	NA	31.4000	38.9609	NO
SCF	CHI	Zinc	55.5	NA	114.1718	146.0309	YES
K-1420 OU	CK[d]	Aluminum	15300	9510	19950.0000	49308.9445	YES
K-1420 OU	CK	Arsenic	30.70	11.80	18.4700	26.9549	NO
K-1420 OU	CK	Barium	151.0	69.5	31.8500	83.9384	YES
K-1420 OU	CK	Beryllium	0.911	0.460	0.3750	1.2905	YES

Table G.8 (continued)

LOCATION	FORMATION[a]	ANALYTE	BACKGROUND		OU SOIL		Retained[b]-Exceeds Background?
			95% UCB HIGH	95% UCB LOW	MEAN	95% UCB	
K-1420 OU	CK	Boron	4.87	NA	2.7000	NA	NO
K-1420 OU	CK	Chromium	23.9	15.0	15.2000	25.4717	YES
K-1420 OU	CK	Copper	11.6	5.26	26.2000	47.0354	YES
K-1420 OU	CK	Lead	52.2	24.6	66.2500	90.5177	YES
K-1420 OU	CK	Lithium	9.17	3.48	52.2000	228.3537	YES
K-1420 OU	CK	Manganese	3060	1170	470.0000	1960.0454	NO
K-1420 OU	CK	Mercury	0.1840	0.1300	0.2025	0.4301	YES
K-1420 OU	CK	Nickel	10.70	6.06	24.0500	33.8363	YES
K-1420 OU	CK	Strontium	7.68	3.33	38.2500	255.7587	YES
K-1420 OU	CK	Thallium	1.370	NA	0.7200	NA	NO
K-1420 OU	CK	Vanadium	39.4	26.4	48.9000	141.0808	YES
K-1420 OU	CK	Zinc	54.5	43.2	84.3500	154.1170	YES
CR OU2	CR, CK, CG, CHE	Aluminum	18600	9510	NA	21900	YES

Table G.8 (continued)

LOCATION	FORMATION[a]	ANALYTE	BACKGROUND		OU SOIL		Retained[b]-Exceeds Background?
			95% UCB HIGH	95% UCB LOW	MEAN	95% UCB	
CR OU2	CR, CK, CG, CHE	Arsenic	30.70	9.73	NA	131.0	YES
CR OU2	CR, CK, CG, CHE	Barium	151.0	69.5	NA	450.0	YES
CR OU2	CR, CK, CG, CHE	Chromium	38.5	15.0	NA	25.1	NO
CR OU2	CR, CK, CG, CHE	Copper	20.6	5.26	NA	69.1	YES
CR OU2	CR, CK, CG, CHE	Lead	52.2	24.6	NA	18.8	NO
CR OU2	CR, CK, CG, CHE	Manganese	3060	1710	NA	152.0	NO
CR OU2	CR, CK, CG, CHE	Mercury	0.184	0.130	NA	0.705	YES
CR OU2	CR, CK, CG, CHE	Nickel	16.70	6.06	NA	36.0	YES
CR OU2	CR, CK, CG, CHE	Selenium	1.310	0.621	NA	14.8	YES
CR OU2	CR, CK, CG, CHE	Vanadium	42.0	26.4	NA	84.9	YES
CR OU2	CR, CK, CG, CHE	Zinc	55.5	43.2	NA	53.9	NO

NA= Not Available.
If data on formation of OU is not available, then the range of background levels in all formations was used for comparison.

[a] Formations and Groups: CHI = Chickamauga Group; C (R) = Conasauga Group (Remaining) = Dismal Gap Formation and Nolichucky Formation; CK = Knox Group = Copper Ridge Formation and Chepultepec Formation; MN = Maynardville; Formation; CK(R) = Knox Group Remaining; NL = Nolichucky Formation; CHE = Chepultepec Formation; DG = Dismal Gap Formation; CR = Copper Ridge Formation; R = Rome Formation

Operable Units and Corresponding Formations or Groups:
BCVOU1 = C(R), DG, NL, MN   SCF = CHI
BCOU2 = MN, CR   K1420 = CK
WAG 1 = C(R), DG K1407 = CR, CHI
WAG 6 = NL, DG   LEFPC/UEFPC = CHI, CK, CK(R)
CR OU2 = CR, CK, CG, CHE

Table G.9. Soil-plant organic contaminant uptake factors using octanol water partition coefficients (Travis and Arms 1988)

Chemical	K_{ow}[a]	log B_v	Soil-plant uptake factor
Acetone	-0.24	1.72672	53.2991
4,4'DDT	6.53	-2.18634	0.0065
4,4'DDD	6.53	-2.18634	0.0065
Benzo(a)pyrene	6.11	-1.94358	0.0114
Bis(2ethylhexyl)phthalate	7.3	-2.6314	0.0023
Chloroform	1.92	0.47824	3.0077
Di-N-Butylphthalate	4.61	-1.07658	0.0838
Dibenzofuran	4.12	-0.79336	0.1609
Methylene Chloride	1.25	0.8655	7.3367
PCB (1254)	6.5	-2.169	0.0068
Tetrachloroethylene/ethene	2.67	0.04474	1.1085
Toluene	2.75	-0.0015	0.9966
Aldrin	6.5	-2.169	0.0068
Endrin	5.06	-1.33668	0.0461
Heptachlor	6.26	-2.03028	0.0093
Lindane (gamma BHC)	3.73	-0.56794	0.2704
1,2 Dichloroethylene	1.86	0.51292	3.2578
1,1,1 Trichlorethane	2.48	0.15456	1.4274
1,2 Dichloroethane	1.47	0.73834	5.4744
Trichloroethene/ethylene	2.71	0.02162	1.0510
Dieldrin	5.37	-1.51586	0.0305
Diethylphthalate	2.5	0.143	1.3900
Chlordane	6.32	-2.06496	0.0086
Benzene	2.13	0.35686	2.2744
Vinyl Chloride	1.5	0.721	5.2602

Soil-Plant Uptake Factors calculated using the following equation: $\log B_v = 1.588 - 0.578 \log K_{ow}$

Where:

B_v= Bioaccumulation factor for vegetation = soil-plant uptake factor

K_{ow}= Octanol Water Partitioning Coeffient.

[a] K_{ow} Source: Hull and Suter 1994.

[b] K_{ow} for Aldrin Source: Travis and Arms 1988.

Table G.10. Estimated exposure of white-tailed deer to contaminants on the ORR

Location	Analyte	Total Exposure	NOAEL HQ	LOAEL HQ
BC OU 2	Aluminum	55.310966	188.77	18.88
BC OU 2	Mercury	0.2693573	29.93	5.99
BC OU 2	Total PCBs	0.1002301	11.14	1.18
BC OU 2	Vanadium	0.2004252	3.64	0.37
BC OU 2	Arsenic	0.0561985	2.96	0.29
BC OU 2	Manganese	20.932918	0.84	0.26
BC OU 2	Barium	1.2186874	0.81	0.22
BC OU 2	Niobium	0.0060669	0.25	0.03
BC OU 2	Thallium	0.0004826	0.24	0.02
BC OU 2	Zirconium	0.045876	0.17	
BC OU 2	Copper	0.7084259	0.16	0.13
BC OU 2	Chromium	0.1185112	0.13	0.03
BC OU 2	Lead	0.2812088	0.13	0.01
BC OU 2	Cadmium	0.0299591	0.11	0.01
BC OU 2	Selenium	0.0044054	0.08	0.05
BC OU 2	Zinc	3.3867375	0.08	0.04
BC OU 2	Acetone	0.1725784	0.06	0.01
BC OU 2	Vinyl chloride	0.0026343	0.05	0.01
BC OU 2	Lithium	0.0784847	0.03	0.01
BC OU 2	Nickel	0.2727563	0.02	0.01
BC OU 2	Beryllium	0.0024306	0.01	
BC OU 2	Pentachlorophenol	0.0007981	0.01	0.00
BC OU 2	Antimony	0.0002199	0.01	0.00
BC OU 2	Strontium	0.8327868	0.01	
BC OU 2	Boron	0.0489085	0.01	0.00
BC OU 2	Uranium	0.0017051	0.00	0.00
BC OU 2	Benzo(a)pyrene	0.0005113	0.00	0.00
BC OU 2	Methylene chloride	0.0040554	0.00	0.00
BC OU 2	Trichloroethene	0.0002672	0.00	0.00
BC OU 2	Dieldrin	0.0000087	0.00	0.00
BC OU 2	Tetrachloroethene	0.0002711	0.00	0.00
BC OU 2	Endrin	0.0000114	0.00	0.00
BC OU 2	Chloroform	0.0007553	0.00	0.00
BC OU 2	1,2-Dichlorethane	0.0013706	0.00	
BC OU 2	Benzene	0.0005723	0.00	0.00
BC OU 2	Bis(2-ethylhexyl)Phthalate	0.0003639	0.00	0.00
BC OU 2	Endosulfan	0.0000052	0.00	
BC OU 2	Mixed-BHC	0.0000501	0.00	0.00
BC OU 2	Toxaphene	0.0001748	0.00	
BC OU 2	Heptachlor	0.0000025	0.00	0.00
BC OU 2	Toluene	0.0002536	0.00	0.00

Table G.10 (Continued)

Location	Analyte	Total Exposure	NOAEL HQ	LOAEL HQ
BC OU 2	DDT and metabolites	0.0000137	0.00	0.00
BC OU 2	Aldrin	0.0000023	0.00	0.00
BC OU 2	Diethylphthalate	0.02297	0.00	
BC OU 2	Di-N-Butylphthalate	0.0016916	0.00	0.00
BC OU 2	Methoxychlor	0.0000175	0.00	0.00
BC OU 2	Lindane	0.000025	0.00	
BC OU 2	Total-chlordane	0.0000049	0.00	0.00
BC OU 2	Carbon tetrachloride	0.000005	0.00	
BC OU 2	1,2-Dichlorethene	0.000005	0.00	
BC OU 2	1,1-Dichlorethene	0.000005	0.00	
BC OU 2	1,1,1-Trichlorethane	0.000005	0.00	
K-1407 OU	Aluminum	44.229148	150.95	15.10
K-1407 OU	Mercury	0.0226538	2.52	0.50
K-1407 OU	Vanadium	0.1324067	2.41	0.24
K-1407 OU	Arsenic	0.0209275	1.10	0.11
K-1407 OU	Barium	0.9915144	0.66	0.18
K-1407 OU	Manganese	15.943738	0.64	0.20
K-1407 OU	Uranium	0.1733441	0.38	0.19
K-1407 OU	Selenium	0.0176203	0.31	0.19
K-1407 OU	Cadmium	0.0751231	0.28	0.03
K-1407 OU	Antimony	0.0044043	0.23	0.02
K-1407 OU	Chromium	0.1871866	0.20	0.05
K-1407 OU	Copper	0.6006714	0.14	0.11
K-1407 OU	Molybdenum	0.0050115	0.13	0.01
K-1407 OU	Nickel	1.3609517	0.12	0.06
K-1407 OU	Lead	0.0731644	0.03	0.00
K-1407 OU	Zinc	1.4613145	0.03	0.02
K-1407 OU	Acetone	0.0308704	0.01	0.00
K-1407 OU	Beryllium	0.0020823	0.01	
K-1407 OU	Trichloroethene	0.0009269	0.01	0.00
K-1407 OU	Tetrachloroethene	0.0008445	0.00	0.00
K-1407 OU	Methylene chloride	0.0048031	0.00	0.00
K-1407 OU	Strontium	0.1285826	0.00	
K-1407 OU	Boron	0.0051736	0.00	0.00
K-1407 OU	Chloroform	0.0011096	0.00	0.00
K-1407 OU	Toluene	0.0000313	0.00	0.00
K-1407 OU	1,2-Dichlorethene	0.0000171	0.00	
K-1407 OU	Di-N-Butylphthalate	0.0000592	0.00	0.00
K-1407 OU	1,1,1-Trichlorethane	0.0000095	0.00	
K-1407 OU	Methylene chloride	0.0357965	0.02	0.00
K-1407 OU	Acetone	0.0509032	0.02	0.00
K-1407 OU	Benzo(a)pyrene	0.0002774	0.00	0.00

Table G.10 (Continued)

Location	Analyte	Total Exposure	NOAEL HQ	LOAEL HQ
K-1407 OU	Tetrachloroethene	0.000139	0.00	0.00
K-1407 OU	Di-N-Butylphthalate	0.0076157	0.00	0.00
K-1407 OU	Bis(2-ethylhexyl)phthalate	0.0001537	0.00	0.00
K-1420 OU	Aluminum	75927.048	259136.68	25913.67
K-1420 OU	Total PCBs	0.3836566	42.63	4.51
K-1420 OU	Vanadium	0.4518581	8.22	0.83
K-1420 OU	Arsenic	0.043166	2.27	0.23
K-1420 OU	Manganese	23.05846	0.92	0.29
K-1420 OU	Thallium	0.0009535	0.48	0.05
K-1420 OU	Barium	0.6643464	0.44	0.12
K-1420 OU	Uranium	0.191443	0.42	0.21
K-1420 OU	Mercury	0.0015232	0.17	0.03
K-1420 OU	Lithium	0.3797542	0.15	0.07
K-1420 OU	Copper	0.5808581	0.14	0.10
K-1420 OU	Lead	0.200709	0.09	0.01
K-1420 OU	Zinc	3.4932459	0.08	0.04
K-1420 OU	Chromium	0.0682461	0.07	0.02
K-1420 OU	Strontium	1.5910454	0.02	
K-1420 OU	Pentachlorophenol	0.0012971	0.02	0.00
K-1420 OU	Nickel	0.1833987	0.02	0.01
K-1420 OU	Acetone	0.0408868	0.01	0.00
K-1420 OU	Trichloroethene	0.0013524	0.01	0.00
K-1420 OU	Beryllium	0.0023846	0.01	
K-1420 OU	Benzo(a)pyrene	0.0003733	0.00	0.00
K-1420 OU	Methylene chloride	0.002107	0.00	0.00
K-1420 OU	Tetrachloroethene	0.0002085	0.00	0.00
K-1420 OU	Boron	0.001663	0.00	0.00
K-1420 OU	Aldrin	0.0000094	0.00	0.00
K-1420 OU	1,2-Dichlorethane	0.0012521	0.00	
K-1420 OU	Bis(2-ethylhexyl)phthalate	0.0001989	0.00	0.00
K-1420 OU	Fluoride	0.0000185	0.00	0.00
K-1420 OU	Nitrate	0.0000165	0.00	0.00
LEFPC	Aluminum	20.371444	69.53	6.95
LEFPC	Total PCBs	0.224181	24.91	2.64
LEFPC	Mercury	0.1473614	16.37	3.27
LEFPC	Vanadium	0.0906584	1.65	0.17
LEFPC	DDT and metabolites	0.1861524	0.85	0.17
LEFPC	Barium	1.0292841	0.69	0.18
LEFPC	Arsenic	0.0127506	0.67	0.07
LEFPC	Cadmium	0.1623473	0.60	0.06
LEFPC	Manganese	14.054035	0.56	0.18
LEFPC	Thallium	0.0010716	0.54	0.05

Table G.10 (Continued)

Location	Analyte	Total Exposure	NOAEL HQ	LOAEL HQ
LEFPC	Selenium	0.0214454	0.38	0.23
LEFPC	Acetone	0.9471287	0.34	0.07
LEFPC	Copper	1.1073862	0.26	0.20
LEFPC	Chromium	0.1755759	0.19	0.05
LEFPC	Zinc	3.7671034	0.08	0.04
LEFPC	Lead	0.1363346	0.06	0.01
LEFPC	Antimony	0.0004849	0.03	0.00
LEFPC	Nickel	0.2054578	0.02	0.01
LEFPC	Uranium	0.008059	0.02	0.01
LEFPC	Beryllium	0.0018073	0.01	
LEFPC	Methylene chloride	0.011985	0.01	0.00
LEFPC	Pentachlorophenol	0.000232	0.00	0.00
LEFPC	Benzo(a)Pyrene	0.0004676	0.00	0.00
LEFPC	Dieldrin	0.0000023	0.00	0.00
LEFPC	Cyanide	0.0035872	0.00	
LEFPC	Endrin	0.0000014	0.00	0.00
LEFPC	Bis(2-ethylhexyl)Phthalate	0.0001381	0.00	0.00
LEFPC	Endosulfan	0.0000012	0.00	
LEFPC	DiethylPhthalate	0.007525	0.00	
LEFPC	Di-N-Butylphthalate	0.0005887	0.00	0.00
LEFPC	Mixed-BHC	0.0000027	0.00	0.00
LEFPC	Aldrin	0.0000003	0.00	0.00
LEFPC	Heptachlor	0.0000002	0.00	0.00
LEFPC	Methoxychlor	0.0000036	0.00	0.00
LEFPC	Lindane	0.0000063	0.00	
LEFPC	Total-chlordane	0.0000012	0.00	0.00
SCF	Acetone	349.73153	124.90	24.98
SCF	Aluminum	31.638653	107.98	10.80
SCF	Methylene chloride	63.697118	39.81	4.55
SCF	1,2-Dichlorethane	26.602428	3.37	
SCF	Total PCBs	0.0242193	2.69	0.28
SCF	Vanadium	0.1247852	2.27	0.23
SCF	Arsenic	0.0232756	1.23	0.12
SCF	Cadmium	0.2591139	0.96	0.10
SCF	Manganese	21.755195	0.87	0.27
SCF	Barium	1.1059877	0.74	0.20
SCF	Trichloroethene	0.0492456	0.46	0.05
SCF	Mercury	0.0030252	0.34	0.07
SCF	Tetrachloroethene	0.0396962	0.19	0.04
SCF	Chromium	0.163858	0.18	0.04
SCF	Selenium	0.0073039	0.13	0.08
SCF	Copper	0.3445354	0.08	0.06

Table G.10 (Continued)

Location	Analyte	Total Exposure	NOAEL HQ	LOAEL HQ
SCF	Zinc	3.3099648	0.07	0.04
SCF	Lead	0.1157725	0.05	0.01
SCF	Chloroform	0.1852937	0.04	0.02
SCF	Antimony	0.0007482	0.04	0.00
SCF	Benzene	0.1441429	0.04	0.00
SCF	Toluene	0.0640275	0.02	0.00
SCF	Beryllium	0.0029775	0.02	
SCF	Nickel	0.1104188	0.01	0.00
SCF	Uranium	0.0022448	0.00	0.00
SCF	Benzo(a)pyrene	0.0003116	0.00	0.00
SCF	1,1-Dichlorethene	0.0121206	0.00	
SCF	Dieldrin	0.000002	0.00	0.00
SCF	Endrin	0.0000022	0.00	0.00
SCF	Heptachlor	0.0000025	0.00	0.00
SCF	Pentachlorophenol	0.0000032	0.00	0.00
SCF	Bis(2-ethylhexyl)phthalate	0.0001208	0.00	0.00
SCF	Endosulfan	0.0000017	0.00	
SCF	DDT and metabolites	0.000008	0.00	0.00
SCF	Methoxychlor	0.0000087	0.00	0.00
SCF	Mixed-BHC	0.0000036	0.00	0.00
SCF	Aldrin	0.0000003	0.00	0.00
SCF	Di-N-Butylphthalate	0.0003783	0.00	0.00
SCF	1,1,1-Trichlorethane	0.0005882	0.00	
SCF	Total-chlordane	0.000002	0.00	0.00
SCF	Carbon tetrachloride	6.159e-08	0.00	
UEFPC OU 2	Aluminum	100.48424	342.95	34.29
UEFPC OU 2	Barium	4.4916239	2.99	0.80
UEFPC OU 2	Vanadium	0.1115844	2.03	0.20
UEFPC OU 2	Manganese	30.502259	1.22	0.38
UEFPC OU 2	Arsenic	0.0138646	0.73	0.07
UEFPC OU 2	Lead	0.5543469	0.25	0.02
UEFPC OU 2	Chromium	0.2061745	0.22	0.06
UEFPC OU 2	Copper	0.67837	0.16	0.12
UEFPC OU 2	Zinc	6.5046834	0.14	0.07
UEFPC OU 2	Nickel	0.309142	0.03	0.01
UEFPC OU 2	Beryllium	0.0040598	0.02	
UEFPC OU 2	Lithium	0.0524501	0.02	0.01
UEFPC OU 2	Strontium	0.7322006	0.01	
UEFPC OU 2	Uranium	0.0042044	0.01	0.00
UEFPC OU 2	Nitrate	0.0006909	0.00	0.00
WAG 1	Aluminum	20149.26	68768.81	6876.88
WAG 1	Total PCBs	0.1511834	16.80	1.78

Table G.10 (Continued)

Location	Analyte	Total Exposure	NOAEL HQ	LOAEL HQ
WAG 1	Thallium	0.0209905	10.50	1.00
WAG 1	Vanadium	0.0731869	1.33	0.13
WAG 1	Arsenic	0.0156449	0.82	0.08
WAG 1	Selenium	0.0414922	0.74	0.45
WAG 1	Mercury	0.0065505	0.73	0.15
WAG 1	Barium	0.9129453	0.61	0.16
WAG 1	Manganese	10.705067	0.43	0.13
WAG 1	Cadmium	0.0685727	0.25	0.03
WAG 1	Antimony	0.0037336	0.20	0.02
WAG 1	Boron	1.0847955	0.14	0.04
WAG 1	Chromium	0.0883036	0.10	0.02
WAG 1	Copper	0.2748503	0.06	0.05
WAG 1	Zinc	2.3941825	0.05	0.03
WAG 1	Lead	0.1027154	0.05	0.00
WAG 1	Vinyl chloride	0.0019513	0.04	0.00
WAG 1	Uranium	0.0098037	0.02	0.01
WAG 1	Acetone	0.0481118	0.02	0.00
WAG 1	Nickel	0.1114378	0.01	0.00
WAG 1	Beryllium	0.0018713	0.01	
WAG 1	Tin	0.0333843	0.01	0.01
WAG 1	Methylene chloride	0.0082921	0.01	0.00
WAG 1	Benzo(a)Pyrene	0.0007015	0.00	0.00
WAG 1	Endrin	0.0000427	0.00	0.00
WAG 1	Pentachlorophenol	0.0001725	0.00	0.00
WAG 1	Trichloroethene	0.0000759	0.00	0.00
WAG 1	Tetrachloroethene	0.0001494	0.00	0.00
WAG 1	Heptachlor	0.0000095	0.00	0.00
WAG 1	Total-chlordane	0.0001843	0.00	0.00
WAG 1	Mixed-BHC	0.0001055	0.00	0.00
WAG 1	Chloroform	0.0008392	0.00	0.00
WAG 1	DDT and metabolites	0.0000435	0.00	0.00
WAG 1	Cyanide	0.0028833	0.00	
WAG 1	1,2-Dichlorethane	0.0010153	0.00	
WAG 1	Bis(2-ethylhexyl)Phthalate	0.0003036	0.00	0.00
WAG 1	Benzene	0.000219	0.00	0.00
WAG 1	Toluene	0.0001096	0.00	0.00
WAG 1	Di-N-Butylphthalate	0.0022394	0.00	0.00
WAG 1	Diethylphthalate	0.0020886	0.00	
WAG 1	Carbon tetrachloride	0.0000037	0.00	
WAG 1	1,1-Dichlorethene	0.0000037	0.00	
WAG 1	1,2-Dichlorethene	0.0000014	0.00	
WAG 1	1,1,1-Trichlorethane	0.000002	0.00	

Table G.10 (Continued)

Location	Analyte	Total Exposure	NOAEL HQ	LOAEL HQ
WAG 6	Aluminum	26512.46	90486.21	9048.62
WAG 6	Vanadium	0.0597485	1.09	0.11
WAG 6	Barium	1.1355254	0.76	0.20
WAG 6	Manganese	14.53714	0.58	0.18
WAG 6	Cadmium	0.0994651	0.37	0.04
WAG 6	Arsenic	0.0033428	0.18	0.02
WAG 6	Chromium	0.0706441	0.08	0.02
WAG 6	Copper	0.2238646	0.05	0.04
WAG 6	1,4-Dioxane	0.0046557	0.03	0.02
WAG 6	Zinc	1.4190897	0.03	0.02
WAG 6	Nickel	0.2256187	0.02	0.01
WAG 6	Lead	0.0408732	0.02	0.00
WAG 6	Tin	0.0549674	0.02	0.01
WAG 6	Mercury	0.0001325	0.01	0.00
WAG 6	Beryllium	0.0027456	0.01	
WAG 6	Acetone	0.024138	0.01	0.00
WAG 6	Methylene chloride	0.008564	0.01	0.00
WAG 6	Uranium	0.0006819	0.00	0.00
WAG 6	Trichloroethene	0.0001187	0.00	0.00
WAG 6	Cyanide	0.0146697	0.00	
WAG 6	Tetrachloroethene	0.0001147	0.00	0.00
WAG 6	Chloroform	0.0011935	0.00	0.00
WAG 6	Bis(2-ethylhexyl)phthalate	0.0003181	0.00	0.00
WAG 6	Toluene	0.0000783	0.00	0.00
WAG 6	1,2-Dichlorethene	0.0000042	0.00	

Table G.11. Estimated exposure of wild turkey to contaminants on the ORR

Location	Analyte	Total Exposure	NOAEL HQ	LOAEL HQ
BC OU 2	Mercury	1.39171444969	217.46	21.75
BC OU 2	Aluminum	141.856012184	1.29	
BC OU 2	Chromium	1.27616127881	1.28	0.26
BC OU 2	Total PCBs	0.1051021484	0.58	0.06
BC OU 2	Lead	0.59340451546	0.53	0.05
BC OU 2	Zinc	6.13262773897	0.42	0.05
BC OU 2	Arsenic	0.21125963008	0.09	0.03
BC OU 2	Barium	1.4903572444	0.07	0.04
BC OU 2	Selenium	0.0151594286	0.04	0.02
BC OU 2	Cadmium	0.0442705465	0.03	0.00
BC OU 2	Vanadium	0.33320913313	0.03	
BC OU 2	Di-N-Butylphthalate	0.002678944	0.02	0.00
BC OU 2	Manganese	23.0252859028	0.02	
BC OU 2	Copper	0.89019779148	0.02	0.01
BC OU 2	DDT and metabolites	0.0000499	0.02	0.00
BC OU 2	Nickel	1.20007216233	0.02	0.01
BC OU 2	Boron	0.22178945172	0.01	0.00
BC OU 2	Endrin	0.0000226	0.00	0.00
BC OU 2	Bis(2-ethylhexyl)Phthalate	0.001511038	0.00	
BC OU 2	Uranium	0.007626842	0.00	
BC OU 2	Dieldrin	0.0000203	0.00	
BC OU 2	Mixed-BHC	0.0000567	0.00	0.00
BC OU 2	1,2-Dichlorethane	0.001223876	0.00	0.00
BC OU 2	Lindane	0.0000283	0.00	0.00
BC OU 2	Total-chlordane	0.0000169	0.00	0.00
BC OU 2	Endosulfan	0.0000235	0.00	
K-1407 OU	Mercury	0.11704759264	18.29	1.83
K-1407 OU	Chromium	2.01567602894	2.02	0.40
K-1407 OU	Aluminum	113.434477405	1.03	
K-1407 OU	Zinc	2.64611530219	0.18	0.02
K-1407 OU	Selenium	0.0606334753	0.15	0.08
K-1407 OU	Lead	0.15439092931	0.14	0.01
K-1407 OU	Nickel	5.98790994136	0.08	0.06
K-1407 OU	Cadmium	0.11100951867	0.08	0.01
K-1407 OU	Barium	1.21254285104	0.06	0.03
K-1407 OU	Uranium	0.7753827538	0.05	
K-1407 OU	Arsenic	0.0786698764	0.03	0.01
K-1407 OU	Vanadium	0.22012755652	0.02	
K-1407 OU	Manganese	17.5374082339	0.02	
K-1407 OU	Copper	0.75479501611	0.02	0.01
K-1407 OU	Molybdenum	0.0173276372	0.00	0.00

Table G.11. (continued)

Location	Analyte	Total Exposure	NOAEL HQ	LOAEL HQ
K-1407 OU	Di-N-Butylphthalate	0.0000937	0.00	0.00
K-1407 OU	Boron	0.0234609517	0.00	0.00
K-1414	Di-N-Butylphthalate	0.0120608166	0.11	0.01
K-1414	Bis(2-ethylhexyl)phthalate	0.00063841	0.00	
K-1420 OU	Aluminum	194730.069446	1775.11	
K-1420 OU	Total PCBs	0.4023055563	2.24	0.22
K-1420 OU	Mercury	0.007870268	1.23	0.12
K-1420 OU	Chromium	0.73489276491	0.73	0.15
K-1420 OU	Zinc	6.32549083275	0.44	0.05
K-1420 OU	Lead	0.42353444078	0.37	0.04
K-1420 OU	Arsenic	0.1622683214	0.07	0.02
K-1420 OU	Vanadium	0.75121906548	0.07	
K-1420 OU	Uranium	0.85634044003	0.05	
K-1420 OU	Barium	0.81244258119	0.04	0.02
K-1420 OU	Manganese	25.3632882416	0.03	
K-1420 OU	Copper	0.72989785116	0.02	0.01
K-1420 OU	Nickel	0.8069170331	0.01	0.01
K-1420 OU	Bis(2-ethylhexyl)phthalate	0.00082607	0.00	
K-1420 OU	Boron	0.007541379	0.00	0.00
K-1420 OU	1,2-Dichlorethane	0.001118109	0.00	0.00
K-1420 OU	Fluoride	0.0000838	0.00	0.00
LEFPC	DDT and metabolites	0.67704998633	241.80	24.18
LEFPC	Mercury	0.76138667595	118.97	11.90
LEFPC	Chromium	1.89064873211	1.89	0.38
LEFPC	Total PCBs	0.23507815517	1.31	0.13
LEFPC	Aluminum	52.2466346903	0.48	
LEFPC	Zinc	6.82138580436	0.47	0.05
LEFPC	Lead	0.28769209623	0.25	0.03
LEFPC	Selenium	0.0737963458	0.18	0.09
LEFPC	Cadmium	0.23990080515	0.17	0.01
LEFPC	Barium	1.25873216656	0.06	0.03
LEFPC	Copper	1.39152557798	0.03	0.02
LEFPC	Arsenic	0.0479317898	0.02	0.01
LEFPC	Manganese	15.4588184454	0.02	
LEFPC	Vanadium	0.15072059062	0.01	
LEFPC	Nickel	0.9039722945	0.01	0.01
LEFPC	Di-N-Butylphthalate	0.00093231	0.01	0.00
LEFPC	Uranium	0.0360485408	0.00	
LEFPC	Bis(2-ethylhexyl)Phthalate	0.00057328	0.00	
LEFPC	Endrin	0.000003	0.00	0.00
LEFPC	Dieldrin	0.000005	0.00	
LEFPC	Mixed-BHC	0.000003	0.00	0.00

Table G.11. (continued)

Location	Analyte	Total Exposure	NOAEL HQ	LOAEL HQ
LEFPC	Lindane	0.000007	0.00	0.00
LEFPC	Total-chlordane	0.000004	0.00	0.00
LEFPC	Endosulfan	0.000005	0.00	
SCF	Mercury	0.0156307439	2.44	0.24
SCF	Chromium	1.76446738153	1.76	0.35
SCF	1,2-Dichlorethane	23.7546749984	1.38	0.69
SCF	Aluminum	81.1436393099	0.74	
SCF	Zinc	5.99360952554	0.41	0.05
SCF	Cadmium	0.38289296571	0.26	0.02
SCF	Lead	0.24430210809	0.22	0.02
SCF	Total PCBs	0.0253965182	0.14	0.01
SCF	Barium	1.35253458342	0.07	0.03
SCF	Selenium	0.0251337408	0.06	0.03
SCF	Arsenic	0.0874969928	0.04	0.01
SCF	Manganese	23.9297547503	0.02	
SCF	Vanadium	0.20745679701	0.02	
SCF	DDT and metabolites	0.0000291	0.01	0.00
SCF	Copper	0.43293817315	0.01	0.01
SCF	Nickel	0.48582003395	0.01	0.00
SCF	Di-N-Butylphthalate	0.00059909	0.01	0.00
SCF	Uranium	0.0100413315	0.00	
SCF	Bis(2-ethylhexyl)phthalate	0.00050158	0.00	
SCF	Endrin	0.000004	0.00	0.00
SCF	Dieldrin	0.000005	0.00	
SCF	Mixed-BHC	0.000004	0.00	0.00
SCF	Total-chlordane	0.000007	0.00	0.00
SCF	Endosulfan	0.000008	0.00	
UEFPC OU 2	Aluminum	257.711899827	2.35	
UEFPC OU 2	Chromium	2.22014261482	2.22	0.44
UEFPC OU 2	Lead	1.16977832138	1.04	0.10
UEFPC OU 2	Zinc	11.7785337137	0.81	0.09
UEFPC OU 2	Barium	5.49289697335	0.26	0.13
UEFPC OU 2	Manganese	33.5511392796	0.03	
UEFPC OU 2	Arsenic	0.0521192973	0.02	0.01
UEFPC OU 2	Copper	0.85242995299	0.02	0.01
UEFPC OU 2	Nickel	1.36016159419	0.02	0.01
UEFPC OU 2	Vanadium	0.18551033442	0.02	
UEFPC OU 2	Uranium	0.0188067748	0.00	
WAG 1	Aluminum	51676.7991122	471.07	
WAG 1	Mercury	0.0338452634	5.29	0.53
WAG 1	Chromium	0.9508768071	0.95	0.19
WAG 1	Total PCBs	0.15853224148	0.88	0.09

Table G.11. (continued)

Location	Analyte	Total Exposure	NOAEL HQ	LOAEL HQ
WAG 1	Selenium	0.14277975741	0.36	0.18
WAG 1	Zinc	4.33533168393	0.30	0.03
WAG 1	Lead	0.21674921061	0.19	0.02
WAG 1	Boron	4.91930903793	0.17	0.05
WAG 1	Cadmium	0.10133001755	0.07	0.01
WAG 1	DDT and metabolites	0.00015827	0.06	0.01
WAG 1	Barium	1.116459086	0.05	0.03
WAG 1	Di-N-Butylphthalate	0.003546435	0.03	0.00
WAG 1	Arsenic	0.058811724	0.02	0.01
WAG 1	Tin	0.15139039655	0.02	0.01
WAG 1	Manganese	11.7751009667	0.01	
WAG 1	Vanadium	0.12167411511	0.01	
WAG 1	Endrin	0.0000849	0.01	0.00
WAG 1	Copper	0.34537290116	0.01	0.01
WAG 1	Nickel	0.49030339656	0.01	0.00
WAG 1	Uranium	0.0438526735	0.00	
WAG 1	Bis(2-ethylhexyl)Phthalate	0.001260817	0.00	
WAG 1	Total-chlordane	0.00063312	0.00	0.00
WAG 1	Mixed-BHC	0.00011941	0.00	0.00
WAG 1	1,2-Dichlorethane	0.00090657	0.00	0.00
WAG 6	Aluminum	67996.4956251	619.84	
WAG 6	Chromium	0.7607147173	0.76	0.15
WAG 6	Zinc	2.56965549002	0.18	0.02
WAG 6	Mercury	0.00068437	0.11	0.01
WAG 6	Cadmium	0.14697966049	0.10	0.01
WAG 6	Lead	0.0862503108	0.08	0.01
WAG 6	Barium	1.38865673624	0.07	0.03
WAG 6	Tin	0.24926493103	0.04	0.01
WAG 6	Manganese	15.9902123168	0.02	
WAG 6	Nickel	0.99267610066	0.01	0.01
WAG 6	Vanadium	0.0993325566	0.01	
WAG 6	Copper	0.28130506569	0.01	0.00
WAG 6	Arsenic	0.0125661343	0.01	0.00
WAG 6	Bis(2-ethylhexyl)phthalate	0.001320801	0.00	
WAG 6	Uranium	0.003050312	0.00	

Table G.12. Estimated exposure of short-tailed shrews to contaminants on the ORR

Location	Analyte	Total Exposure	NOAEL HQ	LOAEL HQ
BC OU 2	Mercury	196.7928912	2798.11	559.62
BC OU 2	Aluminum	5227.271558	2277.51	227.75
BC OU 2	Arsenic	18.82531699	125.64	12.56
BC OU 2	Total PCBs	3.228897394	48.31	4.83
BC OU 2	Chromium	211.3797392	29.32	7.32
BC OU 2	Vanadium	8.157202404	19.04	1.90
BC OU 2	Niobium	0.7683	4.17	0.42
BC OU 2	Selenium	1.549789184	3.53	2.14
BC OU 2	Zirconium	5.8096428	2.81	
BC OU 2	Barium	27.08760739	2.29	0.62
BC OU 2	Nickel	168.3116404	1.91	0.96
BC OU 2	Thallium	0.028694751	1.75	0.17
BC OU 2	Zinc	561.1175437	1.60	0.80
BC OU 2	Cadmium	3.196439599	1.51	0.15
BC OU 2	Manganese	277.077382	1.43	0.44
BC OU 2	Lead	21.83636507	1.24	0.12
BC OU 2	Copper	31.90706173	0.95	0.73
BC OU 2	Beryllium	0.981214738	0.68	
BC OU 2	Lithium	9.509180778	0.46	0.23
BC OU 2	Pentachlorophenol	0.1010646	0.19	0.02
BC OU 2	Antimony	0.027846	0.19	0.02
BC OU 2	Boron	6.1936758	0.10	0.03
BC OU 2	Uranium	0.285877707	0.08	0.04
BC OU 2	Strontium	32.22088931	0.06	
BC OU 2	Benzo(a)pyrene	0.041457173	0.03	0.00
BC OU 2	Vinyl chloride	0.004024559	0.01	0.00
BC OU 2	Dieldrin	0.000442332	0.01	0.00
BC OU 2	Acetone	0.189694079	0.01	0.00
BC OU 2	Endrin	0.000445157	0.00	0.00
BC OU 2	Endosulfan	0.0006552	0.00	
BC OU 2	Bis(2-ethylhexyl)Phthalate	0.04130205	0.00	0.00
BC OU 2	Toxaphene	0.0221364	0.00	
BC OU 2	Trichloroethene	0.000907635	0.00	0.00
BC OU 2	Heptachlor	0.000219246	0.00	0.00
BC OU 2	DDT and metabolites	0.001313944	0.00	0.00
BC OU 2	Tetrachloroethene	0.000888543	0.00	0.00
BC OU 2	Aldrin	0.000219015	0.00	0.00
BC OU 2	Methylene chloride	0.005651185	0.00	0.00
BC OU 2	Methoxychlor	0.0022152	0.00	0.00
BC OU 2	Mixed-BHC	0.000485867	0.00	0.00

Table G.12. (continued)

Location	Analyte	Total Exposure	NOAEL HQ	LOAEL HQ
BC OU 2	Total chlordane	0.000438362	0.00	0.00
BC OU 2	Di-N-Butylphthalate	0.042698881	0.00	0.00
BC OU 2	Chloroform	0.001421151	0.00	0.00
BC OU 2	Benzene	0.001228684	0.00	0.00
BC OU 2	1,2-Dichlorethane	0.002068513	0.00	
BC OU 2	Toluene	0.000893335	0.00	0.00
BC OU 2	Carbon tetrachloride	0.0006318	0.00	
BC OU 2	Lindane	0.000242934	0.00	
BC OU 2	Diethylphthalate	0.065085232	0.00	
BC OU 2	1,2-Dichlorethene	0.0006318	0.00	
BC OU 2	1,1-Dichlorethene	0.0006318	0.00	
BC OU 2	1,1,1-Trichlorethane	0.0006318	0.00	
K-1407 OU	Aluminum	4179.962543	1821.20	182.12
K-1407 OU	Mercury	16.55090537	235.33	47.07
K-1407 OU	Arsenic	7.010262018	46.78	4.68
K-1407 OU	Chromium	333.8708675	46.31	11.56
K-1407 OU	Selenium	6.198723376	14.10	8.55
K-1407 OU	Vanadium	5.388883001	12.58	1.26
K-1407 OU	Nickel	839.8119519	9.55	4.78
K-1407 OU	Uranium	29.06375264	8.10	4.06
K-1407 OU	Molybdenum	1.952868884	6.32	0.63
K-1407 OU	Cadmium	8.015153407	3.78	0.38
K-1407 OU	Antimony	0.5577468	3.75	0.38
K-1407 OU	Barium	22.03826285	1.86	0.51
K-1407 OU	Manganese	211.0383854	1.09	0.34
K-1407 OU	Copper	27.05386533	0.81	0.61
K-1407 OU	Zinc	242.1118291	0.69	0.34
K-1407 OU	Beryllium	0.840604294	0.58	
K-1407 OU	Lead	5.681346549	0.32	0.03
K-1407 OU	Boron	0.6551688	0.01	0.00
K-1407 OU	Strontium	4.974917152	0.01	
K-1407 OU	Trichloroethene	0.003148711	0.00	0.00
K-1407 OU	Tetrachloroethene	0.002768153	0.00	0.00
K-1407 OU	Acetone	0.033931957	0.00	0.00
K-1407 OU	Methylene chloride	0.006693024	0.00	0.00
K-1407 OU	Chloroform	0.002087863	0.00	0.00
K-1407 OU	1,2-Dichlorethene	0.0021606	0.00	
K-1407 OU	Toluene	0.000110288	0.00	0.00
K-1407 OU	Di-N-Butylphthalate	0.00149325	0.00	0.00
K-1407 OU	1,1,1-Trichlorethane	0.001209	0.00	
K-1414	Benzo(a)pyrene	0.022491888	0.02	0.00
K-1414	Methylene chloride	0.049881969	0.00	0.00

Table G.12. (continued)

Location	Analyte	Total Exposure	NOAEL HQ	LOAEL HQ
K-1414	Acetone	0.055951631	0.00	0.00
K-1414	Bis(2-ethylhexyl)phthalate	0.017449921	0.00	0.00
K-1414	Di-N-Butylphthalate	0.192233751	0.00	0.00
K-1414	Tetrachloroethene	0.000455663	0.00	0.00
K-1420 OU	Aluminum	7175634.912	3126407.09	312640.71
K-1420 OU	Total PCBs	12.35943682	184.92	18.49
K-1420 OU	Arsenic	14.45970812	96.50	9.65
K-1420 OU	Vanadium	18.39039017	42.92	4.29
K-1420 OU	Chromium	121.7255558	16.89	4.21
K-1420 OU	Mercury	1.112881169	15.82	3.16
K-1420 OU	Uranium	32.09829804	8.94	4.48
K-1420 OU	Thallium	0.056696544	3.45	0.34
K-1420 OU	Lithium	46.01089567	2.23	1.11
K-1420 OU	Zinc	578.7639541	1.65	0.82
K-1420 OU	Manganese	305.2119975	1.58	0.49
K-1420 OU	Nickel	113.1711357	1.29	0.64
K-1420 OU	Barium	14.7663426	1.25	0.34
K-1420 OU	Lead	15.58541	0.89	0.09
K-1420 OU	Copper	26.16148458	0.78	0.59
K-1420 OU	Beryllium	0.962640732	0.66	
K-1420 OU	Pentachlorophenol	0.164268	0.31	0.03
K-1420 OU	Strontium	61.55825459	0.11	
K-1420 OU	Benzo(a)pyrene	0.030266088	0.03	0.00
K-1420 OU	Trichloroethene	0.004594204	0.01	0.00
K-1420 OU	Boron	0.2106	0.00	0.00
K-1420 OU	Acetone	0.044941794	0.00	0.00
K-1420 OU	Aldrin	0.000891703	0.00	0.00
K-1420 OU	Bis(2-ethylhexyl)phthalate	0.022579495	0.00	0.00
K-1420 OU	Tetrachloroethene	0.000683495	0.00	0.00
K-1420 OU	Methylene chloride	0.002936091	0.00	0.00
K-1420 OU	1,2-Dichlorethane	0.001889753	0.00	
K-1420 OU	Fluoride	0.00234	0.00	0.00
K-1420 OU	Nitrate	0.0020904	0.00	0.00
LEFPC	Mercury	107.6625203	1530.81	306.16
LEFPC	Aluminum	1925.243374	838.82	83.88
LEFPC	Total PCBs	7.221957441	108.05	10.81
LEFPC	Chromium	313.1617002	43.44	10.84
LEFPC	Arsenic	4.271195294	28.51	2.85
LEFPC	Selenium	7.544399058	17.16	10.40
LEFPC	DDT and metabolites	17.83225584	10.14	2.03

Table G.12. (continued)

Location	Analyte	Total Exposure	NOAEL HQ	LOAEL HQ
LEFPC	Vanadium	3.689749896	8.61	0.86
LEFPC	Cadmium	17.32141332	8.17	0.82
LEFPC	Thallium	0.063720616	3.88	0.39
LEFPC	Barium	22.87776496	1.93	0.53
LEFPC	Zinc	624.136897	1.77	0.89
LEFPC	Copper	49.87598592	1.49	1.13
LEFPC	Nickel	126.783259	1.44	0.72
LEFPC	Manganese	186.0254401	0.96	0.30
LEFPC	Lead	10.58662258	0.60	0.06
LEFPC	Beryllium	0.729607826	0.50	
LEFPC	Antimony	0.0614016	0.41	0.04
LEFPC	Uranium	1.351211217	0.38	0.19
LEFPC	Pentachlorophenol	0.0293826	0.06	0.01
LEFPC	Acetone	1.041061322	0.05	0.01
LEFPC	Benzo(a)Pyrene	0.037914897	0.03	0.00
LEFPC	Cyanide	0.454272	0.00	
LEFPC	Dieldrin	0.000118482	0.00	0.00
LEFPC	Methylene chloride	0.016700988	0.00	0.00
LEFPC	Bis(2-ethylhexyl)Phthalate	0.015669795	0.00	0.00
LEFPC	Endrin	0.000055645	0.00	0.00
LEFPC	Endosulfan	0.0001482	0.00	
LEFPC	Aldrin	0.000031288	0.00	0.00
LEFPC	Heptachlor	0.00001566	0.00	0.00
LEFPC	Methoxychlor	0.0004602	0.00	0.00
LEFPC	Di-N-Butylphthalate	0.014859856	0.00	0.00
LEFPC	Total chlordane	0.000109591	0.00	0.00
LEFPC	Mixed-BHC	0.000026029	0.00	0.00
LEFPC	DiethylPhthalate	0.021321873	0.00	
LEFPC	Lindane	0.000060733	0.00	
SCF	Aluminum	2990.073042	1302.77	130.28
SCF	Arsenic	7.796845164	52.03	5.20
SCF	Chromium	292.2613788	40.54	10.12
SCF	Mercury	2.210237375	31.43	6.29
SCF	Acetone	384.4165858	17.49	3.50
SCF	Cadmium	27.64579016	13.04	1.30
SCF	Vanadium	5.078693574	11.85	1.19
SCF	Total PCBs	0.780219556	11.67	1.17
SCF	Methylene chloride	88.7612066	6.90	0.81
SCF	Selenium	2.56948997	5.85	3.54
SCF	Barium	24.58264683	2.08	0.56
SCF	Zinc	548.3977829	1.56	0.78

Table G.12. (continued)

Location	Analyte	Total Exposure	NOAEL HQ	LOAEL HQ
SCF	Manganese	287.9614101	1.49	0.46
SCF	Beryllium	1.202014162	0.83	
SCF	Nickel	68.13687497	0.78	0.39
SCF	1,2-Dichlorethane	40.14856096	0.65	
SCF	Antimony	0.0947544	0.64	0.06
SCF	Lead	8.989938366	0.51	0.05
SCF	Copper	15.51765815	0.46	0.35
SCF	Trichloroethene	0.167296257	0.20	0.02
SCF	Uranium	0.376380277	0.10	0.05
SCF	Tetrachloroethene	0.130114576	0.08	0.02
SCF	1,1-Dichlorethene	1.5349308	0.02	
SCF	Benzo(a)pyrene	0.025266149	0.02	0.00
SCF	Chloroform	0.348655652	0.01	0.00
SCF	Benzene	0.309446372	0.01	0.00
SCF	Toluene	0.225561605	0.01	0.00
SCF	Dieldrin	0.000102684	0.00	0.00
SCF	Endrin	0.000087442	0.00	0.00
SCF	Pentachlorophenol	0.0004056	0.00	0.00
SCF	Heptachlor	0.000219246	0.00	0.00
SCF	Endosulfan	0.0002184	0.00	
SCF	Bis(2-ethylhexyl)phthalate	0.013710094	0.00	0.00
SCF	DDT and metabolites	0.000766467	0.00	0.00
SCF	Methoxychlor	0.0011076	0.00	0.00
SCF	Aldrin	0.000031288	0.00	0.00
SCF	1,1,1-Trichlorethane	0.07449	0.00	
SCF	Total chlordane	0.000180042	0.00	0.00
SCF	Di-N-Butylphthalate	0.009548729	0.00	0.00
SCF	Mixed-BHC	0.000034705	0.00	0.00
SCF	Carbon tetrachloride	0.0000078	0.00	
UEFPC OU 2	Aluminum	9496.460978	4137.59	413.76
UEFPC OU 2	Chromium	367.7381336	51.01	12.73
UEFPC OU 2	Arsenic	4.644343514	31.00	3.10
UEFPC OU 2	Vanadium	4.541428176	10.60	1.06
UEFPC OU 2	Barium	99.83474582	8.44	2.29
UEFPC OU 2	Zinc	1077.701466	3.06	1.53
UEFPC OU 2	Lead	43.04602647	2.45	0.24
UEFPC OU 2	Nickel	190.764386	2.17	1.08
UEFPC OU 2	Manganese	403.741429	2.09	0.65
UEFPC OU 2	Beryllium	1.638913562	1.13	
UEFPC OU 2	Copper	30.55336172	0.91	0.69
UEFPC OU 2	Lithium	6.354840941	0.31	0.15

Table G.12. (continued)

Location	Analyte	Total Exposure	NOAEL HQ	LOAEL HQ
UEFPC OU 2	Uranium	0.704936302	0.20	0.10
UEFPC OU 2	Strontium	28.32916804	0.05	
UEFPC OU 2	Nitrate	0.0874926	0.00	0.00
WAG 1	Aluminum	1904245.425	829675.21	82967.52
WAG 1	Thallium	1.248182291	75.94	7.59
WAG 1	Total PCBs	4.870350884	72.87	7.29
WAG 1	Mercury	4.785828902	68.05	13.61
WAG 1	Arsenic	5.240704752	34.98	3.50
WAG 1	Selenium	14.5967589	33.21	20.13
WAG 1	Chromium	157.5005407	21.85	5.45
WAG 1	Vanadium	2.978671008	6.95	0.70
WAG 1	Cadmium	7.316270219	3.45	0.35
WAG 1	Antimony	0.4728126	3.18	0.32
WAG 1	Boron	137.3762598	2.23	0.67
WAG 1	Barium	20.29191693	1.71	0.47
WAG 1	Zinc	396.670199	1.13	0.56
WAG 1	Nickel	68.76567225	0.78	0.39
WAG 1	Manganese	141.6970092	0.73	0.23
WAG 1	Beryllium	0.755417489	0.52	
WAG 1	Uranium	1.643734336	0.46	0.23
WAG 1	Lead	7.976034507	0.45	0.05
WAG 1	Copper	12.37908539	0.37	0.28
WAG 1	Tin	4.227717	0.15	0.10
WAG 1	Benzo(a)Pyrene	0.056872345	0.05	0.00
WAG 1	Pentachlorophenol	0.02184	0.04	0.00
WAG 1	Endrin	0.001669339	0.02	0.00
WAG 1	Vinyl chloride	0.002981155	0.01	0.00
WAG 1	Total chlordane	0.016375964	0.00	0.00
WAG 1	Heptachlor	0.000822173	0.00	0.00
WAG 1	Cyanide	0.3651414	0.00	
WAG 1	Acetone	0.052883316	0.00	0.00
WAG 1	DDT and metabolites	0.004168644	0.00	0.00
WAG 1	Bis(2-ethylhexyl)Phthalate	0.034462618	0.00	0.00
WAG 1	Methylene chloride	0.011554937	0.00	0.00
WAG 1	Trichloroethene	0.000257724	0.00	0.00
WAG 1	Tetrachloroethene	0.000489838	0.00	0.00
WAG 1	Mixed-BHC	0.001023792	0.00	0.00
WAG 1	Di-N-Butylphthalate	0.056525569	0.00	0.00
WAG 1	Chloroform	0.001579056	0.00	0.00
WAG 1	1,2-Dichlorethane	0.001532232	0.00	
WAG 1	Benzene	0.000470237	0.00	0.00

Table G.12. (continued)

Location	Analyte	Total Exposure	NOAEL HQ	LOAEL HQ
WAG 1	Carbon tetrachloride	0.000468	0.00	
WAG 1	Toluene	0.000386009	0.00	0.00
WAG 1	1,1-Dichlorethene	0.000468	0.00	
WAG 1	1,2-Dichlorethene	0.0001794	0.00	
WAG 1	Diethylphthalate	0.005917958	0.00	
WAG 1	1,1,1-Trichlorethane	0.0002574	0.00	
WAG 6	Aluminum	2505612.15	1091689.26	109168.93
WAG 6	Chromium	126.0026309	17.48	4.36
WAG 6	Arsenic	1.119766526	7.47	0.75
WAG 6	Vanadium	2.431733373	5.68	0.57
WAG 6	Cadmium	10.61228389	5.01	0.50
WAG 6	Barium	25.23917579	2.13	0.58
WAG 6	Nickel	139.2240802	1.58	0.79
WAG 6	Mercury	0.096772276	1.38	0.28
WAG 6	Manganese	192.4200283	0.99	0.31
WAG 6	Beryllium	1.10839819	0.76	
WAG 6	Zinc	235.1159793	0.67	0.33
WAG 6	1,4-Dioxane	0.5895864	0.54	0.27
WAG 6	Copper	10.08272339	0.30	0.23
WAG 6	Tin	6.960954	0.25	0.17
WAG 6	Lead	3.173877559	0.18	0.02
WAG 6	Uranium	0.114335179	0.03	0.02
WAG 6	Cyanide	1.8577416	0.01	
WAG 6	Bis(2-ethylhexyl)phthalate	0.036102208	0.00	0.00
WAG 6	Acetone	0.026531903	0.00	0.00
WAG 6	Methylene chloride	0.011933787	0.00	0.00
WAG 6	Trichloroethene	0.000403394	0.00	0.00
WAG 6	Tetrachloroethene	0.000375922	0.00	0.00
WAG 6	Chloroform	0.002245769	0.00	0.00
WAG 6	1,2-Dichlorethene	0.0005304	0.00	
WAG 6	Toluene	0.000275721	0.00	0.00

Table G.13. Estimated exposure of American woodcock to contaminants on the ORR

Location	Analyte	Total Exposure	NOAEL HQ	LOAEL HQ
BC OU 2	Mercury	262.0454236	40944.60	4094.46
BC OU 2	Chromium	282.6510989	282.65	56.53
BC OU 2	Aluminum	6041.148091	55.07	
BC OU 2	Zinc	745.1656773	51.39	5.69
BC OU 2	Total PCBs	4.184366667	23.25	2.32
BC OU 2	Lead	25.74877	22.79	2.28
BC OU 2	Arsenic	24.32582955	9.89	3.30
BC OU 2	Selenium	2.030577197	5.08	2.54
BC OU 2	Cadmium	4.229658636	2.92	0.21
BC OU 2	Nickel	224.4302794	2.90	2.10
BC OU 2	Barium	30.79558	1.48	0.74
BC OU 2	Copper	40.41646136	0.86	0.66
BC OU 2	Vanadium	9.102181818	0.80	
BC OU 2	DDT and metabolites	0.001323636	0.47	0.05
BC OU 2	Di-N-Butylphthalate	0.041678788	0.38	0.04
BC OU 2	Manganese	297.9092222	0.30	
BC OU 2	Boron	6.256238182	0.22	0.06
BC OU 2	Endrin	0.000441212	0.04	0.00
BC OU 2	Bis(2-ethylhexyl)Phthalate	0.041678788	0.04	
BC OU 2	Uranium	0.31838803	0.02	
BC OU 2	Dieldrin	0.000441212	0.01	
BC OU 2	Mixed-BHC	0.000441212	0.00	0.00
BC OU 2	Total chlordane	0.000441212	0.00	0.00
BC OU 2	Lindane	0.000220606	0.00	0.00
BC OU 2	Endosulfan	0.000661818	0.00	
BC OU 2	1,2-Dichlorethane	0.000638182	0.00	0.00
K-1407 OU	Mercury	22.03885	3443.57	344.36
K-1407 OU	Chromium	446.4428235	446.44	89.29
K-1407 OU	Aluminum	4830.774995	44.04	
K-1407 OU	Zinc	321.5251904	22.17	2.45
K-1407 OU	Selenium	8.121740985	20.30	10.15
K-1407 OU	Nickel	1119.82291	14.47	10.47
K-1407 OU	Cadmium	10.60597636	7.31	0.53
K-1407 OU	Lead	6.699269091	5.93	0.59
K-1407 OU	Arsenic	9.058569318	3.68	1.23
K-1407 OU	Uranium	32.36891417	2.02	
K-1407 OU	Barium	25.05504	1.20	0.60
K-1407 OU	Molybdenum	2.577129545	0.74	0.07
K-1407 OU	Copper	34.26895	0.73	0.56
K-1407 OU	Vanadium	6.013163636	0.53	
K-1407 OU	Manganese	226.9051367	0.23	

Table G.13. (continued)

Location	Analyte	Total Exposure	NOAEL HQ	LOAEL HQ
K-1407 OU	Boron	0.661786667	0.02	0.01
K-1407 OU	Di-N-Butylphthalate	0.001457576	0.01	0.00
K-1414	Di-N-Butylphthalate	0.187641212	1.71	0.17
K-1414	Bis(2-ethylhexyl)phthalate	0.017609091	0.02	
K-1420 OU	Aluminum	8292868.023	75595.88	
K-1420 OU	Mercury	1.48189	231.55	23.15
K-1420 OU	Chromium	162.7680223	162.77	32.55
K-1420 OU	Total PCBs	16.01674167	88.98	8.90
K-1420 OU	Zinc	768.6001598	53.01	5.87
K-1420 OU	Lead	18.37783606	16.26	1.63
K-1420 OU	Arsenic	18.68464659	7.60	2.53
K-1420 OU	Uranium	35.74855136	2.23	
K-1420 OU	Nickel	150.9047713	1.95	1.41
K-1420 OU	Vanadium	20.52084364	1.80	
K-1420 OU	Barium	16.78768	0.81	0.40
K-1420 OU	Copper	33.13857727	0.71	0.54
K-1420 OU	Manganese	328.1591162	0.33	
K-1420 OU	Bis(2-ethylhexyl)phthalate	0.022785455	0.02	
K-1420 OU	Boron	0.212727273	0.01	0.00
K-1420 OU	Fluoride	0.002363636	0.00	0.00
K-1420 OU	1,2-Dichlorethane	0.00058303	0.00	0.00
LEFPC	Mercury	143.3612291	22400.19	2240.02
LEFPC	DDT and metabolites	17.96379394	6415.64	641.56
LEFPC	Chromium	418.7511019	418.75	83.75
LEFPC	Zinc	828.8555558	57.16	6.33
LEFPC	Total PCBs	9.359020833	51.99	5.20
LEFPC	Selenium	9.884882955	24.71	12.36
LEFPC	Aluminum	2225.000214	20.28	
LEFPC	Cadmium	22.92039727	15.81	1.15
LEFPC	Lead	12.4834197	11.05	1.10
LEFPC	Arsenic	5.519182955	2.24	0.75
LEFPC	Nickel	169.0554627	2.18	1.58
LEFPC	Copper	63.17757727	1.34	1.02
LEFPC	Barium	26.00946	1.25	0.62
LEFPC	Vanadium	4.117192727	0.36	
LEFPC	Manganese	200.0116133	0.20	
LEFPC	Di-N-Butylphthalate	0.014504848	0.13	0.01
LEFPC	Uranium	1.504872424	0.09	
LEFPC	Bis(2-ethylhexyl)Phthalate	0.015812727	0.01	

Table G.13. (continued)

Location	Analyte	Total Exposure	NOAEL HQ	LOAEL HQ
LEFPC	Endrin	0.000055152	0.01	0.00
LEFPC	Dieldrin	0.000118182	0.00	
LEFPC	Total chlordane	0.000110303	0.00	0.00
LEFPC	Mixed-BHC	0.000023636	0.00	0.00
LEFPC	Lindane	0.000055152	0.00	0.00
LEFPC	Endosulfan	0.000149697	0.00	
SCF	Mercury	2.943107273	459.86	45.99
SCF	Chromium	390.8037742	390.80	78.16
SCF	Zinc	728.273799	50.23	5.56
SCF	Aluminum	3455.621895	31.50	
SCF	Cadmium	36.58203182	25.23	1.83
SCF	Lead	10.60065879	9.38	0.94
SCF	Selenium	3.366617727	8.42	4.21
SCF	Total PCBs	1.011095833	5.62	0.56
SCF	Arsenic	10.07498182	4.10	1.37
SCF	Barium	27.94772	1.34	0.67
SCF	Nickel	90.85514136	1.17	0.85
SCF	1,2-Dichlorethane	12.38671515	0.72	0.36
SCF	Vanadium	5.66704	0.50	
SCF	Copper	19.65611364	0.42	0.32
SCF	Manganese	309.6115573	0.31	
SCF	DDT and metabolites	0.000772121	0.28	0.03
SCF	Di-N-Butylphthalate	0.009320606	0.08	0.01
SCF	Uranium	0.419182652	0.03	
SCF	Bis(2-ethylhexyl)phthalate	0.013835152	0.01	
SCF	Endrin	0.000086667	0.01	0.00
SCF	Dieldrin	0.000102424	0.00	
SCF	Total chlordane	0.000181212	0.00	0.00
SCF	Mixed-BHC	0.000031515	0.00	0.00
SCF	Endosulfan	0.000220606	0.00	
UEFPC OU 2	Chromium	491.7291883	491.73	98.35
UEFPC OU 2	Aluminum	10975.04242	100.05	
UEFPC OU 2	Zinc	1431.19058	98.70	10.93
UEFPC OU 2	Lead	50.7585503	44.92	4.49
UEFPC OU 2	Barium	113.50094	5.46	2.72
UEFPC OU 2	Nickel	254.3692423	3.29	2.38
UEFPC OU 2	Arsenic	6.001360227	2.44	0.81
UEFPC OU 2	Copper	38.70173864	0.82	0.63
UEFPC OU 2	Vanadium	5.067534545	0.44	
UEFPC OU 2	Manganese	434.0964038	0.44	
UEFPC OU 2	Uranium	0.785102424	0.05	

Table G.13. (continued)

Location	Analyte	Total Exposure	NOAEL HQ	LOAEL HQ
WAG 1	Aluminum	2200732.923	20061.38	
WAG 1	Mercury	6.372712727	995.74	99.57
WAG 1	Chromium	210.6053356	210.61	42.12
WAG 1	Selenium	19.12508235	47.81	23.91
WAG 1	Zinc	526.7791407	36.33	4.02
WAG 1	Total PCBs	6.311545833	35.06	3.51
WAG 1	Lead	9.405094545	8.32	0.83
WAG 1	Cadmium	9.681185758	6.68	0.48
WAG 1	Boron	138.7638988	4.82	1.39
WAG 1	Arsenic	6.771970455	2.75	0.92
WAG 1	DDT and metabolites	0.004199394	1.50	0.15
WAG 1	Nickel	91.69359288	1.18	0.86
WAG 1	Barium	23.06964	1.11	0.55
WAG 1	Tin	4.270421212	0.63	0.25
WAG 1	Di-N-Butylphthalate	0.055175152	0.50	0.05
WAG 1	Copper	15.68050455	0.33	0.25
WAG 1	Vanadium	3.323738182	0.29	
WAG 1	Endrin	0.001654545	0.17	0.02
WAG 1	Manganese	152.3503849	0.15	
WAG 1	Uranium	1.830661591	0.11	
WAG 1	Bis(2-ethylhexyl)Phthalate	0.03477697	0.03	
WAG 1	Total chlordane	0.016482424	0.01	0.00
WAG 1	Mixed-BHC	0.000929697	0.00	0.00
WAG 1	1,2-Dichlorethane	0.000472727	0.00	0.00
WAG 6	Aluminum	2895731.336	26396.82	
WAG 6	Chromium	168.487208	168.49	33.70
WAG 6	Zinc	312.2346823	21.53	2.38
WAG 6	Mercury	0.12886	20.13	2.01
WAG 6	Cadmium	14.04260485	9.68	0.70
WAG 6	Lead	3.742538788	3.31	0.33
WAG 6	Nickel	185.6443151	2.40	1.73
WAG 6	Barium	28.69412	1.38	0.69
WAG 6	Tin	7.031266667	1.03	0.42
WAG 6	Arsenic	1.446947727	0.59	0.20
WAG 6	Copper	12.77171818	0.27	0.21
WAG 6	Vanadium	2.71344	0.24	
WAG 6	Manganese	206.8869735	0.21	
WAG 6	Bis(2-ethylhexyl)phthalate	0.036431515	0.03	
WAG 6	Uranium	0.1273375	0.01	

Table G.14. Estimated exposure of red fox to contaminants on the ORR

Location	Analyte	Total Exposure	NOAEL HQ	LOAEL HQ
BC OU 2	Mercury	7.852933005	785.29	461.94
BC OU 2	Aluminum	189.7168677	344.31	34.40
BC OU 2	Arsenic	0.383075188	10.64	1.06
BC OU 2	Total PCBs	0.269788945	2.81	0.57
BC OU 2	Vanadium	0.27834472	2.70	0.27
BC OU 2	Chromium	4.187312605	2.42	0.60
BC OU 2	Barium	1.786390005	0.64	0.17
BC OU 2	Niobium	0.02758	0.63	0.06
BC OU 2	Selenium	0.061447699	0.58	0.35
BC OU 2	Copper	4.234890015	0.53	0.40
BC OU 2	Thallium	0.00190246	0.48	0.05
BC OU 2	Zinc	38.7475539	0.46	0.23
BC OU 2	Zirconium	0.20855128	0.42	
BC OU 2	Manganese	14.23209141	0.31	0.09
BC OU 2	Lead	1.067843766	0.25	0.03
BC OU 2	Nickel	3.726796428	0.18	0.09
BC OU 2	Cadmium	0.069827594	0.14	0.01
BC OU 2	Lithium	0.364793834	0.07	0.04
BC OU 2	Beryllium	0.017912591	0.05	
BC OU 2	Pentachlorophenol	0.00362796	0.03	0.00
BC OU 2	Antimony	0.0009996	0.03	0.00
BC OU 2	Boron	0.22233708	0.02	0.00
BC OU 2	Acetone	0.058552345	0.01	0.00
BC OU 2	Vinyl chloride	0.000931594	0.01	0.00
BC OU 2	Uranium	0.008494028	0.01	0.00
BC OU 2	Strontium	1.23695418	0.01	
BC OU 2	Benzo(a)pyrene	0.001543848	0.01	0.00
BC OU 2	Mixed-BHC	0.00003143	0.00	0.00
BC OU 2	Dieldrin	0.000017456	0.00	0.00
BC OU 2	Endrin	0.000018363	0.00	0.00
BC OU 2	Trichloroethene	0.00011122	0.00	0.00
BC OU 2	Methylene chloride	0.001415918	0.00	0.00
BC OU 2	Endosulfan	0.00002352	0.00	
BC OU 2	Bis(2-ethylhexyl)Phthalate	0.001494056	0.00	0.00
BC OU 2	Tetrachloroethene	0.000111762	0.00	0.00
BC OU 2	Toxaphene	0.00079464	0.00	
BC OU 2	Heptachlor	0.000008112	0.00	0.00
BC OU 2	DDT and metabolites	0.000048178	0.00	0.00
BC OU 2	Aldrin	0.000008037	0.00	0.00
BC OU 2	Methoxychlor	0.00007952	0.00	0.00
BC OU 2	Chloroform	0.000276052	0.00	0.00

Table G.14. (continued)

Location	Analyte	Total Exposure	NOAEL HQ	LOAEL HQ
BC OU 2	1,2-Dichlorethane	0.000483847	0.00	
BC OU 2	Benzene	0.000214272	0.00	0.00
BC OU 2	Toluene	0.00010663	0.00	0.00
BC OU 2	Total chlordane	0.000016181	0.00	0.00
BC OU 2	Di-N-Butylphthalate	0.001942421	0.00	0.00
BC OU 2	1,1-Dichlorethene	0.00002268	0.00	
BC OU 2	Diethylphthalate	0.009128163	0.00	
BC OU 2	Lindane	0.000015715	0.00	
BC OU 2	Carbon tetrachloride	0.00002268	0.00	
BC OU 2	1,2-Dichlorethene	0.00002268	0.00	
BC OU 2	1,1,1-Trichlorethane	0.00002268	0.00	
K-1407 OU	Aluminum	151.7061802	275.33	27.51
K-1407 OU	Mercury	0.660456535	66.05	38.85
K-1407 OU	Arsenic	0.14265138	3.96	0.40
K-1407 OU	Chromium	6.613792303	3.82	0.95
K-1407 OU	Selenium	0.245773613	2.32	1.41
K-1407 OU	Vanadium	0.183882544	1.79	0.18
K-1407 OU	Uranium	0.863545258	1.00	0.50
K-1407 OU	Nickel	18.59531625	0.88	0.44
K-1407 OU	Antimony	0.02002168	0.56	0.06
K-1407 OU	Barium	1.45339276	0.52	0.14
K-1407 OU	Molybdenum	0.035479261	0.51	0.05
K-1407 OU	Copper	3.590745683	0.45	0.34
K-1407 OU	Cadmium	0.175094464	0.34	0.03
K-1407 OU	Manganese	10.83999557	0.24	0.07
K-1407 OU	Zinc	16.71885196	0.20	0.10
K-1407 OU	Lead	0.277829688	0.07	0.01
K-1407 OU	Beryllium	0.015345673	0.04	
K-1407 OU	Acetone	0.010473683	0.00	0.00
K-1407 OU	Trichloroethene	0.000385836	0.00	0.00
K-1407 OU	Boron	0.02351888	0.00	0.00
K-1407 OU	Strontium	0.19098618	0.00	
K-1407 OU	Tetrachloroethene	0.000348183	0.00	0.00
K-1407 OU	Methylene chloride	0.001676953	0.00	0.00
K-1407 OU	Chloroform	0.000405558	0.00	0.00
K-1407 OU	1,2-Dichlorethene	0.00007756	0.00	
K-1407 OU	Toluene	0.000013164	0.00	0.00
K-1407 OU	Di-N-Butylphthalate	0.00006793	0.00	0.00
K-1407 OU	1,1,1-Trichlorethane	0.0000434	0.00	
K-1414	Methylene chloride	0.012498044	0.00	0.00
K-1414	Acetone	0.017270435	0.00	0.00
K-1414	Benzo(a)pyrene	0.000837589	0.00	0.00

Table G.14. (continued)

Location	Analyte	Total Exposure	NOAEL HQ	LOAEL HQ
K-1414	Tetrachloroethene	0.000057314	0.00	0.00
K-1414	Bis(2-ethylhexyl)phthalate	0.000631231	0.00	0.00
K-1414	Di-N-Butylphthalate	0.008744933	0.00	0.00
K-1420 OU	Aluminum	260430.1239	472649.95	47222.14
K-1420 OU	Total PCBs	1.032686708	10.76	2.18
K-1420 OU	Arsenic	0.294239688	8.17	0.82
K-1420 OU	Vanadium	0.627527398	6.09	0.61
K-1420 OU	Mercury	0.044409029	4.44	2.61
K-1420 OU	Chromium	2.411314141	1.39	0.35
K-1420 OU	Uranium	0.953707988	1.11	0.55
K-1420 OU	Thallium	0.003758976	0.94	0.10
K-1420 OU	Zinc	39.96611361	0.47	0.24
K-1420 OU	Copper	3.472303741	0.43	0.33
K-1420 OU	Lithium	1.76508276	0.35	0.18
K-1420 OU	Barium	0.973819741	0.35	0.09
K-1420 OU	Manganese	15.67722713	0.34	0.10
K-1420 OU	Lead	0.762159034	0.18	0.02
K-1420 OU	Nickel	2.50586224	0.12	0.06
K-1420 OU	Beryllium	0.017573513	0.05	
K-1420 OU	Pentachlorophenol	0.0058968	0.05	0.00
K-1420 OU	Strontium	2.363210388	0.02	
K-1420 OU	Benzo(a)pyrene	0.001127097	0.00	0.00
K-1420 OU	Trichloroethene	0.000562964	0.00	0.00
K-1420 OU	Acetone	0.013872059	0.00	0.00
K-1420 OU	Boron	0.00756	0.00	0.00
K-1420 OU	Aldrin	0.000032723	0.00	0.00
K-1420 OU	Methylene chloride	0.000735644	0.00	0.00
K-1420 OU	Tetrachloroethene	0.000085971	0.00	0.00
K-1420 OU	Bis(2-ethylhexyl)phthalate	0.000816788	0.00	0.00
K-1420 OU	1,2-Dichlorethane	0.000442033	0.00	
K-1420 OU	Fluoride	0.000084	0.00	0.00
K-1420 OU	Nitrate	0.00007504	0.00	0.00
LEFPC	Mercury	4.296225105	429.62	252.72
LEFPC	Aluminum	69.87414725	126.81	12.67
LEFPC	Total PCBs	0.603427128	6.29	1.27
LEFPC	Chromium	6.203555458	3.59	0.89
LEFPC	Selenium	0.299128402	2.82	1.72
LEFPC	Arsenic	0.086914284	2.41	0.24
LEFPC	DDT and metabolites	0.653845056	1.56	0.31
LEFPC	Vanadium	0.125903754	1.22	0.12
LEFPC	Thallium	0.004224671	1.06	0.11
LEFPC	Copper	6.619829696	0.83	0.62

Table G.14. (continued)

Location	Analyte	Total Exposure	NOAEL HQ	LOAEL HQ
LEFPC	Cadmium	0.378393704	0.74	0.07
LEFPC	Barium	1.508756756	0.54	0.14
LEFPC	Zinc	43.09930838	0.51	0.26
LEFPC	Manganese	9.555204577	0.21	0.06
LEFPC	Nickel	2.807265116	0.13	0.07
LEFPC	Lead	0.51770791	0.12	0.01
LEFPC	Antimony	0.00220416	0.06	0.01
LEFPC	Acetone	0.321341509	0.06	0.01
LEFPC	Uranium	0.040147329	0.05	0.02
LEFPC	Beryllium	0.013319375	0.04	
LEFPC	Pentachlorophenol	0.00105476	0.01	0.00
LEFPC	Benzo(a)Pyrene	0.001411935	0.00	0.00
LEFPC	Methylene chloride	0.004184472	0.00	0.00
LEFPC	Cyanide	0.0163072	0.00	
LEFPC	Dieldrin	0.000004676	0.00	0.00
LEFPC	Mixed-BHC	0.000001684	0.00	0.00
LEFPC	Bis(2-ethylhexyl)Phthalate	0.000566837	0.00	0.00
LEFPC	Endrin	0.000002295	0.00	0.00
LEFPC	Endosulfan	0.00000532	0.00	
LEFPC	Aldrin	0.000001148	0.00	0.00
LEFPC	Heptachlor	0.000000579	0.00	0.00
LEFPC	Methoxychlor	0.00001652	0.00	0.00
LEFPC	Di-N-Butylphthalate	0.000675992	0.00	0.00
LEFPC	Total chlordane	0.000004045	0.00	0.00
LEFPC	DiethylPhthalate	0.002990379	0.00	
LEFPC	Lindane	0.000003929	0.00	
SCF	Aluminum	108.5207236	196.95	19.68
SCF	Acetone	118.6568006	22.39	4.49
SCF	Mercury	0.088198542	8.82	5.19
SCF	Methylene chloride	22.23932855	7.17	0.84
SCF	Arsenic	0.15865751	4.41	0.44
SCF	Chromium	5.789531958	3.35	0.83
SCF	Vanadium	0.173298083	1.68	0.17
SCF	Cadmium	0.603934145	1.19	0.12
SCF	Selenium	0.101877886	0.96	0.59
SCF	Total PCBs	0.065190864	0.68	0.14
SCF	1,2-Dichlorethane	9.391174392	0.63	
SCF	Barium	1.621191342	0.58	0.15
SCF	Zinc	37.86920029	0.45	0.22
SCF	Manganese	14.79114998	0.32	0.10
SCF	Copper	2.059593457	0.26	0.19
SCF	Lead	0.439626724	0.10	0.01

Table G.14. (continued)

Location	Analyte	Total Exposure	NOAEL HQ	LOAEL HQ
SCF	Trichloroethene	0.020500137	0.10	0.01
SCF	Antimony	0.00340144	0.09	0.01
SCF	Nickel	1.508702913	0.07	0.04
SCF	Beryllium	0.021943401	0.06	
SCF	Tetrachloroethene	0.016366029	0.04	0.01
SCF	1,1-Dichlorethene	0.05510008	0.02	
SCF	Uranium	0.01118305	0.01	0.01
SCF	Chloroform	0.06772472	0.01	0.00
SCF	Benzene	0.05396491	0.01	0.00
SCF	Toluene	0.026923302	0.00	0.00
SCF	Benzo(a)pyrene	0.000940901	0.00	0.00
SCF	Dieldrin	0.000004052	0.00	0.00
SCF	Mixed-BHC	0.000002245	0.00	0.00
SCF	Endrin	0.000003607	0.00	0.00
SCF	Heptachlor	0.000008112	0.00	0.00
SCF	Pentachlorophenol	0.00001456	0.00	0.00
SCF	Endosulfan	0.00000784	0.00	
SCF	Bis(2-ethylhexyl)phthalate	0.000495947	0.00	0.00
SCF	DDT and metabolites	0.000028104	0.00	0.00
SCF	Methoxychlor	0.00003976	0.00	0.00
SCF	Aldrin	0.000001148	0.00	0.00
SCF	1,1,1-Trichlorethane	0.002674	0.00	
SCF	Total chlordane	0.000006646	0.00	0.00
SCF	Di-N-Butylphthalate	0.000434383	0.00	0.00
SCF	Carbon tetrachloride	0.00000028	0.00	
UEFPC OU 2	Aluminum	344.6614187	625.52	62.50
UEFPC OU 2	Chromium	7.284683613	4.21	1.05
UEFPC OU 2	Arsenic	0.094507453	2.63	0.26
UEFPC OU 2	Barium	6.583962528	2.35	0.63
UEFPC OU 2	Vanadium	0.154965206	1.50	0.15
UEFPC OU 2	Zinc	74.41987176	0.88	0.44
UEFPC OU 2	Copper	4.055219111	0.51	0.38
UEFPC OU 2	Lead	2.105040416	0.50	0.05
UEFPC OU 2	Manganese	20.73819553	0.45	0.14
UEFPC OU 2	Nickel	4.223950467	0.20	0.10
UEFPC OU 2	Beryllium	0.029919229	0.09	
UEFPC OU 2	Lithium	0.243786173	0.05	0.02
UEFPC OU 2	Uranium	0.020945141	0.02	0.01
UEFPC OU 2	Strontium	1.087551696	0.01	
UEFPC OU 2	Nitrate	0.00314076	0.00	0.00
WAG 1	Aluminum	69112.05462	125430.23	12531.65
WAG 1	Thallium	0.082754379	20.69	2.12

Table G.14. (continued)

Location	Analyte	Total Exposure	NOAEL HQ	LOAEL HQ
WAG 1	Mercury	0.190976379	19.10	11.23
WAG 1	Selenium	0.578747906	5.46	3.33
WAG 1	Total PCBs	0.40693979	4.24	0.86
WAG 1	Arsenic	0.10664277	2.96	0.30
WAG 1	Chromium	3.119996278	1.80	0.45
WAG 1	Vanadium	0.101639914	0.99	0.10
WAG 1	Barium	1.338223677	0.48	0.13
WAG 1	Antimony	0.01697276	0.47	0.05
WAG 1	Boron	4.93145548	0.33	0.10
WAG 1	Zinc	27.39176504	0.32	0.16
WAG 1	Cadmium	0.159827061	0.31	0.03
WAG 1	Copper	1.643023904	0.21	0.16
WAG 1	Manganese	7.278272854	0.16	0.05
WAG 1	Lead	0.390044712	0.09	0.01
WAG 1	Nickel	1.522625892	0.07	0.04
WAG 1	Uranium	0.048838806	0.06	0.03
WAG 1	Beryllium	0.013790544	0.04	
WAG 1	Tin	0.1517642	0.02	0.02
WAG 1	Vinyl chloride	0.00069007	0.01	0.00
WAG 1	Benzo(a)Pyrene	0.002117903	0.01	0.00
WAG 1	Mixed-BHC	0.000066228	0.01	0.00
WAG 1	Pentachlorophenol	0.000784	0.01	0.00
WAG 1	Acetone	0.016323346	0.00	0.00
WAG 1	Endrin	0.000068859	0.00	0.00
WAG 1	Methylene chloride	0.002895117	0.00	0.00
WAG 1	Total chlordane	0.000604494	0.00	0.00
WAG 1	Heptachlor	0.000030418	0.00	0.00
WAG 1	Cyanide	0.01310764	0.00	
WAG 1	DDT and metabolites	0.000152849	0.00	0.00
WAG 1	Bis(2-ethylhexyl)Phthalate	0.001246647	0.00	0.00
WAG 1	Trichloroethene	0.000031581	0.00	0.00
WAG 1	Tetrachloroethene	0.000061613	0.00	0.00
WAG 1	Chloroform	0.000306724	0.00	0.00
WAG 1	1,2-Dichlorethane	0.000358405	0.00	
WAG 1	Di-N-Butylphthalate	0.002571413	0.00	0.00
WAG 1	Benzene	0.000082006	0.00	0.00
WAG 1	Toluene	0.000046074	0.00	0.00
WAG 1	1,1-Dichlorethene	0.0000168	0.00	
WAG 1	Carbon tetrachloride	0.0000168	0.00	
WAG 1	Diethylphthalate	0.00082999	0.00	
WAG 1	1,2-Dichlorethene	0.00000644	0.00	
WAG 1	1,1,1-Trichlorethane	0.00000924	0.00	

Table G.14. (continued)

Location	Analyte	Total Exposure	NOAEL HQ	LOAEL HQ
WAG 6	Aluminum	90937.85994	165041.49	16489.19
WAG 6	Chromium	2.496040569	1.44	0.36
WAG 6	Vanadium	0.082976995	0.81	0.08
WAG 6	Arsenic	0.022786058	0.63	0.06
WAG 6	Barium	1.664488513	0.59	0.16
WAG 6	Cadmium	0.231829894	0.46	0.05
WAG 6	Mercury	0.003861655	0.39	0.23
WAG 6	Manganese	9.883662872	0.21	0.07
WAG 6	Zinc	16.23575877	0.19	0.10
WAG 6	Copper	1.33823744	0.17	0.13
WAG 6	Nickel	3.082732741	0.15	0.07
WAG 6	1,4-Dioxane	0.02116464	0.08	0.04
WAG 6	Beryllium	0.020234392	0.06	
WAG 6	Tin	0.2498804	0.04	0.02
WAG 6	Lead	0.155209228	0.04	0.00
WAG 6	Uranium	0.003397139	0.00	0.00
WAG 6	Cyanide	0.06668816	0.00	
WAG 6	Acetone	0.008189529	0.00	0.00
WAG 6	Methylene chloride	0.002990038	0.00	0.00
WAG 6	Bis(2-ethylhexyl)phthalate	0.001305957	0.00	0.00
WAG 6	Trichloroethene	0.000049431	0.00	0.00
WAG 6	Tetrachloroethene	0.000047284	0.00	0.00
WAG 6	Chloroform	0.00043623	0.00	0.00
WAG 6	Toluene	0.00003291	0.00	0.00
WAG 6	1,2-Dichlorethene	0.00001904	0.00	

Table G.15. Estimated exposure of red-tailed hawk to contaminants on the ORR

Location	Analyte	Total Exposure	NOAEL HQ	LOAEL HQ
BC OU 2	Mercury	5.49969701083	916.62	85.93
BC OU 2	Zinc	34.3811348792	2.37	0.26
BC OU 2	Total PCBs	0.22354951332	1.24	0.12
BC OU 2	Chromium	0.94628052815	0.95	0.19
BC OU 2	Lead	0.55245415764	0.49	0.05
BC OU 2	Aluminum	48.6806739254	0.44	
BC OU 2	Copper	4.10931180995	0.09	0.07
BC OU 2	Selenium	0.03998452034	0.08	0.04
BC OU 2	Barium	0.90923539707	0.04	0.02
BC OU 2	Nickel	1.13015350906	0.01	0.01
BC OU 2	Cadmium	0.01095200249	0.01	0.00
BC OU 2	Arsenic	0.02717681705	0.01	0.00
BC OU 2	Manganese	0.86123905728	0.00	
K-1407 OU	Mercury	0.46254193561	77.09	7.23
K-1407 OU	Chromium	1.49463473694	1.49	0.30
K-1407 OU	Zinc	14.8348230127	1.02	0.11
K-1407 OU	Aluminum	38.9272666092	0.35	
K-1407 OU	Selenium	0.15992690062	0.32	0.16
K-1407 OU	Lead	0.14373653819	0.13	0.01
K-1407 OU	Copper	3.48426844405	0.07	0.06
K-1407 OU	Nickel	5.6390420881	0.07	0.05
K-1407 OU	Barium	0.73974671829	0.04	0.02
K-1407 OU	Cadmium	0.02746242416	0.02	0.00
K-1407 OU	Arsenic	0.01012023375	0.00	0.00
K-1407 OU	Manganese	0.65597017984	0.00	
K-1407 OU	Molybdenum	0.00150025044	0.00	0.00
K-1420 OU	Aluminum	66825.4441119	609.17	
K-1420 OU	Mercury	0.03110127202	5.18	0.49
K-1420 OU	Total PCBs	0.85569336767	4.75	0.48
K-1420 OU	Zinc	35.4623764485	2.45	0.27
K-1420 OU	Chromium	0.54492698162	0.54	0.11
K-1420 OU	Lead	0.39430667718	0.35	0.03
K-1420 OU	Copper	3.36933868917	0.07	0.05
K-1420 OU	Barium	0.49565401563	0.02	0.01
K-1420 OU	Nickel	0.7599044	0.01	0.01
K-1420 OU	Arsenic	0.02087448739	0.00	0.00
K-1420 OU	Manganese	0.94868982504	0.00	
LEFPC	Mercury	3.00880401634	501.47	47.01
LEFPC	Total PCBs	0.50000507105	2.78	0.28
LEFPC	Zinc	38.2424949606	2.64	0.29
LEFPC	Chromium	1.40192631643	1.40	0.28

Table G.15 (continued)

Location	Analyte	Total Exposure	NOAEL HQ	LOAEL HQ
LEFPC	Selenium	0.19464529796	0.39	0.19
LEFPC	Lead	0.26783870115	0.24	0.02
LEFPC	Aluminum	17.9294578206	0.16	
LEFPC	Copper	6.42353030551	0.14	0.10
LEFPC	Cadmium	0.0593485833	0.04	0.00
LEFPC	Barium	0.76792584165	0.04	0.02
LEFPC	Nickel	0.8513050238	0.01	0.01
LEFPC	Arsenic	0.00616603126	0.00	0.00
LEFPC	Manganese	0.57822249334	0.00	
SCF	Mercury	0.06176867371	10.29	0.97
SCF	Zinc	33.601761966	2.32	0.26
SCF	Chromium	1.30836215879	1.31	0.26
SCF	Total PCBs	0.05401772824	0.30	0.03
SCF	Aluminum	27.8460319414	0.25	
SCF	Lead	0.22744302043	0.20	0.02
SCF	Selenium	0.06629277389	0.13	0.07
SCF	Cadmium	0.09472312966	0.07	0.00
SCF	Copper	1.99851984014	0.04	0.03
SCF	Barium	0.82515270995	0.04	0.02
SCF	Nickel	0.45751516732	0.01	0.00
SCF	Arsenic	0.0112557698	0.00	0.00
SCF	Manganese	0.89506985968	0.00	
UEFPC OU 2	Zinc	66.0335786758	4.55	0.50
UEFPC OU 2	Chromium	1.64624782229	1.65	0.33
UEFPC OU 2	Lead	1.08905288099	0.96	0.10
UEFPC OU 2	Aluminum	88.438894968	0.81	
UEFPC OU 2	Barium	3.35110013348	0.16	0.08
UEFPC OU 2	Copper	3.93496873002	0.08	0.06
UEFPC OU 2	Nickel	1.28091580391	0.02	0.01
UEFPC OU 2	Arsenic	0.00670471972	0.00	0.00
UEFPC OU 2	Manganese	1.25494865453	0.00	
WAG 1	Aluminum	17733.9075613	161.66	
WAG 1	Mercury	0.1337477627	22.29	2.09
WAG 1	Total PCBs	0.33719392007	1.87	0.19
WAG 1	Zinc	24.3050173132	1.68	0.19
WAG 1	Selenium	0.37659599707	0.75	0.38
WAG 1	Chromium	0.70508032345	0.71	0.14
WAG 1	Lead	0.20179152575	0.18	0.02
WAG 1	Copper	1.59430292362	0.03	0.03
WAG 1	Barium	0.68112804778	0.03	0.02
WAG 1	Cadmium	0.02506783162	0.02	0.00
WAG 1	Nickel	0.46173732007	0.01	0.00

Table G.15 (continued)

Location	Analyte	Total Exposure	NOAEL HQ	LOAEL HQ
WAG 1	Arsenic	0.00756564547	0.00	0.00
WAG 1	Manganese	0.44043652265	0.00	
WAG 6	Aluminum	23334.331627	212.71	
WAG 6	Zinc	14.4061690609	0.99	0.11
WAG 6	Chromium	0.56407409973	0.56	0.11
WAG 6	Mercury	0.00270445844	0.45	0.04
WAG 6	Lead	0.08029824778	0.07	0.01
WAG 6	Barium	0.84719007052	0.04	0.02
WAG 6	Copper	1.2985543659	0.03	0.02
WAG 6	Cadmium	0.03636100604	0.03	0.00
WAG 6	Nickel	0.93484076519	0.01	0.01
WAG 6	Manganese	0.59809877886	0.00	
WAG 6	Arsenic	0.00161653002	0.00	0.00

Table G.16. Experimental information for derivation of mammalian NOAELs and LOAELs

Contaminant	Form	Test species	NOAEL (mg/kg/d) and duration	LOAEL (mg/kg/d) and duration	Endpoint	Citation
Acetone	NA	rat	10[a] 90 d	50[a] 90 d	liver, kidney damage	EPA 1986c
Aldrin	NA	rat	0.2 3 gen.	1 3 gen.	reproduction	Treon and Cleveland 1955
Aluminum	AlCl3	mouse	1.93[b] 3 gen.	19.3 3 gen.	reproduction	Ondreicka et al. 1966
Antimony	potassium tartrate	mouse	0.125 lifetime	1.25 lifetime	reproduction	Schroeder et al. 1968
Aroclor-1254	NA	mink	0.14 4.5 months	0.69 4.5 months	reproduction	Aulerich and Ringer 1977
Arsenic	As+3	mouse	0.126[b] 3 gen.	1.26 3 gen.	reproduction	Schroeder and Mitchner 1971
Barium	chloride	rat	5.1 16 months		growth, hypertension	Perry et al. 1983
Barium	chloride	rat		19.8[a] 10 d	mortality	Borzelleca et al. 1988
Benzene	NA	mouse	26.36[b] 6-12 d, gest.	263.6 6-12 d, gest.	reproduction	Nawrot and Staples 1979
Benzo(a)pyrene	NA	mouse	1[b] 7-16 d, gest.	10 7-16 d, gest.	reproduction	Mackenzie and Angevine 1981
Beryllium	sulfate	rat	0.66 1126 d		longevity/ weight loss	Schroeder and Mitchner 1975

Table G.16 (continued)

Contaminant	Form	Test species	NOAEL (mg/kg/d) and duration	LOAEL (mg/kg/d) and duration	Endpoint	Citation
BHC (mixed isomers)	NA	rat	1.6 4 gen.	3.2 4 gen.	reproduction	Grant et al. 1977
Bis(2-ethylhexyl) phthalate	NA	mouse	18.3 105 d	183 105 d	reproduction	Lamb et al. 1987
Boron	boric acid, borax	rat	28 3 gen.	93.6 3 gen.	reproduction	Weir and Fisher 1972
Cadmium	$CdCl_2$	rat	1 6 wks	10 6 wks	reproduction	Sutou et al. 1980
Carbon tetrachloride	NA	rat	16 2 years		reproduction	Alumot et al. 1976a
Chlordane	NA	mouse	4.6 6 gen.	9.2 6 gen.	reproduction	WHO 1984 (Keplinger et al. 1968)
Chromium	Cr^{+6}	rat	3.28 1 year		weight loss, food consumption	Mackenzie et al. 1958
Chromium	Cr^{+6}	rat		13.14[a] 3 months	Mortality	Steven et al. 1976
Copper	sulfate	mink	11.71 1 year	15.14 1 year	reproduction	Aulerich et al. 1982
Cyanide	potassium cyanide	rat	68.7 gest. lact.		reproduction	Tewe and Maner 1981
DDT and metabolites	NA	rat	0.8 2 years	4.0 2 years	reproduction	Fitzhugh 1948

Table G.16 (continued)

Contaminant	Form	Test species	NOAEL (mg/kg/d) and duration	LOAEL (mg/kg/d) and duration	Endpoint	Citation
1,2 Dichloroethane	NA	mouse	50 2 gen.		reproduction	Lane et al. 1982
1,1 Dichloroethene	NA	rat	30 2 years		mortality, body weight, blood chem., liver histology	Quast et al. 1983
1,1 Dichloroethene	NA	dog	2.5[a] 97 d		mortality, body weight, blood chem., liver histology	Quast et al. 1983
1,2 Dichloroethene	NA	mouse	45.2[a] 90 d		body, organ weight, blood chem. hepatic function	Palmer et al. 1979
Dieldrin	NA	rat	0.02[b] 3 gen.	0.2 3 gen.	reproduction	Treon and Cleveland 1955
Diethylphthalate	NA	mouse	4583 105 d		reproduction	Lamb et al. 1987
1,4-Dioxane	NA	rat	0.5 gest.	1 gest.	reproduction	Giavini et al. 1985
Endosulfan	NA	rat	0.15[a] 30 d		reproduction, blood chem.	Dikshith et al 1984
Endrin	NA	mouse	0.092[b] 120 d	0.92 120 d	reproduction	Good and Ware 1969

Table G.16 (continued)

Contaminant	Form	Test species	NOAEL (mg/kg/d) and duration	LOAEL (mg/kg/d) and duration	Endpoint	Citation
Fluoride	NaF	mink	31.37 382 d	52.75 382 d	reproduction	Aulerich et al. 1987
Heptachlor	NA	mink	0.1[b] 181 d	1 181 d	reproduction	Crum et al. 1993
Lead	acetate	rat	8 3 gen.	80 3 gen.	reproduction	Azar et al. 1973
Lindane	NA	rat	8 3 gen.		reproduction	Palmer et al. 197
Lithium	carbonate	rat	9.4 gest.	18.8 gest.	reproduction	Marathe and Thomas 1986
Manganese	oxide	rat	88 224 d, gest.	284 224 d, gest.	reproduction	Laskey et al. 1982
Mercury	methyl	mink	0.015[a] 93 d	93 d	mortality	Wobeser et al. 1976
Mercury	methyl	rat	3 gen.	0.16 3 gen.	reproduction	Verschuuren et al. 1976
Methylene Chloride	NA	rat	5.85 2 yr.	50 2 yr.	liver histology	NCA 1982
Methoxychlor	NA	rat	4 11 months	8 11 months	reproduction	Gray et al. 1988
Molybdenum	molybdate	mouse	0.26[b] 3 gen.	2.6 3 gen.	reproduction	Schroeder and Mitchner 1971

Table G.16 (continued)

Contaminant	Form	Test species	NOAEL (mg/kg/d) and duration	LOAEL (mg/kg/d) and duration	Endpoint	Citation
Nickel	sulfate	rat	40 3 gen.	80 3 gen.	reproduction	Ambrose et al. 1976
Niobium	sodium niobate	mouse	0.155[b] lifetime	1.55 lifetime	lifespan, longevity	Schroeder et al. 1968
Nitrate	potassium nitrate	guinea pig	507 143-204 d	1130 143-204 d	reproduction	Sleight and Atallah 1968
Pentachlorophenol	NA	rat	0.24 62 d + gest.	2.4 62 d + gest.	reproduction	Schwetz et al. 1978
Selenium	potassium selenate	rat	0.2 2 gen.	0.33 2 gen.	reproduction	Rosenfeld and Beath 1954
Strontium	chloride	rat	263 3 years	3 years	body weight, bone changes	Skoryna 1981
1,1,2,2-Tetrachloroethene	NA	mouse	1.4[a] 6 weeks	7[a] 6 weeks	Hepatotoxicity	Buben and O'Flaherty 1985
Thallium	sulfate	rat	0.0074[a,b] 60 d	0.074[a,b] 60 d	reproduction	Formigli et al. 1986
Tin	(TBTO)	mouse	23.4 6-15 d, gest.	35 6-15 d, gest.	reproduction	Davis et al. 1987
Toluene	NA	mouse	26[b] 6-12 d, gest.	260 6-12 d, gest.	reproduction	Nawrot and Staples 1979
Trichloroethene	NA	mouse	0.7[a,b] 6 weeks	7[a] 6 weeks	hepatotoxicity	Buben and O'Flaherty 1985

Table G.16 (continued)

Contaminant	Form	Test species	NOAEL (mg/kg/d) and duration	LOAEL (mg/kg/d) and duration	Endpoint	Citation
1,1,1 Trichloroethane	NA	mouse	1000 3 gen.	 3 gen.	reproduction	Lane et al. 1982
Uranium	acetate	mouse	3.07 gest.	6.13 gest.	reproduction	Paternain et al. 1989
Vanadium	NaVO3	rat	0.21[b] 60 d + gest.	2.1 60 d + gest.	reproduction	Domingo et al. 1986
Vinyl chloride	NA	rat	0.17[b] lifetime	1.7 lifetime	longevity, mortality	Feron et al. 1981
Zinc	oxide	rat	160 gest.	320 gest.	reproduction	Schlicker and Cox 1968
Zirconium	sulfate	mouse	1.74 lifetime	 lifetime	lifespan, longevity	Schroeder et al. 1968b

[a]Estimated NOAEL: subchronic to chronic factor of 10 applied.
[b]Estimated NOAEL: LOAEL to NOAEL factor of 10 applied.

Table G.17. Estimated NOAELs and LOAELs for mammalian endpoints

	Estimated NOAELs			Estimated LOAELs		
Contaminant	**Shrew**	**Fox**	**Deer**	**Shrew**	**Fox**	**Deer**
Acetone	21.978	5.281	2.806	109.892	26.405	14.028
Aldrin	0.440	0.106	0.056	2.198	0.528	0.281
Aluminum	2.295	0.551	0.293	22.952	5.515	2.930
Antimony	0.149	0.036	0.019	1.487	0.357	0.190
Aroclor 1254	0.067	0.096	0.009	0.668	0.474	0.085
Arsenic	0.150	0.036	0.019	1.498	0.360	0.191
Barium	11.835	2.844	1.511	43.517	10.456	5.555
Benzene	31.348	7.532	4.001	313.476	75.321	40.014
BHC-mixed	3.517	0.010	0.449	7.033	0.096	0.898
Benzo(a)pyrene	1.189	0.286	0.152	11.892	2.857	1.518
Beryllium	1.451	0.349	0.185			
Bis(2-ethylhexyl)phthalate	21.763	5.229	2.778	217.625	52.290	27.779
Boron	61.539	14.787	7.855	205.717	49.430	26.259
Cadmium	2.12	0.509	0.271	21.2	5.1	2.7
Carbon Tetrachloride	35.165	8.450	4.489			
Chlordane	5.470	1.314	0.698	10.941	2.629	1.397
Chromium (Cr+6)	7.209	1.732	0.920	28.879	6.939	3.686
Copper	33.432	8.033	4.267	43.262	10.395	5.522
Cyanide	141.890	34.095	18.113			
DDT	1.758	0.422	0.224	8.791	2.112	1.122
1,2-Dichloroethane	61.797	14.849	7.888			
1,1-Dichloroethene	65.935	3.052	8.417			
1,2-Dichloroethene	53.752	12.915	6.861			
Dieldrin	0.044	0.011	0.006	0.440	0.106	0.056
Diethylphthalate	5450.149	1309.546	695.699			
1,4-Dioxane	1.10	0.26	0.14	2.20	0.53	0.28
Endosulfan	0.330	0.079	0.042			
Endrin	0.109	0.026	0.014	1.094	0.263	0.140
Fluoride	89.638	21.538	11.442	150.730	36.218	19.240
Heptachlor	0.286	0.069	0.036	2.857	0.687	0.365

Table G.17 (continued)

Contaminant	Estimated NOAELs			Estimated LOAELs		
	Shrew	Fox	Deer	Shrew	Fox	Deer
Lead	17.583	4.225	2.244	175.826	42.248	22.444
Lindane (Gamma-BHC)	17.583	4.225	2.244			
Lithium	20.660	4.964	2.637	41.319	9.928	5.274
Manganese	193.409	46.473	24.688	624.140	149.980	79.676
Methylmercury	0.070	0.010	0.009	0.352	0.085	0.045
Methoxychlor	8.791	2.112	1.122	17.583	4.225	2.244
Methylene Chloride	12.9	3.1	1.6	109.9	26.4	14.0
Molybdenum	0.309	0.074	0.039	3.092	0.743	0.395
Nickel	87.913	21.124	11.222	175.826	42.248	22.444
Niobium	0.184	0.044	0.024	1.843	0.443	0.235
Nitrate	1395.112	335.218	178.084	3109.421	747.133	396.913
Pentachlorophenol	0.527	0.127	0.067	5.275	1.267	0.673
Selenium (Sodium selenite)	0.44	0.106	0.056	0.725	0.174	0.093
Strontium	578.029	138.890	73.785			
1,1,2,2-Tetrachloroethene	1.665	0.400	0.213	8.324	2.000	1.063
Thallium	0.016	0.004	0.002	0.164	0.039	0.021
Tin	27.828	6.686	3.552	41.622	10.001	5.313
Toluene	30.919	7.429	3.947	309.195	74.292	39.468
1,1,1-Trichloroethane	1235.930	296.970	157.760			
Trichloroethene	0.832	0.200	0.106	8.324	2.000	1.063
Uranium	3.588	0.862	0.458	7.165	1.722	0.915
Vanadium	0.428	0.103	0.055	4.285	1.030	0.547
Vinyl Chloride	0.374	0.090	0.048	3.736	0.898	0.477
Xylene(mixed)	2.497	0.600	0.319	3.092	0.743	0.395
Zinc	351.653	84.496	44.888	703.306	168.992	89.776
Zirconium	2.069	0.497	0.264			

Table G.18. Estimated NOAELs and LOAELs for avian endpoints

Contaminant	Form	Test species	NOAEL (mg/kg/d) and duration	LOAEL (mg/kg/d) and duration	Endpoint	Citation	Estimated NOAEL (mg/kg/d)	Estimate d LOAEL (mg/kg/d)
Aluminum	$Al_2(SO_4)_3$	ringed dove	109.7 4 months		reproduction	Carriere et al. 1986	109.7	
Aroclor 1254	NA	Ring-necked pheasant	0.18[a] 17 weeks	1.8 17 weeks	reproduction	Dahlgren et al. 1972	0.18	1.8
Arsenic	arsenite	mallard duck	5.14 128 d	12.84 128 d	mortality	USFWS 1964	5.14	12.84
Barium	hydroxide	day-old chicks	20.8[a] 4 weeks	41.7[a] 4 weeks	mortality	Johnson et al. 1960	20.8	41.7
BHC (mixed isomers)	NA	Japanese Quail	0.56 90 d	2.25 90 d	reproduction	Vos et al. 1971	0.56	2.25
bis(2-ethylhexyl) Phthalate	NA	ringed dove	1.1 4 weeks	4 weeks	reproduction	Peakall 1974	1.1	
Boron	boric acid	mallard duck	28.8 3 weeks before, during, 3 weeks post reproduction	100 3 weeks before, during, 3 weeks post reproduction	reproduction	Smith and Anders 1989	28.8	100
Cadmium	$CdCl_2$	mallard duck	1.45 90 d	20 90 d	reproduction	White and Finley 1978	1.45	20
Chlordane	NA	red-winged blackbird	2.14 84 d	10.7 84 d	mortality	Stickel et al. 1983	2.14	10.7

Table G.18 (continued)

Contaminant	Form	Test species	NOAEL (mg/kg/d) and duration	LOAEL (mg/kg/d) and duration	Endpoint	Citation	Estimated NOAEL (mg/kg/d)	Estimated LOAEL (mg/kg/d)
Chromium	Cr^{+3}	black duck	1 10 months	5 10 months	reproduction	Haseltine et al., unpubl. data	1	5
Copper	oxide	chicken	33.2 10 weeks	46.97 10 weeks	growth/ mortality	Mehring et al. 1960	33.2	46.97
1,2-Dichloroehtane	NA	chicken	17.2 2 years	34.4 2 years	reproduction	Alumot et al. 1976b	17.2	
DDT and metabolites	NA	Brown Pelican	0.0028[b] >1 year	0.028[b] >1 year	reproduction	Anderson et al. 1975	0.0028	0.028
Dieldrin	NA	barn owl	0.077 2 year		reproduction	Mendenhall et al. 1983	0.077	
Endosulfan	NA	gray partridge	10 4 weeks		reproduction	Abiola 1992	10	
Endrin	NA	screech owl	0.01[c] 83 d	0.1 83 d	reproduction	Fleming et al. 1982	0.01	0.1
Fluoride	NaF	screech owl	7.8 5-6 months	32 5-6 months	reproduction	Pattee et al. 1988	7.8	32
Lead	acetate	Japanese quail	1.13 12 weeks	11.3 12 weeks	reproduction	Edens et al. 1976	1.13	11.3
Lindane	NA	mallard duck	2[c] 8 weeks	20 8 weeks	reproduction	Chakravarty and Lahiri 1986	2	20
Manganese	oxide	Japanese quail	977 75 d	75 d	growth, aggresiveness	Laskey and Edens 1985	977	

Table G.18 (continued)

Contaminant	Form	Test species	NOAEL (mg/kg/d) and duration	LOAEL (mg/kg/d) and duration	Endpoint	Citation	Estimated NOAEL (mg/kg/d)	Estimated LOAEL (mg/kg/d)
Mercury	methyl	mallard duck	0.0064[a] 3 generations	0.064 3 generations	reproduction	Heinz 1979	0.0064	0.064
Molybdenum	sodium Mo	chicken	3.5[c] 21 d	35.3 21 d	reproduction	Lepore and Miller	3.5	35.3
Nickel	sulfate	mallard duck	77.4 90 d	107 90 d	mortality, growth, behavior	Cain and Pafford 1981	77.4	107
Selenium	selenite	mallard duck	0.5 10 weeks	1.0 10 weeks	reproduction	Heinz et al. 1987	0.5	1.0
Tin	(TBTO)	Japanese quail	6.8 6 weeks	16.9 6 weeks	reproduction	Schlatterer et al. 1993	6.8	16.9
Uranium	depleted metal	black duck	16[a] 6 weeks		mortality, growth, behavior	Haseltine and Sileo 1983	16	
Vanadium	vanadyl sulfate	mallard duck	11.4 12 weeks	12 weeks	mortality, body weight, blood chem.	White and Dieter 1978	11.4	
Zinc	zinc sulfate	chicken	14.5 44 week(s)	130.9 44 week(s)	reproduction	Stahl et al. 1990	14.5	1309

[a]Estimated NOAEL: subchronic to chronic factor of 10 applied.
[b]From EPA 1993.
[c]Estimated NOAEL: LOAEL to NOAEL factor of 10 applied.

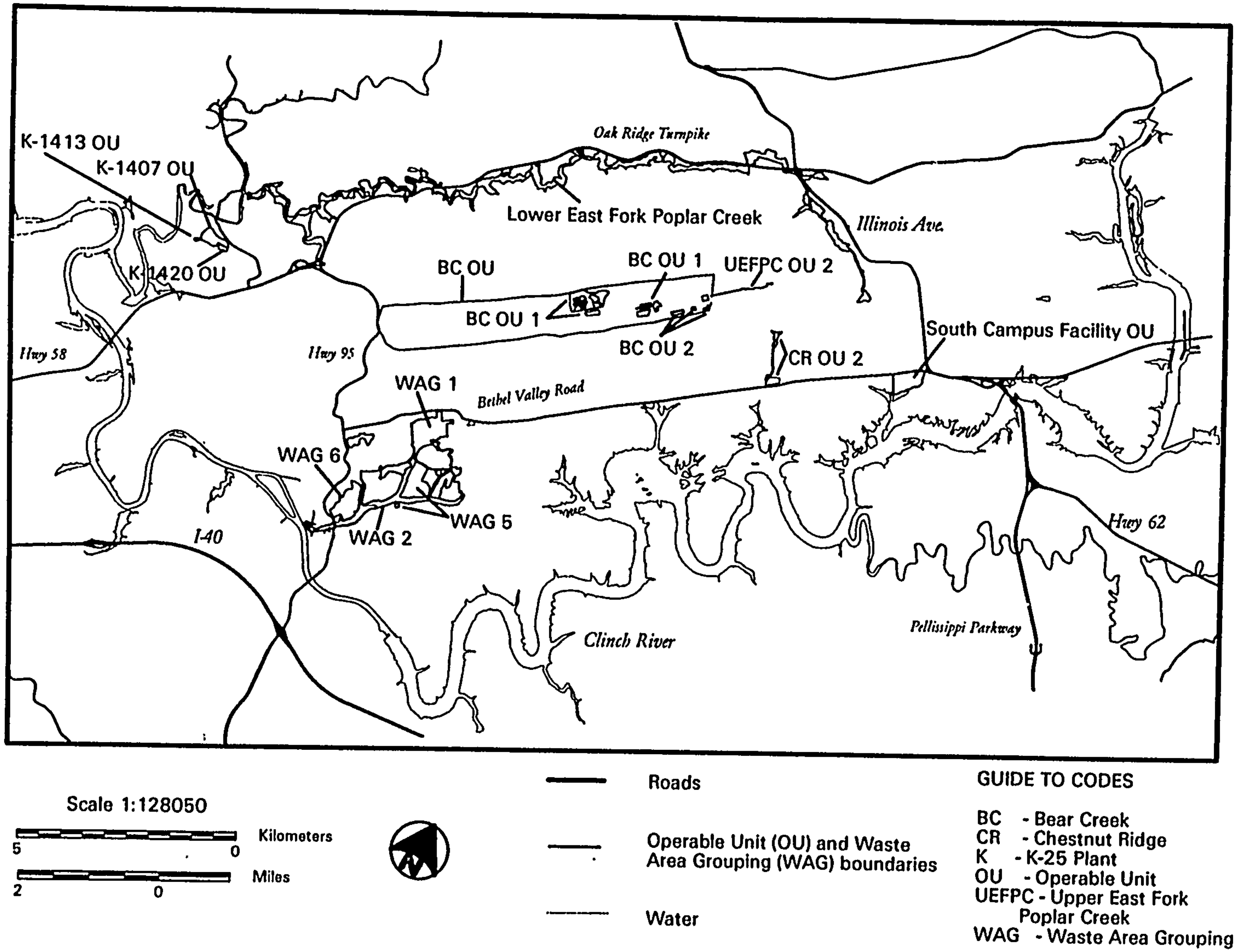

Fig. G.1. Locations of OUs evaluated as part of the ORR-wide assessment of risk to vermivores and herbivores.

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38. J. W. Wagoner II, Team Leader, Portsmouth/Paducah/Weldon Spring Team, Office of Environmental Restoration, U.S. Department of Energy, Cloverleaf Building, EM-424, 19901 Germantown Road, Germantown, MD 20874

39–40. R. C. Sleeman, Director, Environmental Restoration Division, DOE Oak Ridge Operations Office, P.O. Box 2001, Oak Ridge, TN 37831-8541

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