
Chapter 4

Problem Formulation

What's Covered in Chapter 4:

- ◆ Exposure Setting Characterization
 - ◆ Food Web Development
 - ◆ Selecting Assessment Endpoints
 - ◆ Identifying Measures of Effect
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Problem formulation establishes the exposure setting used as the basis for exposure analysis and risk characterization. Problem formulation includes (1) characterization of the exposure setting for identification of potentially exposed habitats in the assessment area (Section 4.1); (2) development of food webs representative of the habitats to be evaluated (Section 4.2); (3) selection of assessment endpoints relevant to food web structure and function (Section 4.3); and (4) identification of measurement receptors (Section 4.4).

4.1 EXPOSURE SETTING CHARACTERIZATION

Exposure setting characterization is important in the identification of habitats consisting of ecological receptors in the assessment area that may be impacted as a result of exposure to compounds emitted from a facility. Ecological receptors within a potentially impacted habitat can be evaluated through consideration of the combination of exposure pathways to which ecological receptors representing a habitat-specific food web may be exposed to a compound. The habitats identified to be evaluated are selected based on existing habitats surrounding the facility (see Section 4.1.1); and also support which habitat-specific food webs are evaluated in risk characterization. Consideration of ecological receptors representative of the habitats also provides the basis for selecting measurement receptors, as well as, it supports demonstration of the presence or absence of federal and state species of special interest (see Section 4.1.1.3).

Exposure setting characterization is generally focused geographically to the assessment area that is defined as the area surrounding the facility that is impacted from facility emissions as predicted by ISCST3 air dispersion modeling; with additional consideration typically extending by a 50-km radius, taken from the centroid of a polygon (also used as the origin of ISCST3 receptor grid node array, see Chapter 3) identified by the UTM coordinates of the facility's emission sources. A 50-km radius is generally the recognized limit of the ISCST3 air dispersion model and its predecessors (U.S. EPA 1990a; 1995c). Resources for characterizing the exposure setting should focus on the areas impacted from emissions as predicted by air dispersion modeling. As discussed in Section 4.1.1, habitats (potentially including water bodies and their associated watersheds)—both within and outside the facility property boundary—should be considered for evaluation.

The following subsections provide information on selection of habitats, and identification of ecological receptors representative of those habitats, to be considered for evaluation in the risk assessment.

4.1.1 Selection of Habitats

Habitats to be considered in the risk assessment are selected by identifying similar habitats surrounding the facility that are potentially impacted by facility emissions, and when overlaid with the air dispersion modeling results, define which habitat-specific food webs should be evaluated in the risk assessment.

Habitats can be defined based on their biotic and abiotic characteristics, and are generally divided into two major groups (i.e., terrestrial and aquatic) that can be classified as follows:

- Terrestrial
 - Forest
 - Shortgrass prairie
 - Tallgrass prairie
 - Agricultural/Cropland
 - Scrub/Shrub
 - Desert

- Aquatic
 - Freshwater
 - Brackish/Intermediate
 - Marine

Habitat types can typically be identified by reviewing hard copy and/or electronic versions of land use land classification (LULC) maps, topographic maps, and aerial photographs. Sources and general information associated with each of these data types or maps are presented below. Also, as noted in Chapter 3, the UTM coordinate system format (NAD27 or NAD83) for all mapping information should be verified to ensure consistency and prevent erroneous georeferencing of locations and areas.

Land Use Land Cover (LULC) Maps - LULC maps can be downloaded directly from the USGS web site (<http://mapping.usgs.gov/index.html>), at a scale of 1:250,000 in a file type GIRAS format. LULC maps can also be downloaded from the EPA web site (<ftp://ftp.epa.gov/pub>), at a scale of 1:250,000, in an Arc/Info export format. These maps provide detailed habitat information based upon the classification system and definitions of Level II Land Use and Land Cover information. Exact boundaries of polygon land use area coverages, in areas being considered for evaluation, should be verified using available topographic maps and aerial photographic coverages.

Topographic Maps - Topographic maps are readily available in both hard copy and electronic format directly from USGS or numerous other vendors. These maps are commonly at a scale of 1:24,000, and in a file type of TIFF format with TIFF World File included for georeferencing.

Aerial Photographs - Hard copy aerial photographs can be purchased directly from USGS in a variety of scales and coverages. Electronic format aerial photographs of Digital Ortho Quarter Quads (DOQQs) can also be purchased directly from USGS, or from an increasing number of commercial sources. Properly georeferenced DOQQs covering a 3-km or more radius of the assessment area, overlays of the LULC map coverage, and the ISCST3 modeled receptor grid node array provide an excellent reference for identifying land use areas and justifying selection of exposure locations.

While these data types or maps do not represent the universe of information available on habitats or land use, they are readily available from a number of governmental sources (typically accessible via the Internet), usually can be obtained free or for a low cost, and, when used together, provide sufficient information to reliably identify and define boundaries of habitats to be considered for evaluation in risk characterization. However, while the use of these or other data can be very accurate, verifying identified habitats by conducting a site visit is recommended. Also, these data sources may be dated, and may not reflect current habitat boundaries or land use (i.e., expanded cropland or urban developments, new lakes).

Additional information useful for habitat identification can be obtained from discussions with representatives of private and government organizations which routinely collect and evaluate ecosystem or habitat information including the following: (1) Soil Conservation Service, (2) U.S. Fish and Wildlife

Service (FWS), (3) U.S Department of Agriculture, (4) state natural resource, wildlife, and park agencies, and (5) local government agencies.

U.S. EPA OSW recommends that habitats identified during exposure setting characterization and selected for evaluation in the risk assessment be clearly mapped and include the following supporting information:

- Facility boundaries
- Facility emission source location(s)
- Habitat types and boundaries
- Water bodies and their associated watersheds
- Special ecological areas (see Section 4.1.1.2)

A facility location map, including land-use and land cover data, which allows for identification of habitats to support selection of habitat-specific food webs to be evaluated in the risk assessment. The map should also note the UTM coordinate system format (NAD27 or NAD83) for all information presented to ensure consistency and prevent erroneous georeferencing of locations and areas; including accurate identification of exposure scenario locations and water bodies within the habitat to be evaluated, as discussed in the following subsections.

4.1.1.1 Selection of Exposure Scenario Locations Within Terrestrial Habitats

Exposure scenario locations to be evaluated within the terrestrial habitats identified during the exposure setting characterization, are selected at specific receptor grid nodes based on evaluation of the magnitude of air parameter values estimated by ISCST3 (see Chapter 3). U.S. EPA OSW would like to note that the methodology and resulting selection of receptor grid nodes as exposure scenario locations is one of the most critical parts of the risk assessment process, ensuring standardization across all facilities evaluated and reproducibility of results. The estimates of risk can vary significantly in direct response to the receptor grid nodes that are selected as exposure scenario locations because the grid node-specific ISCST3 modeled air parameter values are used as inputs into the media equations.

U.S. EPA OSW recommends that, at a minimum, the procedures described below be used in the selection of receptor grid nodes as exposure scenario locations; and that the selected exposure scenario locations correspond to actual ISCST3 modeled receptor grid node locations defined by UTM coordinates. In addition to consistency and reproducibility, these procedures ensure that the exposure scenario location(s) selected for evaluation over a specified habitat do not overlook the most highly impacted locations.

Exposure scenario locations, at actual receptor grid nodes, should be selected as follows:

Step 1: Define Terrestrial Habitats To Be Evaluated - All habitats, identified during exposure setting characterization for evaluation in the risk assessment, should be defined and habitat boundaries mapped in a format (NAD 27 or NAD 83 UTM) consistent with that used to define locations of facility emission sources and modeled ISCST3 receptor grid nodes.

Step 2: Identify Receptor Grid Node(s) Within Each Habitat To Be Evaluated - For each habitat to be evaluated, identify the receptor grid nodes within that area or on the boundary of that area (defined in Step 1) that represent the locations of highest yearly average concentration for each ISCST3 modeled air parameter (i.e., air concentration, dry deposition, wet deposition) for each phase (i.e., vapor, particle, particle-bound). This determination should be performed for each emission source (i.e., stacks, fugitives) and all emissions sources at the facility combined. This results in the selection of one or more receptor grid nodes as exposure scenario locations, within a defined habitat area to be evaluated, and that meet one or more of the following criteria:

- Highest modeled unitized vapor phase air concentration
- Highest modeled unitized vapor phase wet deposition rate
- Highest modeled unitized particle phase air concentration
- Highest modeled unitized particle phase wet deposition rate
- Highest modeled unitized particle phase dry deposition rate
- Highest modeled unitized particle-bound phase air concentration
- Highest modeled unitized particle-bound phase wet deposition rate
- Highest modeled unitized particle-bound phase dry deposition rate

Only ISCST3 modeled air parameters corresponding to a single receptor grid node should be used per exposure scenario location as inputs into the media equations, without averaging or statistical manipulation. However, based generally on the number and location of facility emission sources, multiple exposure scenario locations may be selected to represent the highest potential impact area for a specific habitat being evaluated.

Modeling of the above air parameter criteria for habitats at actual sites being evaluated in U.S. EPA Region 6, using actual modeled air parameters, indicates that only 1 to 3 receptor nodes are typically selected per habitat. This is because, in most cases, the location of some of the highest air concentration and deposition rate, within a habitat for several of the modeled air parameters, occurs at the same receptor grid node. The number of receptor grid nodes with maximum air parameters depends on many factors, including number of and distance between emissions sources, habitat size and shape, distance and direction from facility, topographic features, and meteorological patterns. It should also be noted, that while these criteria minimize overlooking maximum risk within a habitat, they do not preclude the risk assessor from selecting additional exposure scenario locations within that same habitat based on site-specific risk considerations.

Also, a water body and associated watershed in close proximity to the exposure scenario location being evaluated should be identified to represent a drinking water source for applicable receptors (see Appendix F). Although the locations and type of sources (i.e., free water, consumption of water as part of food items) of water ingested by an animal through diet are expected to vary depending on the receptor and availability, COPC intake by the receptor through ingestion of water can be estimated by assuming only water intake from a defined water body for which a COPC concentration can be calculated. Therefore, a representative water body should be defined and evaluated following the guidance provided in Section 4.1.1.2, and a COPC concentration in the water column, C_{water} , calculated as described in Chapter 3 and Appendix B.

If a definable water body is not located within or in close proximity to the terrestrial habitat being evaluated, receptor drinking water intake terms in the exposure equations presented in Appendix F should be adjusted accordingly (i.e., ingestion of drinking water set equal to zero). However, for sites where the permitting authority or risk manager identifies that receptor exposure through ingestion of drinking water may be significant, an available option is to assume that a small water body exists at the same receptor grid node as the exposure scenario location being evaluated. If multiple exposure scenario locations within the habitat are being evaluated, a single assumed water body can be located at the closest receptor grid node located equal distance from each of the exposure scenario locations being evaluated, and utilized as a drinking water source for evaluation of each exposure scenario location within the habitat. Since the assumed water body represents a pool or other drinking source too small for identification on an aerial

photograph or map, it can be assumed to have a unit volume (i.e., surface area of 1 meter square, water column depth of 1 meter). The assumed water body should not have flow or an associated watershed.

4.1.1.2 Selection of Habitat Exposure Scenario Locations Within Aquatic Habitats

Exposure scenario locations to be evaluated within the aquatic habitats identified during the exposure setting characterization may first require differentiating water bodies from land areas within aquatic habitats not typically covered by water (e.g., flood plains or wetland areas transitioning to terrestrial and upland habitats). Exposure scenario locations within land areas of aquatic habitats not characteristic of a standing water body are selected following the same steps as for terrestrial habitats (see Section 4.1.1.1). However, exposure scenario locations for defined water bodies within aquatic habitats should be selected following the guidance provided in this section. The associated watershed contributing COPC loading to the water body being evaluated should also be defined.

U.S. EPA OSW recommends that, at a minimum, the following procedures be used in the selection of exposure scenario locations within defined water body areas of aquatic habitats as follows:

Step 1: Define Aquatic Habitats To Be Evaluated - All habitats, identified during exposure setting characterization for evaluation in the risk assessment, should be defined and habitat boundaries mapped in a format (NAD 27 or NAD 83 UTM) consistent with that used to define locations of facility emission sources and modeled ISCST3 receptor grid nodes. Water body boundaries should reflect annual average shoreline elevations. The area extent of watersheds associated with water bodies to be evaluated should also be defined.

Step 2: Identify Receptor Grid Node(s) Within Each Habitat To Be Evaluated - For each water body and associated watershed to be evaluated, the receptor grid nodes within that area and on the boundary of that area (defined in Step 1) should be considered. For water bodies, the risk assessor can select the receptor grid node that represent the locations of highest yearly average concentration for each ISCST3 modeled air parameter (i.e., air concentration, dry deposition, wet deposition) for each phase (i.e., vapor, particle, particle-bound), or average the air parameter values for all receptor grid nodes within the area of the water body. This determination should be performed for each emission source (i.e., stacks, fugitives), and all emissions sources at the facility combined. For watersheds, the modeled air parameter values should be averaged for all receptor grid nodes within the area extent or effective area of the watershed (excluding the area of the water body).

For evaluating the COPC loading to the water body from its associated watershed, the area extent of the watershed should be defined and the ISCST3 modeled air parameter values at each receptor grid node

within the watershed area (excluding the water body) averaged. These averaged air parameter values are then used in the estimating media equations presented in Chapter 3 and Appendix B for calculating the COPC loading to the water body.

For water bodies identified as potentially impacted from emission sources and selected for evaluation, the area extent of the associated watershed that contributes water to the water body should also be identified and defined by UTM coordinates. The area extent of a watershed is generally defined by topographic highs that result in downslope drainage into the water body. The watershed can be important to determining the overall water body COPC loading, because pervious and impervious areas of the watershed, as well as the soil concentration of COPCs resulting from emissions from facility sources, are also used in the media concentration equations to calculate the water body COPC concentrations resulting from watershed runoff (see Chapter 3 and Appendix B). The total watershed area that contributes water to the water body can be very extensive relative to the area that is impacted from facility emissions. Therefore, it is important that the area extent of all watersheds to be evaluated should be approved by the permitting authority, to ensure that the watershed and its contribution to the water body is defined appropriately in consideration of the aquatic habitat being evaluated and subsequent estimated risk.

For example, if facility emissions impact principally a land area that feeds a specific tributary that drains to a large swamp system and immediately upstream of the ISCST3 receptor grid nodes identified as exposure scenario locations for the aquatic habitat defined by the swamp, the risk assessor should consider evaluating an “effective” watershed area rather than the entire watershed area of the large swamp system. For such a large swamp system, the watershed area can be on the order of thousands of square kilometers and can include numerous tributaries draining into the swamp at points that would have no net impact on the water body COPC concentration at the exposure point(s) of interest.

Similar to large watersheds, water bodies may also be extensive in size relative to the area that is impacted from facility emissions and exposure point(s) of interest. In such cases, the risk assessor should consider defining and evaluating an “effective” area of the water body that focuses the assessment specific to areas potentially impacted and of most concern when considering potential for exposure. Therefore, as with watersheds, it is important that the area extent of all water bodies to be evaluated should be approved by the permitting authority, to ensure that potential impacts and exposure are appropriately considered.

The recommended ISCST3 modeled receptor grid node array extends out about 10 km from facility emission sources (see Chapter 3). To address evaluation of habitat areas, water bodies, or watersheds located beyond the coverage provided by the recommended receptor grid node array (greater than 10 km from the facility), the ISCST3 modeling can be conducted with an additional receptor grid node array specified to provide coverage of the area of concern, or the steps above can be executed using the closest receptor grid nodes from the recommended array. However, using the closest receptor grid nodes from the recommended receptor grid node array will in most cases provide a conservative estimate of risk since the magnitude of air parameter values at these receptor grid nodes would most likely be higher than at receptor grid nodes located further from the facility sources and actually within the area of concern.

RECOMMENDED INFORMATION FOR RISK ASSESSMENT

- Identification and/or mapping of habitats, water bodies, and associated watersheds potentially impacted by facility emissions of COPCs, including surface area of the water body and area extent of the contributing watershed defined by UTM coordinates
- Rational for selection or exclusion from evaluation, habitats within the assessment area
- Description of rational and assumptions made to limit the watershed area to an “effective” area
- Copies of all maps, photographs, or figures used to define characteristics of habitats, water bodies, and watersheds

4.1.1.3 Special Ecological Areas

A special ecological area is a habitat that could require protection or special consideration on a site-specific basis because (1) unique and/or rare ecological receptors and natural resources are present, or (2) legislatively-conferred protection (e.g., a national monument) has been established. All potentially exposed special ecological areas in the assessment area should be identified for consideration. The following are examples of special ecological habitats (U.S. EPA 1997c):

- Marine Sanctuaries
- National river reaches
- Spawning areas critical for maintenance of fish/shellfish species

- Terrestrial areas utilized for breeding by large or dense aggregations of animals
- Migratory pathways and feeding areas critical for maintenance of anadromous fish species
- National Preserves
- Federal lands designated for protection of natural ecosystems
- National or State Wildlife Refuges
- Critical areas identified under the Clean Lakes Program
- Habitats known to be used by Federal or State designated or proposed endangered or threatened species
- Areas identified under the Coastal Zone Management Act
- Sensitive areas identified under the National Estuary Program or Near Coastal Waters Program
- Designated Federal Wilderness Areas
- State lands designated for wildlife or game management
- Federal- or State-designated Scenic or Wild Rivers, or Natural Areas
- Wetlands

RECOMMENDED INFORMATION FOR RISK ASSESSMENT

- Identification and mapping of habitats in the assessment area, information on which the identification is based, and information on any special ecological areas. Maps, photographs, or additional sources used to determine habitats and define boundaries should be referenced. Maps and figures should also note the UTM coordinate system format (NAD27 or NAD83) for all information presented to ensure consistency and prevent erroneous georeferencing of locations and areas.

4.1.2 Identification of Ecological Receptors

Identification of ecological receptors during exposure setting characterization is used to define food webs specific to potentially impacted habitats to be evaluated in the risk assessment. Ecological receptors for each habitat potentially impacted should be identified to ensure (1) plant and animal communities representative of the habitat are represented by the habitat-specific food web, and (2) potentially complete exposure pathways are identified. Examples of sources and general information available for identification of site-specific ecological receptors are presented below:

Government Organizations - U.S. Fish and Wildlife Service (National Wetland Inventory Maps - <http://nwi.fws.gov>) and State Natural Heritage Programs (see Appendix H) provide maps or lists

of species based on geographic location, and are very helpful in identifying threatened or endangered species or areas of special concern.

General Literature (field guides) - Examples of information describing the flora and fauna of North America and useful in the development of habitat-specific food webs (see Section 4.2) include the following: Wharton 1982; Craig et al. 1987; Baker et al. 1991; Carr 1994; Ehrlich et al. 1988; National Geographic Society (1987, 1992); Whitaker 1995; Burt and Grossenheider 1980; Behler 1995; Smith and Brodie 1982; Tynning 1990; and Farrand Jr. 1989.

Private or Local Organizations - Additional private or professional organizations that are examples of sources of information include: National Audubon Society, National Geographic Society, Local Wildlife Clubs, State and National Parks Systems, and Universities.

Ecological receptor identification should include species both known and expected to be present in a specific habitat being evaluated, and include resident and migratory populations. Identification of flora should be based on major taxonomic groups represented in the assessment area. Natural history information may also be useful during food web development in assigning individual receptors to specific habitats and guilds based on feeding behavior (as discussed in Section 4.2.).

4.2 FOOD WEB DEVELOPMENT

Information obtained during exposure setting characterization should be used to develop one or more habitat-specific food web(s) that represent communities and guilds of receptors potentially exposed to emissions from facility sources. Food webs are interlocking patterns of food chains, which are the straight-line transfer of energy from a food source (e.g., plants) to a series of organisms feeding on the source or on other organisms feeding on the food source (Odum 1971). While energy and, therefore, transfer of a compound in a food chain, is not always linear, it is assumed in this guidance that energy and, thus, compounds, are always transferred to a higher trophic level. The importance of a food chain as an exposure pathway primarily depends on receptor dietary habits, the receptors in the food chain, and other factors including bioavailability and depuration of the compound evaluated.

Habitat-specific food webs are developed for use in the risk assessment to:

- Define direct and indirect exposure pathways
- Formulate assessment endpoints

- Develop mathematical relationships between guilds
- Perform quantitative exposure analysis for ecological receptors

Food webs can be developed using the “community approach” (Cohen 1978), which includes (1) identification of potential receptors in a given habitat (see Section 4.1.2) for grouping into feeding guilds by class and communities (see Section 4.2.1), (2) organizing food web structure by trophic level (e.g., primary producer, secondary consumer; see Section 4.2.2), and (3) defining dietary relationships between guilds and communities (see Section 4.2.3). The result is a complete food web for a defined habitat, which should be developed for each habitat in the assessment area to be evaluated in risk characterization. An example of food web development is presented in Section 4.2.4.

4.2.1 Grouping Receptors into Feeding Guilds and Communities

The first step in developing a habitat-specific food web is to identify, based on the dietary habits and feeding strategies of receptors compiled in Section 4.1.2, the major feeding guilds for birds, mammals, reptiles, amphibians, and fish. A guild is a group of species that occupies a particular trophic level and shares similar feeding strategies. Invertebrates and plants are not assigned to guilds, rather these receptors are grouped into their respective community by the environmental media they inhabit. The distinction for grouping upper-trophic-level receptors into class-specific guilds, and invertebrates and plants into communities, is made because the risk to these groups is characterized differently (see Chapter 5).

Once the major feeding guilds are identified (e.g., herbivore, omnivore, carnivore, insectivore), receptors should be grouped by class (e.g., mammals, birds, amphibians and reptiles, and fish). As noted, invertebrates and plants are grouped into their respective community by the media they inhabit (i.e, soil invertebrates, terrestrial vegetation, sediment fauna, water column invertebrates, phytoplankton, and rooted aquatic vegetation).

4.2.2 Organizing Food Web Structure By Trophic Level

The structure of a food web should be organized by trophic level. A trophic level is one of the successive levels of nourishment in a food web or food chain. The first trophic level (TL1) contains the primary producers or the green plants. Members of this trophic level produce their own food from nutrients,

sunlight, carbon dioxide, and water. These primary producers are also the source of food for members of the second trophic level (TL2). The second trophic level is often referred to as the primary consumers and is composed of animals that eat plants (herbivores) and animals that subsist on detritus (decaying organic matter) found in sediment and soil (detritivores). The third trophic level (TL3), contains both omnivores and carnivores. Omnivores are animals that eat both plant and animal matter, while carnivores eat primarily animal matter. The fourth trophic level (TL4), contains only carnivores and is sometimes referred to as the dominant carnivores. TL4 contains animals at the top of the food chain (e.g., raptorial birds).

Some species can occupy more than one trophic level at a time depending on life stage. For this reason, professional judgement should be used to categorize receptors without making the food web unduly complex.

4.2.3 Defining Dietary Relationships Between Guilds and Communities

After species have been grouped into the appropriate guilds and communities, and organized by trophic level, dietary relationships between guilds and communities should be defined. Guilds and communities should be linked together based on dietary relationships by evaluating the dietary composition of the receptors for each guild and community. Although most organisms have a complex diet, it should be assumed that the majority of their diet is composed of a limited number of prey items and, therefore, a limited number of feeding guild interactions occur. Therefore, U.S. EPA OSW recommends that generally only those interactions that contribute more than five percent of the total diet should be considered for development of a food web. This recommendation of five percent of the total diet as a general cutoff is based on the assumption that the food web can be simplified without underestimating exposure.

RECOMMENDED INFORMATION FOR RISK ASSESSMENT

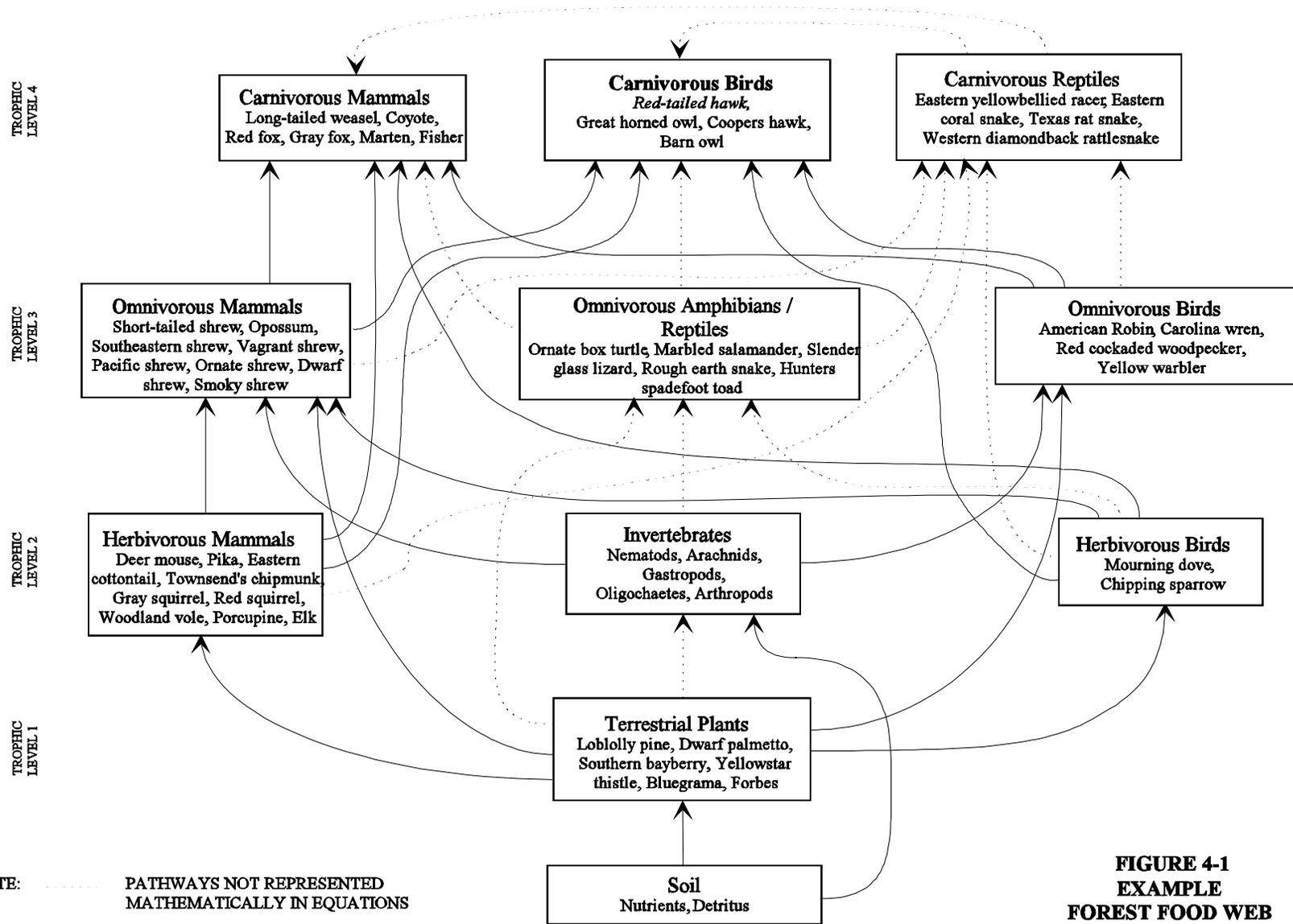
- Habitat-specific food web(s) that include identification of (1) media (e.g., soil, sediment, water), (2) trophic levels that include at a minimum producers (TL 1), primary consumers (TL 2), secondary consumers (TL 3), and carnivores (TL 4), (3) guilds divided into classes (e.g., herbivorous mammals, omnivorous birds) and communities, and (4) major dietary interactions.

4.2.4 Example Habitat-Specific Food Webs

To better illustrate food web development as discussed in the previous sections (see Sections 4.2.1 through 4.2.3), seven habitat-specific example food webs are presented as Figures 4-1 through 4-7. The habitats represented include:

- Forest
- Tallgrass prairie
- Shortgrass prairie
- Shrub/Scrub
- Freshwater/Wetland
- Salt marsh
- Brackish/Intermediate marsh

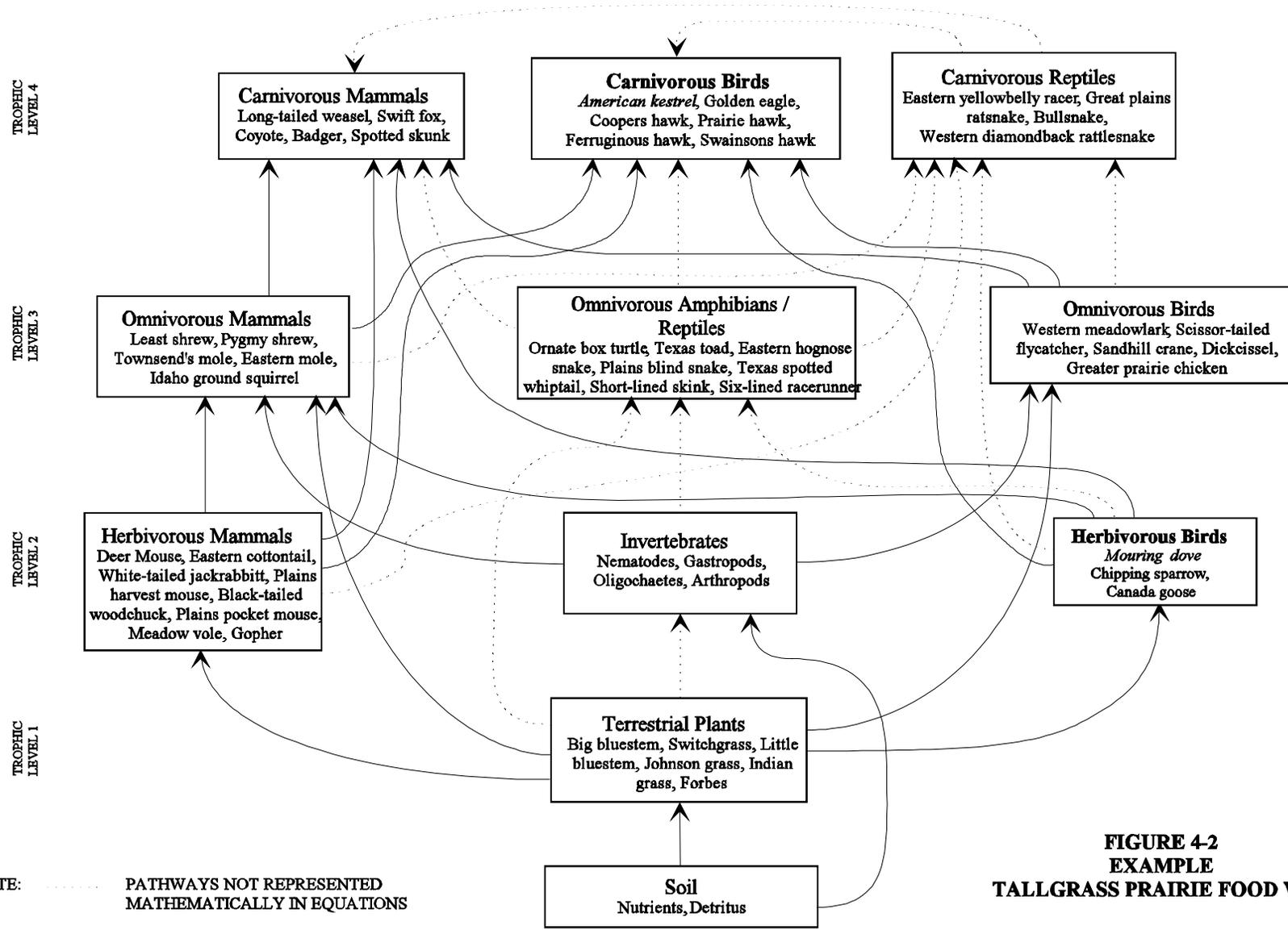
The terrestrial and aquatic example food webs are based on information describing the flora and fauna of North America (U.S. FWS 1979; Wharton 1982; Craig et al. 1987; Baker et al. 1991). Supplemental information was collected from field guides and U.S. EPA's *Wildlife Exposure Factors Handbook* (Carr 1994; Ehrlich et al. 1988; National Geographic Society 1987; U.S. EPA 1993o; Whitaker 1995; Burt and Grossenheider 1980; Behler 1995; Smith and Brodie 1982; Tynning 1990; National Geographic Society 1992; Farrand Jr. 1989).



**FIGURE 4-1
 EXAMPLE
 FOREST FOOD WEB**

NOTE: PATHWAYS NOT REPRESENTED
 MATHEMATICALLY IN EQUATIONS

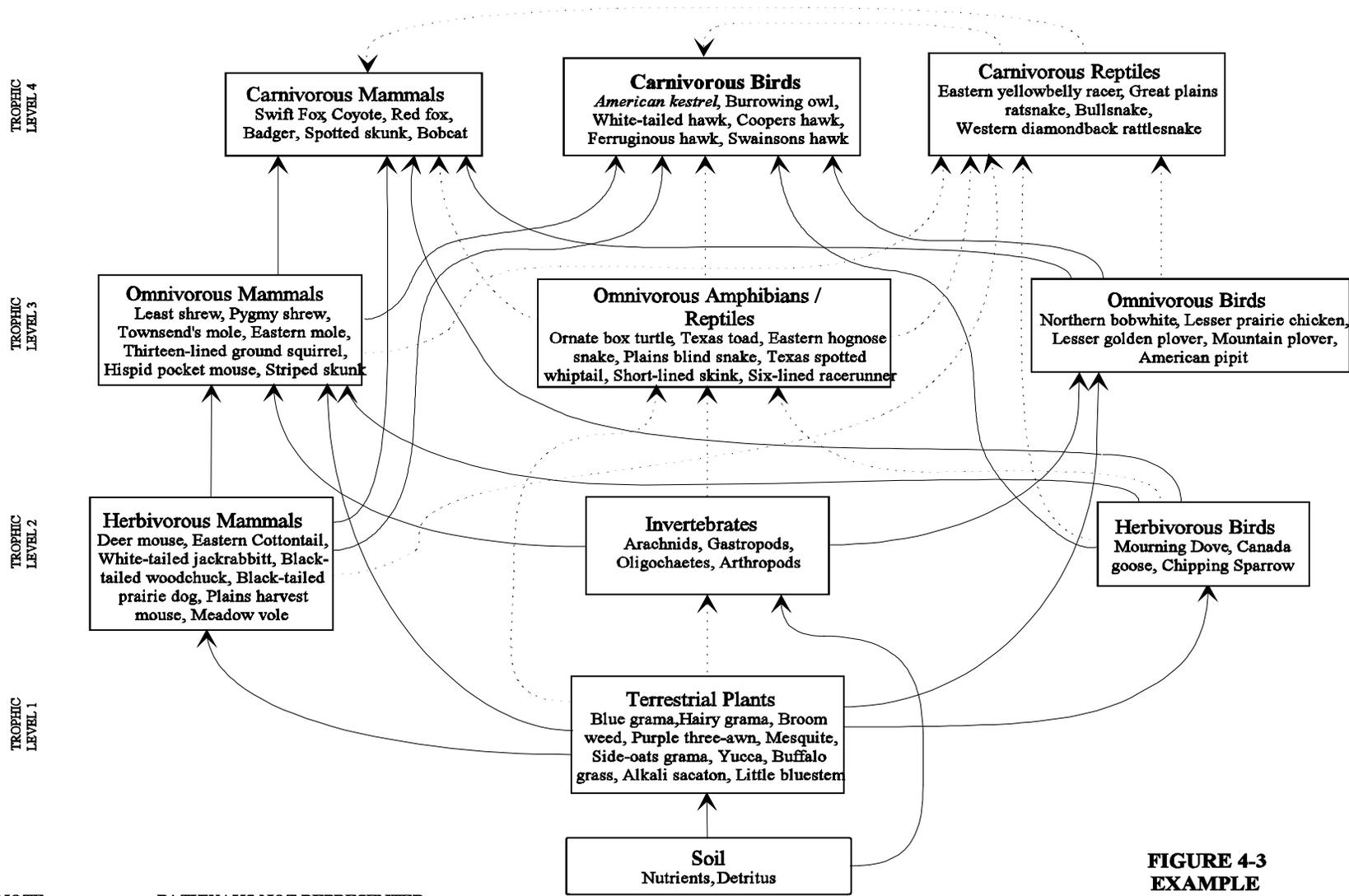
RECEPTORS LISTED IN ITALICS
 ARE MEASUREMENT RECEPTORS



**FIGURE 4-2
 EXAMPLE
 TALLGRASS PRAIRIE FOOD WEB**

NOTE: PATHWAYS NOT REPRESENTED
 MATHEMATICALLY IN EQUATIONS

RECEPTORS LISTED IN ITALICS
 ARE MEASUREMENT RECEPTORS



**FIGURE 4-3
 EXAMPLE
 SHORTGRASS PRAIRIE FOOD WEB**

NOTE: PATHWAYS NOT REPRESENTED
 MATHEMATICALLY IN EQUATIONS

RECEPTORS LISTED IN ITALICS
 ARE MEASUREMENT RECEPTORS

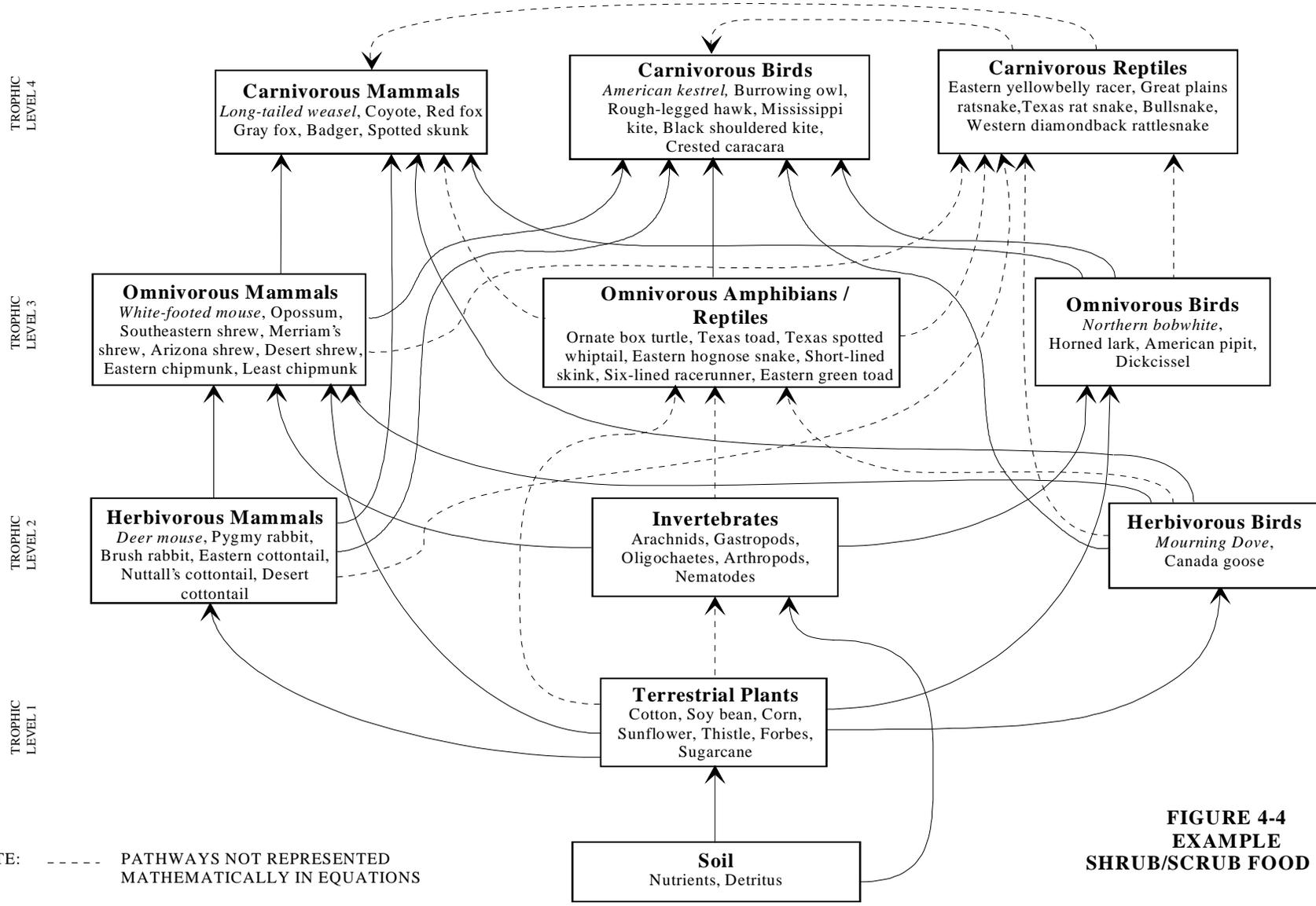
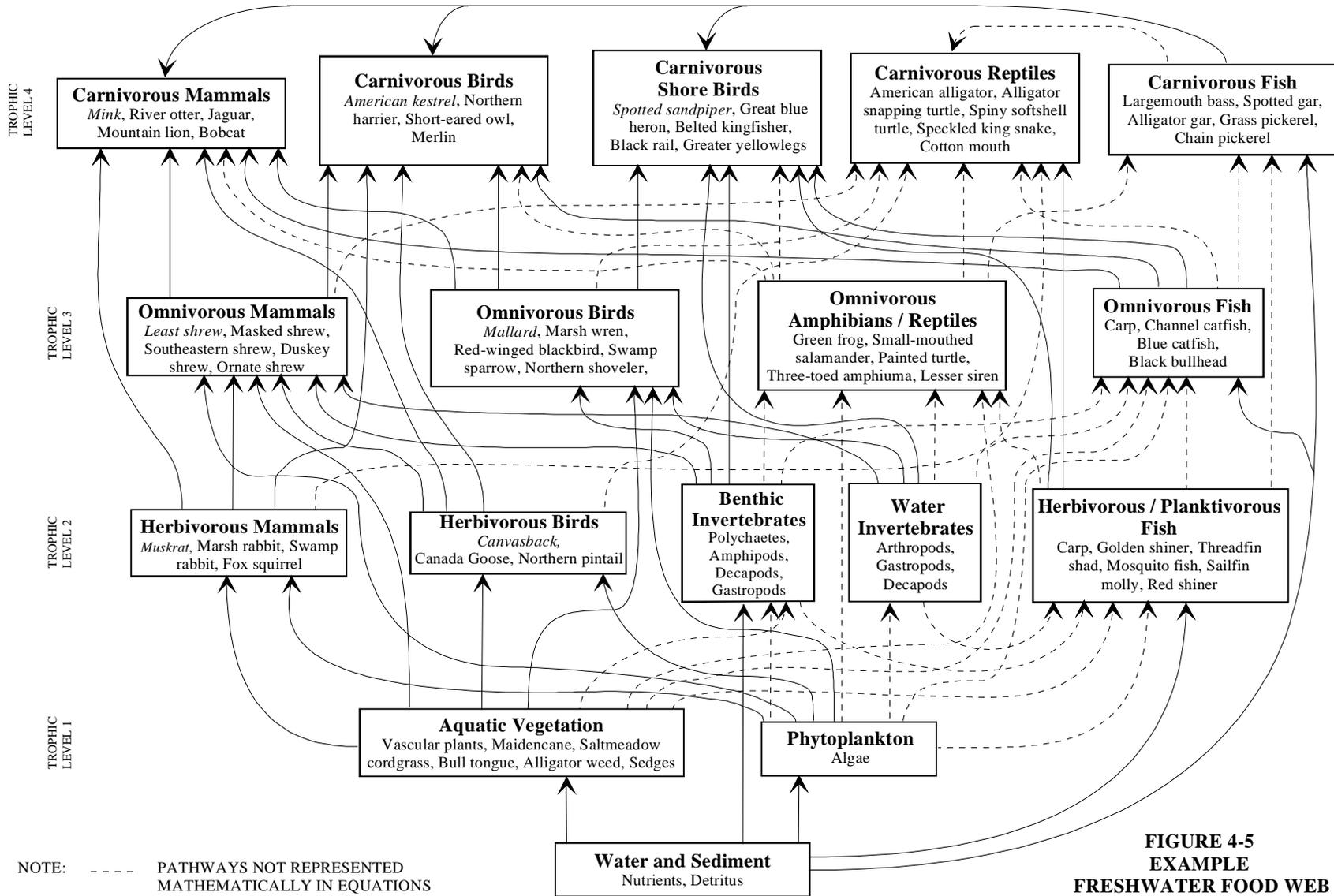


FIGURE 4-4
EXAMPLE
SHRUB/SCRUB FOOD WEB

NOTE: - - - - PATHWAYS NOT REPRESENTED
 MATHEMATICALLY IN EQUATIONS

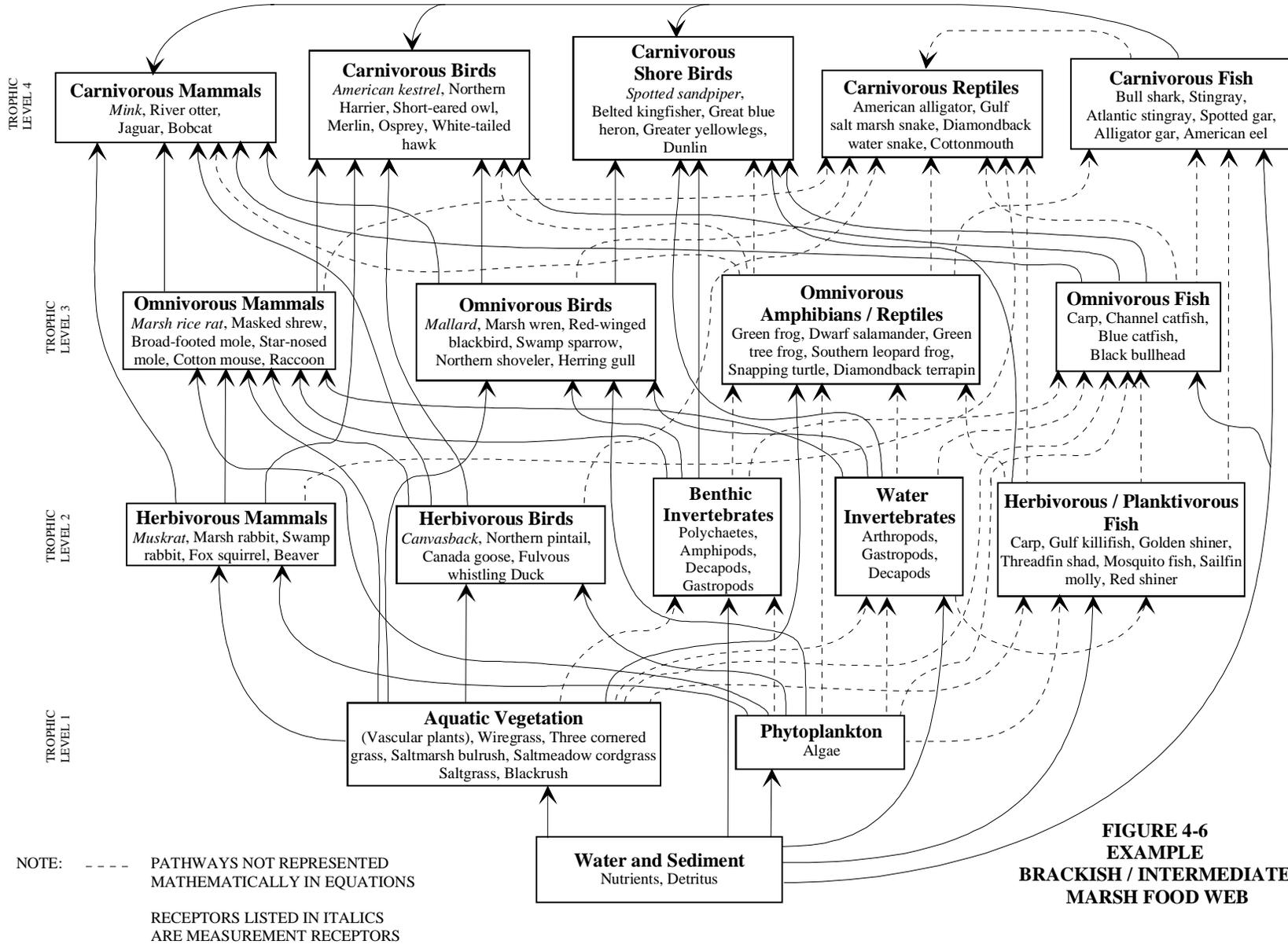
RECEPTORS LISTED IN ITALICS
 ARE MEASUREMENT RECEPTORS



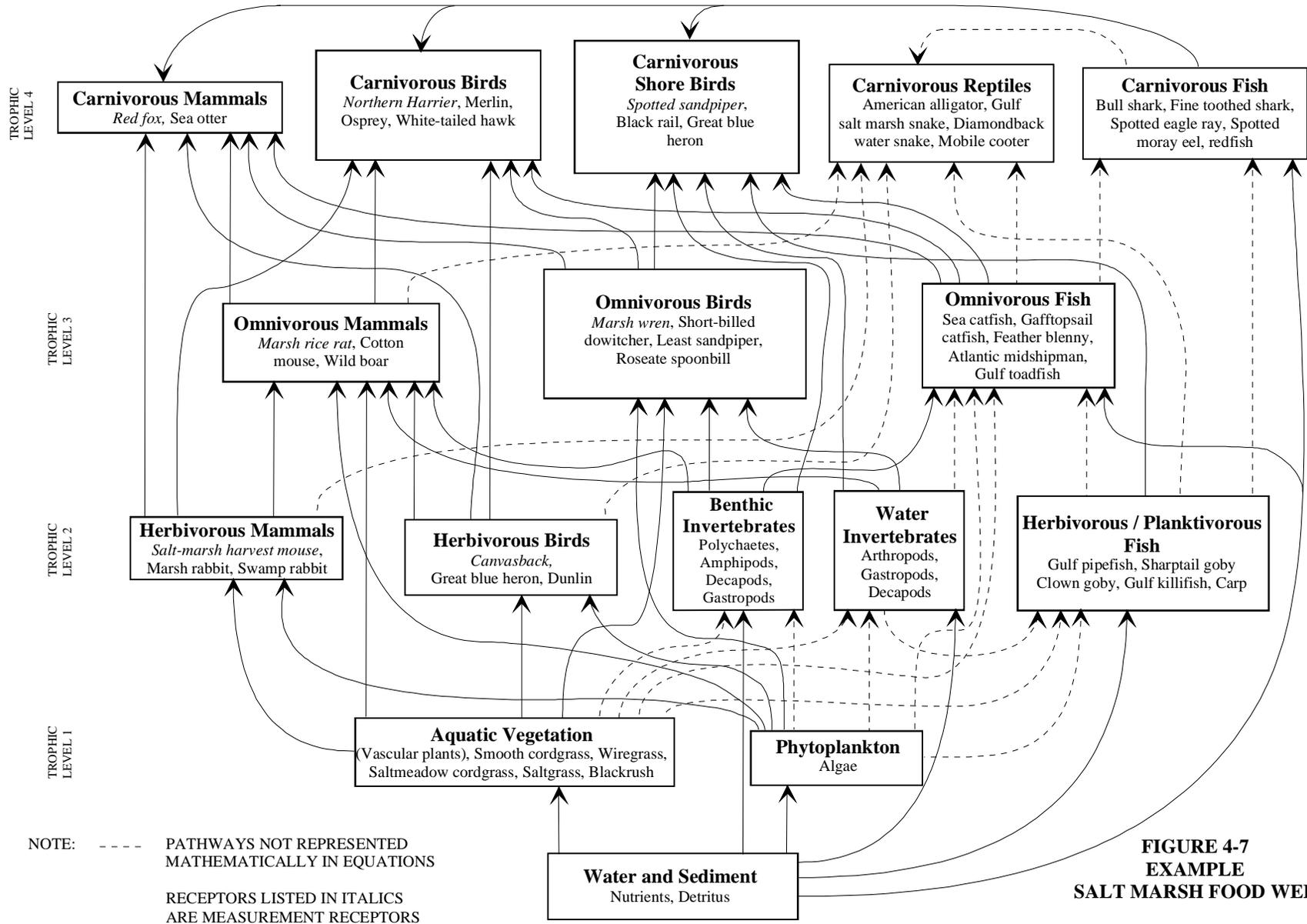
**FIGURE 4-5
 EXAMPLE
 FRESHWATER FOOD WEB**

NOTE: - - - - PATHWAYS NOT REPRESENTED
 MATHEMATICALLY IN EQUATIONS

RECEPTORS LISTED IN ITALICS
 ARE MEASUREMENT RECEPTORS



**FIGURE 4-6
 EXAMPLE
 BRACKISH / INTERMEDIATE
 MARSH FOOD WEB**



**FIGURE 4-7
 EXAMPLE
 SALT MARSH FOOD WEB**

4.3 SELECTING ASSESSMENT ENDPOINTS

An assessment endpoint is an expression of an ecological attribute that is to be protected (U.S. EPA 1997c). A critical ecological attribute of a guild or community is a characteristic that is relevant to ecosystem (food web) structure and function. Protection of the critical ecological attributes of each guild and community is assumed to also ensure the protectiveness of habitat-specific food web structure and function. Therefore, assessment endpoints should be identified specific to each class-specific guild and community within each trophic level of the habitat-specific food web.

Examples of assessment endpoints for guilds include:

- Seed disperser
- Major food source for predator
- Decomposer/detritivore
- Pollinator
- Regulate populations of prey (e.g., forage fish, small rodents)

Examples of assessment endpoints for communities include:

- Diversity or species richness
- Community composition
- Productivity
- Major food source for consumer
- Habitat for wildlife

Descriptions of ecological attributes to be protected (i.e., assessment endpoints) associated with several guilds and communities in a terrestrial ecosystem are provided as examples below.

- Herbaceous plant abundance, habitat, and productivity are attributes to be preserved in a terrestrial ecosystem. As food, herbaceous plants provide an important pathway for energy and nutrient transfer from soil to herbivorous (e.g., rabbit) and omnivorous (e.g., mouse) receptors. Herbaceous plants also provide critically important habitat for small animals.

- Woody plant habitat and productivity are critical attributes to be protected. As food, woody plants provide an important pathway for energy and nutrient transfer from soil to herbivorous and omnivorous vertebrates (e.g., white-tailed deer, yellow-bellied sapsucker). Woody plants also provide critically important habitat for terrestrial wildlife.
- Herbivore productivity is an attribute to be protected in the terrestrial ecosystem because herbivores incorporate energy and nutrients from plants and transfer it to higher trophic levels, such as first- and second-order carnivores (e.g., snakes and owls, respectively). Herbivores also are integral to the success of terrestrial plants, through such attributes as seed dispersal.
- Omnivore productivity is an attribute to be protected in the terrestrial ecosystem because omnivores incorporate energy and nutrients from lower trophic levels and transfer it to higher levels, such as first- and second-order carnivores.
- First-order carnivore productivity is an attribute to be protected in the terrestrial ecosystem because these carnivores provide food to other carnivores (both first- and second-order), omnivores, scavengers, and microbial decomposers. They also affect the abundance, reproduction, and recruitment of lower trophic level receptors, such as vertebrate herbivores and omnivores, through predation.
- Second-order carnivore productivity is an attribute to be protected in the terrestrial ecosystem because carnivores affect the abundance, reproduction, and recruitment of species in lower trophic levels in the food web.
- Soil invertebrate productivity and function as a decomposer are attributes to be preserved in a terrestrial ecosystem, because they provide a mechanism for the physical breakdown of detritus for microbial decomposition, which is a vital function. Soil invertebrates also function as a major food source for omnivorous birds.

Selection of assessment endpoints represents a scientific and management decision point. Since risk characterization, and subsequently final risk management decisions, are dependent on the selection of assessment endpoints, they should be developed with input from risk managers and other stakeholders.

Table 4-1 lists the assessment endpoints for guilds and communities in the three aquatic and four terrestrial example habitat-specific food webs.

TABLE 4-1
ASSESSMENT ENDPOINTS FOR GUILDS AND COMMUNITIES IN EXAMPLE FOOD WEBS

Representative Receptors		Example Critical Ecological Attributes
Aquatic Receptors		
Aquatic Plants	Phytoplankton, Vascular plants	Primary producers convert light energy into biomass, and are the first link in aquatic food chains supporting higher trophic level aquatic consumers and wildlife. Rooted vegetation also provides habitat and bottom stability.
Water Invertebrates	Crustaceans, Rotifers, Amphipods	Aquatic invertebrates are an important food source for many higher trophic level consumers. Zooplankton regulate phytoplankton populations, and are a critical link in energy transfer to higher trophic levels in aquatic ecosystems.
Herbivorous / Planktivorous Fish	Carp, Gulf killifish, Threadfin shad, Molly, Golden Shiner, Goby, Mosquito Fish, Red Shiner	Herbivorous/Planktivorous Fish are an important prey species for higher trophic level predators in the aquatic and terrestrial ecosystems, and provide a critical link for energy transfer from primary producers to higher trophic level consumers. They generally comprise the majority of tissue biomass in aquatic ecosystems, and provide an important role to the ecosystem through regulating algae and plankton biomass.
Omnivorous Fish	Carp, Channel catfish, Gafftopsail fish, Atlantic midshipman, Feather blenny, Gulf toad fish, Bluecat, Bullhead	Omnivorous fish are an important prey item for higher trophic level predators. Through predation, they may also regulate population levels in lower trophic level fish and invertebrates.
Carnivorous Fish	Largemouth bass, Spotted gar, Bull shark, Redfish, Grass pickerel, Alligator gar, Chain pickerel, American eel, Atlantic stingray, Spotted moray eel, Fine toothed shark	Carnivorous fish provide an important function for the aquatic environment by regulating lower trophic populations through predation. They are also an important prey item for many top level mammal and bird carnivores.
Sediment Receptors		
Sediment Invertebrates	Oligochaetes, Pelecypods, Amphipods, Decapods, Polychaetes, Gastropods	Sediment invertebrates are an important food source for many higher trophic level predators. They also provide an important role as decomposers/detritivores in nutrient cycling.
Soil Receptors		
Terrestrial Plants	Vascular plants, Grasses, Forbs, Lichens	Primary producers provide a critical food source and are the first link in the terrestrial food chain for higher trophic level consumers. In addition, vegetation provides critical habitat for wildlife.

TABLE 4-1 (Continued)
ASSESSMENT ENDPOINTS FOR GUILDS AND COMMUNITIES IN EXAMPLE FOOD WEBS

Representative Receptors		Example Critical Ecological Attributes
Soil Invertebrates	Nematodes, Gastropods, Oligochaetes, Arthropods	Soil invertebrates provide an important food source for many higher trophic level species. As decomposers/detritivores they play a critical role in nutrient cycling. They also aid in soil aeration and infiltration by increasing macro, and micro porosity.
Upper Trophic Level Avian and Mammalian Wildlife		
Herbivorous Mammals	Deer mouse, Nutria, Eastern cottontail, Prairie vole, Fox squirrel, Grey squirrel, Swamp rabbit, Eastern wood rat, White-tailed deer, Fulvous harvest mouse, Black-tailed jackrabbit, Hispid cotton rat, Hispid pocket mouse, Black-tailed prairie dog,	Herbivorous mammals are an important prey item for many higher trophic level predators. They provide an important link for energy transfer between primary producers and higher trophic level consumers. In addition, these organisms generally comprise the majority of the terrestrial tissue biomass, and are important in seed dispersal and pollination for many plant species.
Herbivorous Birds	Mourning dove, Canada goose, Chipping sparrow, Northern pintail	Herbivorous birds are an important prey item for many higher trophic level predators. They are important in seed dispersal for many plants in both terrestrial and aquatic ecosystems. Aquatic herbivorous birds may also play an important role in egg dispersion for fish and invertebrate species.
Omnivorous Mammals	Least shrew, Raccoon, Muskrat, Marsh rice rat, Wild boar, Cotton mouse, Eastern spotted skunk, Coyote, Nine-banded armadillo, Virginia opossum, Elliot's short-tailed shrew, Striped skunk, Golden mouse, Seminole bat.	Omnivorous mammals are an important prey item for higher trophic level predators, and influence lower trophic level populations through predation. They play an important role in seed dispersal for many types of terrestrial vegetation and aquatic plants.
Omnivorous Birds	American robin, Northern bobwhite, Marsh wren, Carolina wren, Swamp sparrow, Yellow warbler, Lesser prairie chicken, Roadrunner, Mallard, Least sandpiper, Red cockaded wood pecker, Roseate spoonbill, Greater prairie chicken, Scissor-tailed flycatcher, Sandhill crane, Dickcissel, Canada goose, Red-winged blackbird, Hooded merganser, Northern shovler.	Omnivorous birds are an important prey item for higher trophic level predators. They play an important role in seed dispersal and pollination for many types of terrestrial vegetation and aquatic plants. In addition, aquatic species provide egg dispersal for some fish and invertebrate species.
Omnivorous Amphibians and Reptiles	Ornate box turtle, Green frog, Texas toad, Eastern hognose snake, Plains blind snake, Small-mouthed salamander, Diamondback terrapin, Short-lined skink, Six-lined racerunner, Eastern green toad, Marbled salamander, Slender glass lizard,	Omnivorous amphibians and reptiles provide an important food source for predators. They also provide seed dispersal for many plants and regulate lower trophic level populations through predation.

TABLE 4-1 (Continued)
ASSESSMENT ENDPOINTS FOR GUILDS AND COMMUNITIES IN EXAMPLE FOOD WEBS

Representative Receptors		Example Critical Ecological Attributes
Carnivorous Mammals	Grey fox, Swift fox, River otter, Bobcat, Mountain lion, Long-tailed weasel, American badger, Red fox, American mink, Red wolf	Carnivorous mammals provide an important functional role to the environment by regulating lower trophic level prey populations.
Carnivorous Birds	Red-tailed hawk, American kestrel, Marsh hawk, Great-horned owl, Barn owl, Burrowing owl, White-tailed hawk, Ferruginous hawk, Swansons hawk, Golden eagle, Mississippi kite, Prairie hawk, Merlin	Carnivorous Birds provide an important functional role to the environment by regulating lower trophic level prey populations.
Carnivorous Shore Birds	Great blue heron, Belted kingfisher, Spotted sandpiper, Black rail, Greater yellowlegs, Dunlin,	Carnivorous Shore Birds provide an important functional role to the environment by regulating lower trophic level prey populations, and influencing species composition in terrestrial and aquatic ecosystems. They also provide egg dispersal for some fish and aquatic invertebrates.
Carnivorous Reptiles	Eastern yellowbelly racer, Eastern coral snake, Texas rat snake, Western Diamondback rattlesnake, American alligator, Bullsnake, Alligator snapping turtle, Cotton mouth, Speckled king snake, Spiny softshell turtle, Gulf salt marsh snake,	Carnivorous Reptiles provide an important functional role to the environment by regulating lower trophic level prey and are an important prey item for other upper trophic level predators.

4.4 IDENTIFYING MEASUREMENT RECEPTORS TO EVALUATE MEASURES OF EFFECT

Measures of effect are measures used to evaluate “the response of the assessment endpoint when exposed to a stressor (formerly measurement endpoints)” (U.S. EPA 1997c). Measures of exposure are measures of how exposure may be occurring, including how a stressor may co-occur with the assessment endpoint (U.S. EPA 1997c). Measures of effect, in conjunction with measures of exposure, are used to make inferences about potential changes in the assessment endpoint (U.S. EPA 1997c).

Measures of effect are selected as: (1) toxicity values developed and/or adopted by federal or state agencies (e.g., ambient water quality criteria [AWQC], NOAA effects range low [ERL] values) for protection of media-specific communities, or (2) receptor-specific chronic no-observed-adverse-effects-levels (NOAELs) or their equivalent for ecologically relevant endpoints (see Chapter 5) for this screening assessment. Measures of exposure are selected as the COPC concentrations in media or dose (e.g., ingestion of contaminated media and/or tissue) to which exposure occurs, and determined as discussed in Chapter 5.

The evaluation of the measure of effect to the assessment endpoint (see Chapters 5 and 6) requires identification of a measurement receptor representative of the assessment endpoint. The measurement receptor is selected based on consideration of factors such as (1) ecological relevance, (2) exposure potential, (3) sensitivity, (4) social or economic importance, and (5) availability of natural history information.

A measurement receptor, specific to each guild, may be selected as a species, population, community, or assemblage of communities. For communities (i.e., soil, surface water, sediment), the community or assemblage of communities is selected as the measurement receptor, and no specific species is selected. For guilds, individual species are selected as measurement receptors. Sections 4.4.1 and 4.4.2 discuss measurement receptors for communities and for mammals and birds, respectively. Section 4.4.3 discusses selection of measurement receptors for the example food webs (see Section 4.2).

4.4.1 Measurement Receptors for Communities

For communities (i.e., soil, surface water, sediment), the community or assemblage of communities are selected as the measurement receptors, and no specific species are selected. Therefore, it is inferred that critical ecological attributes of these communities are not adversely affected if a COPC concentration in that respective media does not exceed the toxicity benchmark specific for that community (see Section 5.1). Representative measurement receptors for soil, surface water, sediment communities include:

- Soil—Soil invertebrate community and terrestrial plant community
- Surface Water—Phytoplankton community, water invertebrate community
- Sediment—Benthic invertebrate community

4.4.2 Measurement Receptor for Guilds

A measurement receptor should be selected for each class-specific guild to model (1) COPC dose ingested, and (2) whole body COPC concentration in prey eaten by predators. The selected measurement receptor should be representative of other species in the guild, with respect to the guild's feeding niche in the ecosystem. The risk assessment should demonstrate that using the measurement receptor ensures that risk to other species in the guild is not underestimated. The following factors should be evaluated to identify a measurement receptor:

- **Ecological Relevance** - Highly relevant receptors provide an important functional or structural aspect in the ecosystem. Attributes of highly relevant receptors typically fall under the categories of food, habitat, production, seed dispersal, pollination, and decomposition. Critical attributes include those that affect or determine the function or survival of a population. For example, a sustainable population of forage fish might be critical to the sustainability of a population of carnivorous game fish.
- **Exposure Potential** - Receptors with high exposure potentials are those that, due to their metabolism, feeding habits, location, or reproductive strategy, tend to have higher potentials for exposure than other receptors. For example, the metabolic rates of small receptors are generally higher than those for large animals. This results in a higher ingestion per body weight (i.e., increased exposure potential).
- **Sensitivity** - Highly susceptible receptors include those with low tolerances to a COPC as well as receptors with enhanced COPC susceptibility due to other concomitant stressors that may not be related to a COPC, such as reduced habitat availability. For example,

raptorial birds are highly sensitive to the effects of chlorinated pesticides that bioaccumulate through the food chain.

- ***Social or Economic Importance*** - An assessment endpoint may also be based on socially or economically important receptors. These types of receptors include species valued for economic importance such as crayfish and game fish. For these receptors, critical attributes include those that affect survival, production, and fecundity characteristics. For example, swamp crayfish are highly sensitive to some heavy metals through adverse effects to behavioral characteristics.
- ***Availability of Natural History Information*** - Natural history information is essential to quantitatively evaluate risk to measurement receptors. If this information such as body weight, food, water, soil, and sediment ingestion rates is unavailable for the desired measurement receptor, a surrogate species should be selected. Uncertainty associated with using a surrogate species should be discussed.

It should be noted that more than one measurement receptor can be selected per assessment endpoint.

Also, although each of these factors should be evaluated when selecting the measurement receptor, at least one of the measurement receptors selected to represent a class-specific guild should have the highest exposure potential (i.e., ingestion rate on a body weight basis). This ensures that risk to other species in the guild is not underestimated.

U.S. EPA's *Wildlife Exposure Factors Handbook* (U.S. EPA 1993o) is an example of an excellent source of dietary and other natural history information. However, it is recommended that receptor information obtained from it or any source be verified and documented during measurement receptor identification.

4.4.3 Measurement Receptors for Example Food Webs

Consistent with the discussions presented in Section 4.4, measurement receptors were selected for the example food webs presented in Section 4.2. Receptor information documented in *Wildlife Exposure Factors Handbook* (U.S. EPA 1993o) and available literature was evaluated to determine suitable measurement receptors for each class-specific guild represented in the example food webs.

Ecological relevance, exposure potential, sensitivity, social or economic importance and availability of natural history information (see Section 4.4.3) were evaluated to identify measurement receptors for the example food webs. It should be noted that since these measurement receptors have been provided as examples to facilitate understanding of the previously described selection process, not every assessment

endpoint has been represented (e.g., TL3 omnivorous fish, TL3 omnivorous amphibians and reptiles, and TL4 carnivorous fish) as may be expected for a complete ecological risk assessment at a site. Discussions on each of the example measurement receptors follow.

American Kestrel

The American kestrel (*Falco sparverius*), or sparrow hawk, was selected as the measurement receptor for the carnivorous bird guild in the example shortgrass prairie, tallgrass prairie, shrub/scrub, freshwater wetland, and brackish/intermediate marsh food webs based on the following information:

- The kestrel is important in regulating small mammal populations through predation. Predators of the kestrel include larger raptors such as red-tailed hawks, golden eagles, and great horned owls.
- The kestrel's prey include a variety of invertebrates such as worms, spiders, scorpions, beetles, and other large insects, as well as an assortment of small to medium-sized birds and mammals. Winter home ranges vary from a few hectares to hundreds of hectares, depending on the amount of available prey in the area.
- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

American Robin

The American robin (*Turdus migratorius*) was selected as the measurement receptor for the omnivorous bird guild in the example forest food web based on the following information:

- The robin serves an important function in seed dispersion for many fruit species, making it a valuable component of the ecosystem.
- Habitats include forests, wetlands, swamps, and habitat edge where forested areas are broken with agricultural and range land. The robin forages on snails and other soil invertebrates, seeds, and fruit.
- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

Canvasback

The Canvasback (*Aythya valisineria*) was selected as the measurement receptor for the herbivorous bird guild in all three example aquatic food webs based on the following information:

- The Canvasback provides a valuable functional role to aquatic habitats by dispersing seeds for aquatic vegetation.
- The Canvasback is the largest member of the Pochards (bay ducks) and is common throughout North America. They breed from Alaska to Nebraska, and in intermountain marshes of Washington, Oregon, and northern California. Their diet consists of aquatic vegetation, and small invertebrates, which they obtain by digging in sediments. Although the canvasback consumes aquatic invertebrates during certain times of the year, in winter when they are present along coastal regions, a large portion of their diet is aquatic vegetation and was therefore selected to represent the herbivorous bird guild.
- Since natural history information on the canvasback was scarce, the Lesser Scaup (*Aythya affinis*), for which natural history information is readily available, was selected as a surrogate receptor.

Deer Mouse

The deer mouse (*Peromyscus maniculatus*) was selected as the measurement receptor for the herbivorous mammal guild in the example forest, shortgrass prairie, tallgrass prairie, shrub/scrub food webs based on the following information:

- The deer mouse is preyed upon by owls, snakes, and small carnivorous mammals, making it a very important prey item. This animal also plays an important ecological role in seed and fruit dispersion for many types of vegetation. In addition, their burrowing activities influence soil composition and aeration.
- The deer mouse is almost strictly nocturnal and feeds chiefly on seeds, fruits, bark, roots, and herbage. Due to its burrowing and dietary habits, there is a high potential for direct and indirect exposure. The home range for a deer mouse is rarely over 100 meters, and it spends most of its day in an underground burrow.
- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

Least Shrew

The least shrew (*Cryptotis parva*) was selected as the measurement receptor for the omnivorous mammal guild in the example tallgrass prairie, shortgrass prairie, and freshwater wetland food webs based on the following information:

- Because of the shrews abundance and high population density, they make up a large portion of the diet of owls, hawks, and snakes.
- Shrews feed on snails, insects, sow bugs, and other small invertebrates. The home range size is on average 0.39 hectares. Their diet of invertebrates and their burrowing behavior result in a high potential of direct and indirect exposure to contaminants.
- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

Long-tailed Weasel

The long-tailed weasel (*Mistily Renata*) was selected as the measurement receptor for the carnivorous mammal guild in the example forest, tallgrass prairie and shrub/scrub food webs based on the following information:

- The long-tailed weasel is important in regulating small mammal populations through predation. Predators of the weasel include cats, foxes, snakes, and large raptors such as hawks and owls.
- Habitats are varied and include forested, brushy, open areas including farm lands preferably near water, where they prey on rabbits, chipmunks, shrews, mice, rats and birds.
- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

Mallard Duck

The mallard duck (*Anas platyrhynchos*) was chosen as the measurement receptor for the omnivorous bird guild for the freshwater wetland and brackish/intermediate marsh food webs based on the following information:

- The mallard serves as a valuable component in aquatic food webs providing dispersion of seeds for aquatic vegetation, and due to their role in the nutrient cycle of wetlands. In addition, the mallard is a major prey item for carnivorous mammals, birds, and snakes.
- The mallard is present in a diverse amount of aquatic habitats throughout the United States. Although their diet is considered omnivorous, 90 percent of their diet may be plant material at some times of the year. Mallards are surface feeders that will often filter through soft mud and sediment searching for food items.
- The mallard is very important game species, representing approximately one-third of all waterfowl harvested.
- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

Marsh Rice Rat

The marsh rice rat (*Oryzomys palustris*) was selected as the measurement receptor for the omnivorous mammal guild in the example brackish/intermediate and salt marsh food web based on the following information:

- The marsh rice rat inhabits marsh and wetland areas where it feeds on crabs, insects, fruits, snails, and aquatic plants. The rice rat plays an important role in seed dispersal and is a major food item for many predators including raptors, cats, weasels and snakes.
- The marsh rice rat has a high potential for exposure due to their aquatic diet and direct contact with media.
- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

Marsh Wren

The marsh wren (*Cistothorus palustris*) was selected as the measurement receptor for the omnivorous bird guild in the example salt marsh food web based on the following information:

- The marsh wren consumes large numbers of aquatic insects thus regulating their populations, which make it a valuable component of the ecosystem. Main predators are snakes and turtles which prey heavily upon the eggs.
- The marsh wren is common throughout the United States, inhabiting freshwater, brackish, and saltwater marshes. Its diet consists mainly of aquatic invertebrates, although snails

and spiders may be taken. In addition, its diet of aquatic invertebrates makes it susceptible to accumulation and toxicity of bioaccumulative chemicals

- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

Mink

The mink (*Mustela vison*) was selected as the measurement receptor for the carnivorous mammal guild in the example brackish/intermediate marsh and freshwater food webs based on the following information:

- As a high trophic level predator, the mink provides an important component to the ecosystem by influencing the population dynamics of their prey. Their main predators include fox, bobcats, and great-horned owls.
- The mink is one of the most abundant carnivorous mammals in North America, inhabiting rivers, creeks, lakes, and marshes. They are distributed throughout North America, except in extreme north Canada, Mexico, and areas of the southwestern United States. Mink are predominantly nocturnal hunters, although they are sometimes active during the day. They are opportunistic feeders and will consume whatever prey is most abundant including: small mammals, fish, birds, reptiles, amphibians, crustaceans, and insects.
- They have been shown to be sensitive to PCBs and similar chemicals, and have a high potential for exposure due to their aquatic diet and direct contact with the media.
- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

Mourning Dove

The Mourning Dove (*Zenaida macroura*) was selected as the measurement receptor for the herbivorous bird guild in all four example terrestrial food webs based on the following information:

- The dove plays an important functional role in seed dispersion for many grasses and forbs. Doves provide an important prey item for many higher trophic level omnivores and carnivores. Predators of the mourning dove include falcons, hawks, fox, and snakes.
- The mourning dove inhabits open woodlands, forests, prairies, and croplands. It feeds mostly on seeds, which comprise 99 percent of its diet. It may ingest insignificant amounts of animal matter and green forage incidently.
- Mourning doves have a high potential for exposure through ingestion of inorganic contaminants.

- Mourning doves are an important game species, contributing significantly as a food and economic resource.
- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

Muskrat

The muskrat (*Ondrata zibethicus*) was selected as the measurement receptor for the herbivorous mammal guild in the example freshwater wetland and brackish/intermediate marsh food webs based on the following information:

- The muskrat is important to the overall structure of the aquatic ecosystem by regulating aquatic vegetation diversity and biomass, resulting in stream bank stability and increased habitat diversity for aquatic organisms including fish. It was also chosen as the measurement receptor based on its value to the ecosystem including its large population densities and importance as a prey species (e.g., prey for hawks, mink, otters, owls, red fox, snapping turtles, alligators, and water snakes).
- The muskrat spends a large part of its time in the water, and is common in fresh, brackish, and saltwater habitats. It has relatively high food and water ingestion rates, and a diet that consists mainly of aquatic vegetation, clams, crayfish, frogs, and small fish.
- Due to the large numbers, the muskrat plays an important economic role in the fur industry, and as a food item for some cultures.
- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

Northern Bobwhite

The northern bobwhite (*Colinus virginianus*) was selected as the measurement receptor for the omnivorous bird guild in the example shortgrass prairie and shrub/scrub food webs based on the following information:

- The bobwhite plays an important role in seed dispersion for many plant species, and is an important prey item for snakes, and other small mammals. If habitat conditions permit, their numbers will increase rapidly, providing an additional food source for many predators. They also are valuable in controlling insect populations during certain times of the year.
- The bobwhite's diet consists mainly of seeds and invertebrates, although in the winter green vegetation can dominate its diet. During breeding season, the bobwhite's home

range may encompass several hectares, including areas for foraging, cover, and a nest site. In non-breeding season, the bobwhite's home range can be as large as 16 hectares. It has a high potential for exposure through ingestion and dermal contact with soil during dust bathing.

- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

Northern Harrier

The Northern harrier (*Circus cyaneus*), also called the Marsh hawk was selected as the measurement receptor for carnivorous bird guild in the example salt marsh food web based on the following information:

- The marsh hawk plays an important role in the ecosystem in regulating small mammal populations through predation.
- The marsh hawks diet consists of small mammals, birds, and occasionally snakes, frogs, and insects. Their habitat preferences include wetlands or marshes.
- In addition, the marsh hawk has demonstrated sensitivity to pesticides, which bioaccumulate through food chains.
- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

Red Fox

The red fox (*Vulpes vulpes*) was selected as the measurement receptor for the carnivorous mammal guild in the example salt marsh food web based on the following information:

- Red fox have a high potential for exposure due to bioaccumulation through the food chain, and are a valuable component to ecosystem structure by regulating the abundance, reproduction, distribution, and recruitment of lower trophic level prey.
- Although omnivorous in dietary habits, the majority of the diet consists of cottontail rabbits, voles, mice, birds, and other small mammals. This animal was chosen because of its status as a top carnivore and its widespread distribution in the United States, inhabiting chaparral, wooded and brushy areas, coastal areas and rim rock country.
- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

Red-tailed Hawk

The red-tailed hawk (*Buteo jamaicensis*) was selected as the measurement receptor in the carnivorous bird guild in the example forest food web based on the following information:

- The red-tailed hawks position as a high trophic level predator makes them a valuable component of terrestrial food webs through their regulation of populations of lower trophic level prey species.
- The red-tailed hawk is widely distributed in the United States among a diverse number of habitat types ranging from woodlands to pastures. Its diet includes small mammals (such as mice, shrews, voles, rabbits, and squirrels), birds, lizards, snakes, and large insects. It is an opportunistic feeder, preying on whatever species is most abundant. Red-tailed hawks are territorial throughout the year, and have home ranges that can be over 1,500 hectares.
- Red-tailed hawks have shown sensitivity to many chemicals which disrupt reproduction or egg development.
- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

Salt Marsh Harvest Mouse

The salt marsh harvest mouse (*Reithrodontomys raviventris*) was selected as the measurement receptor for the herbivorous mammal guild in the example salt marsh food web based on the following information:

- The salt marsh harvest mouse plays an important functional role in aquatic habitats through seed dispersal for aquatic vegetation.
- Predators include owls, snakes, and many mammals including weasels, fox, and cats.
- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

Short-tailed Shrew

The short-tailed shrew (*Blarina brevicauda*) was selected as the measurement receptor for the omnivorous mammal guild in the example forest food web based on the following information:

- The short-tailed shrews value as a prey species for many high level predators is very important to the health of an ecosystem. They also play an important role in soil recycling and aeration, through tunnel excavation.

- The short-tailed shrew is one of the most common mammals in the United States. It is a small insectivorous mammal that represents secondary consumers (insectivores) present in terrestrial ecosystems. Their diet of invertebrates such as earthworms and their burrowing behavior result in a high potential of direct and indirect exposure to contaminants. It has a very high metabolism rate which requires almost constant feeding. The most common habitats are wooded and wet areas in the drier parts of the range.
- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

Spotted Sandpiper

The spotted sandpiper (*Actitis macularia*) was selected as the measurement receptor for the carnivorous shore bird guild in the example freshwater wetland, brackish/intermediate, and salt marsh food webs based on the following information:

- The spotted sandpiper inhabits a wide variety of habits usually associated with water or marsh.
- Spotted sandpipers have a high potential for exposure through ingestion of aquatic insects, worms, fish, crustaceans, mollusks, and carrion.
- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

Swift Fox

The Swift Fox (*Vulpes velox*) was selected as the measurement receptor for the carnivorous mammal guild in the example shortgrass prairie food web based on the following information:

- The swift fox fills an important functional role by regulating the population dynamics of many prey species.
- The swift fox is mainly nocturnal and its diet consists of small mammals, insects, birds, lizards, and amphibians. It spends most of its days in a den, emerging at night to hunt. Their home range extends several kilometers.
- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

Western Meadow Lark

The western meadow lark (*Sturnella neglecta*) was selected as the measurement receptor for the omnivorous bird guild in the example tallgrass prairie food web based on the following information:

- The western meadow lark serves an important function in seed dispersion for many forb and grass species, making it a valuable component of the ecosystem.
- Habitats include grassland, savanna, pasture, and cultivated fields. The western meadow lark forages on spiders, sowbugs, snails, and grass and forb seeds.
- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

White-footed Mouse

The white-footed mouse (*Peromyscus polionotus*) was selected as the measurement receptor for the omnivorous mammal guild in the example shrub/scrub food web based on the following information:

- The white-footed mouse plays an important role in seed dispersal and provide an important food source for raptors, snakes and other mammals including cats, weasels and fox.
- The white-footed mouse feeds on nuts, seeds, fruits, beetles, caterpillars, and other insects. Due to its burrowing and dietary habits, there is a high potential for direct and indirect exposure.
- The availability of natural history information (e.g., home range, ingestion rates, body weights) also support selection as a measurement receptor.

