Potential Risks of Labeled Atrazine Uses to the Topeka Shiner (Notropis topeka)

Pesticide Effects Determination

August 31, 2007

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Environmental Fate and Effects Division
Office of Pesticide Programs
Washington, D.C. 20460

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1. Executive Summary

1.1. Purpose of Assessment

The purpose of this assessment is to make an "effects determination" by evaluating the potential direct and indirect effects of the herbicide atrazine on the survival, growth, and reproduction of the Topeka shiner (*Notropis topeka*), a small minnow that inhabits the upper Great plains of the United States. In addition, this assessment evaluates the potential for atrazine use to result in the destruction or adverse modification of critical habitat designated by the U.S. Fish and Wildlife Service (USFWS, 2004: 70 FR No. 57, 15239 – 15245).

1.2. Assessment Procedures

This assessment was completed in accordance with the U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) *Endangered Species Consultation Handbook* (USFWS/NMFS, 1998) and is consistent with procedures and methodology outlined in the Agency's Overview Document (U.S. EPA, 2004).

Acute and chronic risk quotients (RQs) were compared to the Agency's Levels of Concern (LOCs) to identify instances where atrazine use within the action area has the potential to adversely affect the Topeka shiner or adversely modify designated critical habitat. When RQs for a particular type of effect are below LOCs, the pesticide is considered to have "no effect" on the species and its designated critical habitat. Where RQs exceed LOCs, a potential to cause adverse effects or habitat modification was identified, leading to a conclusion of "may affect". If atrazine use "may affect" the Topeka shiner, and/or may cause adverse modification to designated critical habitat, the best available additional information was considered to refine the potential for exposure and effects, and distinguish actions that are NLAA (not likely to adversely affect) from those that are LAA (likely to adversely affect).

Atrazine degradates were not assessed because degradates have been shown to be orders of magnitude less toxic than atrazine to aquatic organisms and are presumed to be less toxic than atrazine to terrestrial plants (Section 4). Therefore, potential risks from exposure to atrazine's degradates were not quantified in this assessment.

1.3. Atrazine Uses and Locations Assessed

All potential uses of atrazine within the action area were evaluated as part of this assessment. Atrazine is used throughout the United States on a number of agricultural commodities (primarily corn and sorghum) and on non-agricultural sites (including residential uses, forestry, and turf). It is typically applied as a spray by air or ground, but residential use products include a granular formulation. Although the action area is likely to encompass a large area of the United States, given its extensive use, the scope of this assessment limits consideration of the overall action area to those portions that are applicable to the protection of the Topeka shiner. As such, the action area was defined by the current range of the species and designated critical habitat.

1.4. Endpoints Assessed

The assessment endpoints include direct toxic effects on survival, reproduction, and growth of individuals, as well as indirect effects, such as reduction of the food source and/or modification of habitat.

Federally designated critical habitat has been established for the Topeka shiner. Primary constituent elements (PCEs), as described in U.S. FWS (2004) were used to evaluate whether atrazine has the potential to adversely modify designated critical habitat. PCEs evaluated as part of this assessment include the following:

- Water quality related to potential effects of atrazine (for example, potential effects on water quality resulting from reduction in aquatic or terrestrial plants);
- Presence of instream aquatic cover; and
- An adequate food base that allows for unimpaired growth, reproduction, and survival of all life stages.

1.5. Summary of Conclusions

Effects determinations for direct/indirect effects to the Topeka shiner and the critical habitat impact analysis, by assessment endpoint, are presented in Tables 1.1 and 1.2. In summary, a likely to adversely affect (LAA) determination was made for direct chronic effects to the Topeka shiner and for indirect effects resulting from potential effects to aquatic and terrestrial plants. This assessment considers an LAA determination to mean that effects to a single individual Topeka shiner could occur that are not “insignificant” or “discountable” as defined in Section 5.2.

Table 1.1 Effects Determination Summary for the Topeka shiner by Assessment Endpoint

Assessment Endpoint	Effects Determination	Basis for Conclusion
1. Survival, growth, and reproduction of individuals via direct acute or chronic effects	**Acute effects** No Effect – all uses	RQs across all uses did not exceed any acute LOC based on the most sensitive available freshwater fish LC50. See Section 5.2.1.1
	Chronic effects [a] **LAA** Corn (all regions); Fallow (west region) **No effect** All other uses	RQs based on the maximum labeled application rates were up to 1.3 to 1.6 for corn and fallow uses, respectively, based on 60-day EECs estimated using PRZM/EXAMS. The LOAEC in the most sensitive life-cycle study was 120 ug/L based on a 7% reduction in length and 16% reduction in weight in brook trout. 60-Day EECs were lower than the fish life-cycle LOAEC; therefore, at the 60-day EECs, the magnitude of potential effect to the Topeka shiner would be expected to be lower than effects observed at the LOAEC if the Topeka shiner is equally sensitive to atrazine as brook trout. Life-cycle studies were also conducted in bluegill sunfish (NOAEC = 95 ug/L, MRID 00024377) and fathead minnows (NOAEC <150 ug/L, MRID 42547103; NOAEC = 210 ug/L, MRID 00024377). Only EECs for the fallow use exceed the NOAEC in bluegill sunfish, and no EECs exceed the NOAEC for fathead minnows. Chronic RQs based on EECs that incorporate typical use rates for corn or fallow uses (0.6 – 0.9 lbs a.i./acre) would not exceed the LOC of 1.0. See Section 5.2.1.2.
2. Indirect effects to individuals via potential effects to aquatic plants (food and primary productivity)	**LAA** Corn, sorghum, fallow, and forestry uses (all regions) **NLAA** All other uses	Community level effects thresholds are exceeded based on PRZM/EXAMS 14- to 90-day EECs. See Section 5.2.2.3. NLAA conclusion was based on significance of effect as defined in Section 5.2.
3. Indirect effects to individuals via direct effects to aquatic and terrestrial invertebrates as food items	**NLAA** for all uses	NLAA conclusion was based on significance of effect as defined in Section 5.2. The potential magnitude of effect to aquatic and terrestrial invertebrate food items is expected to be low such that measurable effects to the Topeka shiner are not expected. See Section 5.2.2.1.
4. Indirect effects to individuals via direct effects to other fish needed for spawning habitat (*e.g.*, sunfish) and diet.	**NLAA** for all uses	NLAA conclusion was based on significance of effect as defined in Section 5.2. No acute LOCs were exceeded for fish. The chronic LOC was exceeded for the most sensitive species tested (brook trout); however, the potential magnitude of effect to fish is expected to be low such that measurable indirect effects to the Topeka shiner are not expected. See Section 5.2.2.4.
4. Indirect effects to individuals via reduction of terrestrial vegetation (i.e., riparian habitat) required to maintain acceptable water quality and habitat	Direct effects to sensitive riparian vegetation: **LAA**	Riparian areas within the Great Plains are expected to be predominantly grasslands. Data presented in Section 4 of this assessment indicates that grassy and herbaceous vegetation may be sensitive to atrazine at estimated exposure levels. Therefore, riparian areas that are predominantly grassy/herbaceous vegetation and that receive runoff or spraydrift from atrazine use sites may be affected. Until data on specific land management practices and sensitivity of riparian vegetation adjacent to Topeka shiner habitat is

Assessment Endpoint	Effects Determination	Basis for Conclusion
		available, potential effects to riparian vegetation as indicated by terrestrial plant LOC exceedance, is presumed to potentially adversely affect the Topeka shiner and its designated critical habitat. See Section 5.2.2.5.

[a] Topeka shiner habitats include side pools of low-order streams with low/negligible flow rates. PRZM/EXAMS was considered appropriate to represent both short-term and long-term potential exposures in these types of habitats. However, there is uncertainty in this assumption as discussed in Section 3 of this assessment.

Table 1.2 Effects Determination Summary for the Critical Habitat Impact Analysis

PCE[a]	Conclusions	Basis for Conclusions (see Section 5.3. for additional information)
Streams and side-channel pools with water quality necessary for unimpaired behavior, growth, and viability of all life stages. The water quality components can vary seasonally and include--temperature (1 to 30[deg]Centigrade), total suspended solids (0 to 2000 ppm), conductivity (100 to 800 mhos), dissolved oxygen (4 ppm or greater), pH (7.0 to 9.0), and other chemical characteristics	LAA	As described in Table 1.1, RQs were exceeded for aquatic and terrestrial plants (Sections 5.2.2.3 and 5.2.2.5), which suggest that effects to aquatic and sensitive riparian plants could occur and potentially result in alteration of suspended solid levels, oxygen levels, and other chemical characteristics.
Living areas for juvenile Topeka shiners with water velocities less than 0.5 meters/second (approx. 20 inches/second) with depths less than 0.25 meters (approx. 10 inches) and moderate amounts of instream aquatic cover, such as woody debris, overhanging terrestrial vegetation, and aquatic plants	LAA	As described in Table 1.1, RQs were exceeded for aquatic and terrestrial plants (Sections 5.2.2.3 and 5.2.2.5), which suggests that "amounts of instream aquatic cover, such as woody debris, overhanging terrestrial vegetation, and aquatic plants" could be affected. Woody plant species are not expected to be adversely affected by atrazine at EECs presented in this assessment; however, other overhanging vegetation and aquatic plants could potentially be impacted in areas that are in close proximity to atrazine use.
Sand, gravel, cobble, and silt substrates with amounts of fine sediment and substrate embeddedness that allows for nest building and maintenance of nests and eggs by native *Lepomis* sunfishes (green sunfish, orangespotted sunfish, longear sunfish) and Topeka shiner as necessary for reproduction, unimpaired behavior, growth, and viability of all life stages	LAA	Atrazine may affect riparian vegetation of the Topeka shiner's habitats that are in close proximity to atrazine use sites. However, sedimentation / siltation in a stream may depend on numerous factors, and determining whether atrazine use is expected to result in an overall increase in sediment/silt levels in a habitat is difficult. Nonetheless, sensitive riparian areas exposed to atrazine could be adversely impacted (MRID 42041403), which could indirectly affect the Topeka shiner. Until further analysis is performed on specific land management practices in areas surrounding Topeka shiner habitats, terrestrial plant LOC exceedance is presumed to indicate potential adverse indirect effects the Topeka shiner and its designated critical habitat.
An adequate terrestrial, semiaquatic, and aquatic invertebrate food base that allows for unimpaired growth, reproduction, and survival of all life stages	NLAA	As indicated in Table 1.1, atrazine is not likely to adversely affect the Topeka shiner via reduction in aquatic and terrestrial invertebrates as food supply.

a Other PCEs (described in Section 2.4) were not evaluated because there was no perceived direct link between those PCEs and processes that could be affected by atrazine use.

When evaluating the significance of this risk assessment's direct/indirect and adverse habitat modification effects determinations, it is important to note that pesticide exposures and predicted risks to the species and its resources (i.e., food and habitat) are not expected to be uniform across the action area. In fact, given the assumptions of drift and downstream transport (i.e., attenuation with distance), pesticide exposure and associated risks to the species and its resources are expected to decrease with increasing distance away from the treated field or site of application. Evaluation of the implication of this non-uniform distribution of risk to the species would require information and assessment techniques that are not currently available. Examples of such information and methodology required for this type of analysis would include the following:

- Enhanced information on the density and distribution of the Topeka shiner within its current range and/or designated critical habitat within the action area. This information would allow for quantitative extrapolation of the present risk assessment's predictions of individual effects to the proportion of the population extant within geographical areas where those effects are predicted. Furthermore, such population information would allow for a more comprehensive evaluation of the significance of potential resource impairment to individuals of the species.

- Enhanced information on land use and land management practices within watersheds inhabited by the Topeka shiner. Terrestrial plant LOC exceedances were used to indicate whether atrazine is likely to adversely modify riparian areas adjacent to the Topeka shiner's habitat and subsequently affect water quality characteristics. However, the potential for atrazine to affect water quality characteristics (e.g., sediment levels, temperature, etc.) depends on a number of factors (discussed in Section 5.2) including riparian area characteristics, soil conservation practices, and land use adjacent to the riparian area of Topeka shiner habitat.

2. Problem Formulation

2.1 Purpose

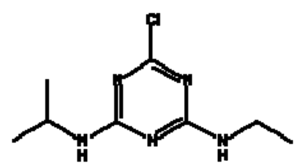
The purpose of this endangered species risk assessment is to evaluate the potential direct and indirect effects resulting from the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) registered uses of the herbicide atrazine (6-chloro-N-ethyl-N-isopropyl-1, 3, 5-triazine-2, 4-diamine) on the survival, growth, and/or reproduction of Topeka shiner individuals. In addition, this assessment evaluates whether FIFRA regulatory actions regarding atrazine use can be expected to result in the destruction or adverse modification of critical habitat. Critical habitat has been designated by the USFWS for the Topeka shiner (USFWS, 2004: 70 FR No. 57, 15239 – 15245) and is further described in Section 2.4. This ecological risk assessment is a component of the settlement for the *Natural Resources Defense Council, Civ. No: 03-CV-02444 RDB (filed March 28, 2006).*

2.2. Stressor Identification, Source, and Distribution in the Environment

2.2.1. Identification

Atrazine is an herbicide that inhibits photosynthesis by associating with a protein complex of the Photosystem II in chloroplast photosynthetic membranes, which stops electron flow in Photosystem II (Schulz et al., 1990). The result is an inhibition in the transfer of electrons that in turn inhibits the formation and release of oxygen. Chemical identity and physical characteristics of atrazine are summarized in Table 2.1 below.

Table 2.1. Summary of Chemical Identification and Selected Physicochemical Properties of Atrazine

Chemical Property	Value
Chemical Name	Atrazine
CAS RN	1912-24-9
PC Code	080803
Chemical Structure	
Molecular Weight	215.7 g/mole
Vapor Pressure	3×10^{-7} mm Hg at 20 deg C
Solubility in Water	33 mg/l

2.2.2. Stressor Source and Distribution

2.2.2.1. Use Characterization

Atrazine is widely used to control broadleaf and many other weeds, primarily in corn, sorghum, and sugarcane (U.S. EPA, 2003a). As a selective herbicide, atrazine is applied pre-emergence and post-emergence**.**

Atrazine is used on a variety of terrestrial food crops, non-food crops, forests, residential/industrial uses, golf course turf, recreational areas and rights-of-way. Atrazine yields season-long weed control in corn, sorghum and certain other crops. The major atrazine uses include: corn (83 percent of total ai produced per year - primarily applied pre-emergence), sorghum (11 percent of total ai produced), sugarcane (4 percent of total ai produced) and others (2 percent ai produced). Atrazine formulations include dry flowable, flowable liquid, liquid, water dispersible granule, wettable powder and coated fertilizer granule. The maximum registered use rate for atrazine is 4 lbs ai/acre; and 4 lbs ai/acre is the maximum, single application rate for the following uses: sugarcane, forest trees (softwoods, conifers), forest plantings, guava, macadamia nuts, ornamental sod (turf farms), and ornamental and/or shade trees.

Assessment of the use information is critical to the development of appropriate modeling scenarios and evaluation of the appropriate model inputs (Kaul and Jones, 2006). Information on the agricultural uses of atrazine in the states comprising the regionalized exposure assessment approach (see Section 3.2.2 for more details) for the Topeka shiner (Missouri, Iowa, Kansas, Nebraska, South Dakota, Minnesota, and North Dakota), as defined in Section 2.6 of this assessment, was gathered (Kaul and Jones, 2006). Use information within the action area is utilized to determine which uses should be modeled, while the application methods, intervals, and timing are critical model inputs. No state or county level usage information is available on non-agricultural uses (residential, rights-of-way, forestry, or turf) of atrazine.

Agricultural cropland (presented as cultivated cropland and hay/pasture) and atrazine use relative to the Topeka shiner's action area are depicted in Figures 2.1 and 2.2, respectively. Non-agricultural uses associated with urban/suburban areas (residential, turf, and rights-of-way) are also likely to be co-located with the listed species habitat ranges. The landuse mapping presented in Figure 2.1 provides a breakout of aggregated turf uses (residential, recreational, and golf course). No consistent coverage is available for rights- of-way uses. Given the potential use pattern shown in Figure 2.1, atrazine could be used in close proximity to the species range.

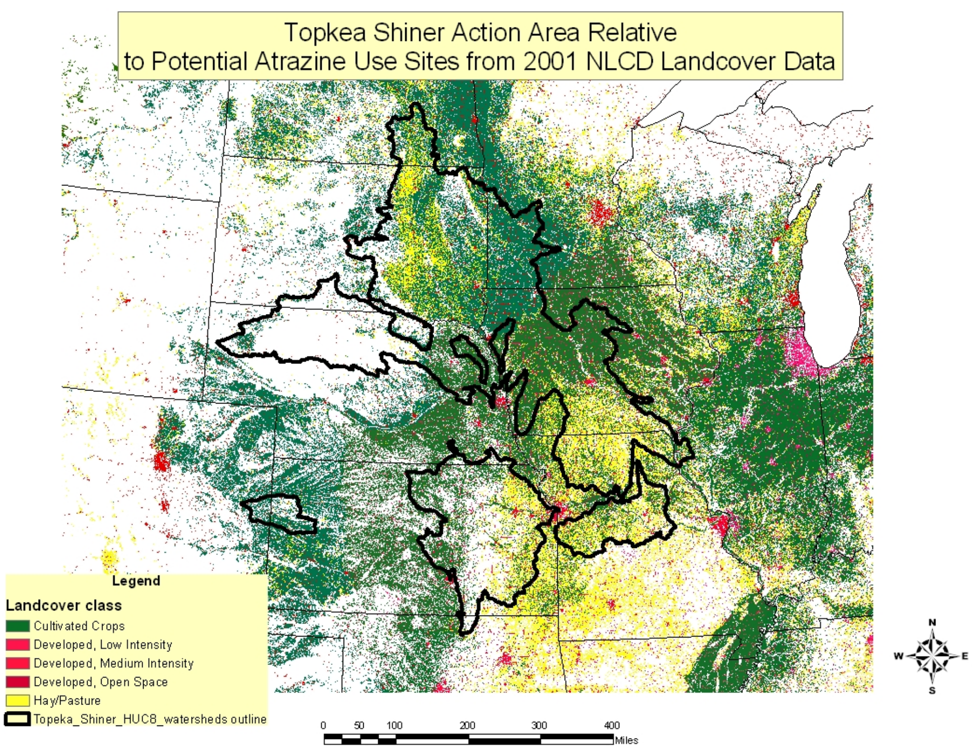


Figure 2.1 Agricultural Cropland Relative to Topeka shiner Action Area

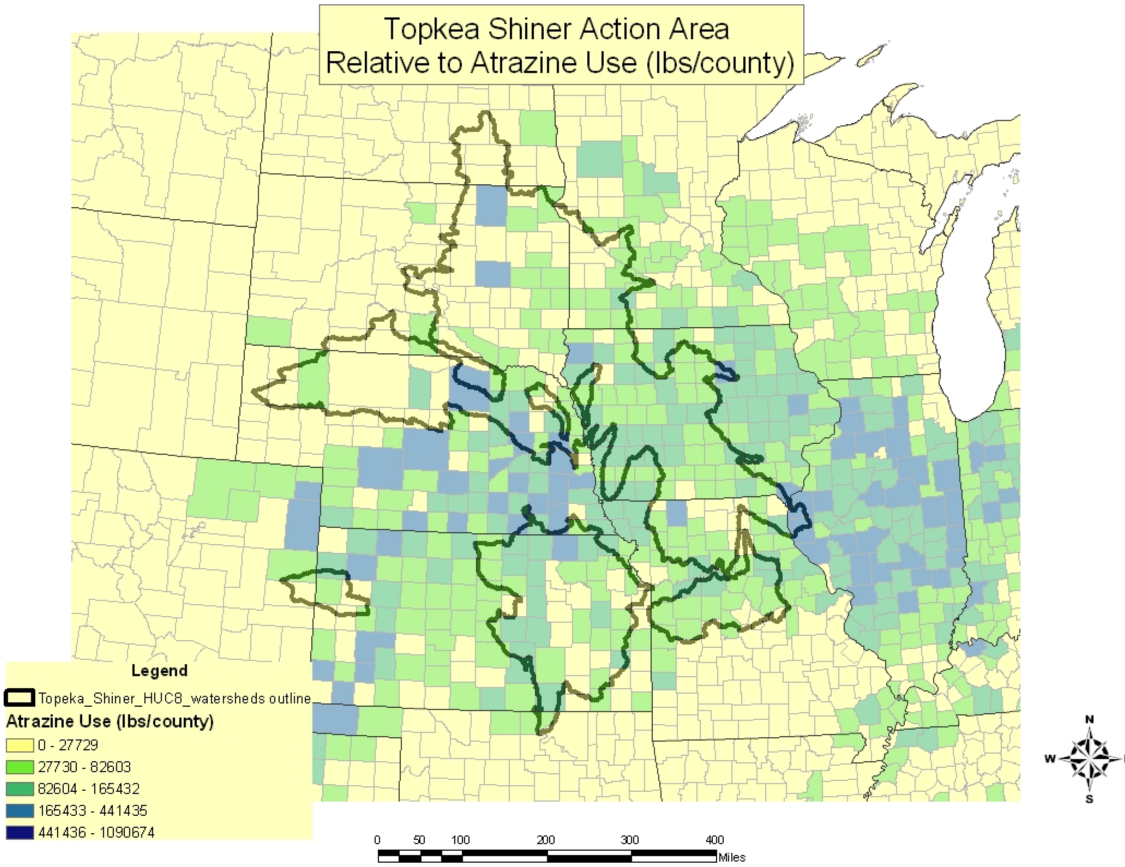


Figure 2.2 Atrazine Use Relative to Action Area

All agricultural use information for atrazine within the action area was considered in order to determine which uses occur within the action area for the Topeka shiner (discussed further in Section 2.5). As noted above, information is not available for non-agricultural uses; therefore, they are presumed to occur within the action area and are included in this assessment. Agricultural uses of atrazine within the action area include corn, sweet corn, sorghum, and fallow land. Specifically, county level data for the areas within and immediately surrounding the action area were used (Kaul and Jones, 2006). County level estimates of atrazine use were derived using state level estimates from USDA-NASS and data obtained from Doane (www.doane.com; the full dataset is not provided due to its proprietary nature). State level data from 1998 to 2004 were averaged together and extrapolated down to the county level based on apportioned county level crop acreage data from the 2002 USDA Agriculture of Census (AgCensus).

Of the six principal states making up the regionalized approach for conducting the exposure assessment (several states far removed from the species location were not evaluated for use information because it is assumed that use in states in close proximity will have the greatest impact on the species), atrazine was used between 1998 and 2004 on average approximately 27,600,000 total pounds across all use sites (Table 2.2). The state with the highest use was Iowa with approximately 8,200,000 lbs used and the least use was reported in North Dakota. Atrazine was used on corn, sorghum, sweet corn, and fallow land. The crop with the greatest use was corn with approximately 23,000,000 lbs. All other crops averaged considerably less use than corn. Of the remaining crops, only sorghum was used at amounts at or above 1,000,000 lbs.

In general, this information suggests that the central portion of the action area is located on the fringe of the highest atrazine use area, but within the areas where atrazine use is moderate (Nebraska and Iowa). In general, atrazine use decreases in intensity further south and north of this area, with the lowest use in the northern Great Plains (North Dakota) and southern Missouri. The atrazine use pattern within the action area is graphically presented in Figure 2.2. It should be noted, however, that information on non-agricultural use of atrazine is not available and, therefore, was not included in Figure 2.2.

Typical use information for atrazine is summarized in Table 2.2. For all uses, the typical application rate and number of applications are fairly consistent across all states and all uses. For all uses, the average application rate is 0.7 lbs per acre, while the average number of applications is 1.1. For corn, the average application rate is 0.9 lbs per acre, and the number of applications is 1.2.

Table 2.2 Summary of Typical Atrazine Use Information Collected between 1998 and 2004 for all States in the Topeka shiner Action Area

Crop	Total Pounds by Crop	Average Number of Applications by Crop	Average Application Rate (lbs/acre) by Crop
corn	23,100,000	1.2	0.9
Fallow/hay/pasture	273,000	1.0	0.9
sorghum	4,480,000	1.1	1.2
sweet corn	2000	1.4	0.6
Wheat [a]	85,000	1.1	0.6

[a] atrazine is used on wheat fields to control fallow conditions and is not applied directly to wheat

2.2.2.2. Environmental Fate and Transport Assessment

Environmental fate and transport characteristics were described in detail in previous assessments (U.S. EPA 2003a; U.S. EPA 2006a,c,d,e). A summary of information pertinent to this assessment is provided below; previous assessments may be referenced for additional information.

In general, atrazine is expected to be mobile and persistent in the environment. The main route of dissipation is microbial degradation under aerobic conditions. Because of its persistence and mobility, atrazine is expected to reach surface and ground water. This is confirmed by the widespread detections of atrazine in surface water and ground water.

Atrazine is persistent in soil, with a half-life (time until 50% of the parent atrazine remains) exceeding 1 year under some conditions (Armstrong et al., 1967). Atrazine can also enter or contact nearby non-target plants, soil, and surface water via spray drift during application. Atrazine is applied directly to target plants during foliar application, but pre-plant and pre-emergent applications are generally more prevalent. A summary of atrazine's degradation half-lives are reported in Table 2.3 below.

Table 2.3. Summary of Environmental Dissipation and Degradation Half-Lives

Dissipation / Degradation Route	Half-Life
Photolysis	Stable
Hydrolysis	Stable
Aerobic Soil Metabolism	3 – 4 Months
Henry's Law constant	2.6×10^{-9} atm-m^3/mol
Terrestrial field dissipation	13 – 261 days
Anaerobic aquatic metabolism	Total system: 608 days Water: 578 days Sediment: 330 days

a The Log Kow (2.7) and Freundlich Kads (<1 to <3) may somewhat offset the low Henry's Law constant value, thereby possibly resulting in some volatilization from foliage, and its relatively low adsorption characteristics indicate that atrazine may undergo substantial washoff from foliage.

A number of degradates of atrazine were detected in laboratory and field environmental fate studies. Deethyl-atrazine (DEA) and deisopropyl-atrazine (DIA) were detected in all studies, and hydroxy-atrazine (HA) and diaminochloro-atrazine (DACT) were detected in all but one of the listed studies. Deethylhydoxy-atrazine (DEHA) and deisopropylhydroxy-atrazine (DIHA) were also detected in one of the aerobic studies. Typically, these degradates have been detected predominantly in groundwater at concentrations less than, or equal to, those of atrazine. In surface water, the degradates are typically found at concentrations below that of atrazine.

All of the chloro-triazine and hydroxy-triazine degradates detected in the laboratory metabolism studies were present at less than the 10% of applied that the Agency uses to classify degradates as "major degradates" (U.S. EPA, 2004). However, several degradates were detected at percentages greater than 10% in soil and aqueous photolysis studies (see Section 3). Insufficient data are available to allow for an estimate of half-lives for these degradates. The dealkylated degradates are more mobile than parent atrazine, while HA is less mobile than atrazine and the dealkylated degradates. As discussed in Section 2.8, degradates are not specifically evaluated as part of this assessment.

2.3. Assessed Species

General information, including a summary of habitat requirements, designated critical habitat, food habits, and reproduction data relevant to this endangered species risk assessment is provided below. Additional information can be found in the following references: KS DWP, 2004; Dahle, 2001; U.S. FWS, 1998, and SD DGFPWD, 2003 and at the following url: http://mountain-prairie.fws.gov/species/fish/shiner/.

The Topeka shiner is a small minnow (<3 inches long) found in small low-order prairie streams with cool temperatures and good water quality, typically with clean gravel, rock, or sand bottoms (U.S. FWS, 1998; KS DWP, 2004; Dahle, 2001). The Topeka shiner is pelagic (prefers open waters) and prefers mid-water and surface areas of streams. It is seldom found in choppy waters. It may be found in streams that are small enough to stop flowing during dry summer months and are, therefore, fed by seepage of groundwater (U.S. FWS, 1998).

Topeka shiners spawn from late May to mid August. Spawning occurs over gravel nests of sunfish (U.S. FWS, 1998). It is unknown if the Topeka shiner utilizes other silt-free substrates for spawning or if it relies solely on sunfish nests for spawning.

Dietary behavior of the Topeka shiner is described as a generalist omnivore. Its diet consists primarily of aquatic insects (particularly midges) in addition to plant material and zooplankton (SDDGFP, 2003). Dahle (2001) studied the stomach content of a population of Topeka shiners in Minnesota and reported that 75% of their diet consisted of microcrustaceans and insects, and the remaining 25% consisted of vascular plant matter, algae, sand/ detritus, and various fish and other invertebrates.

Topeka shiners are currently found in a small fraction of its historical range including fragmented populations primarily in scattered tributaries of the Missouri and Mississippi rivers and the Flint Hills region of Kansas (http://www.fws.gov/mountain-prairie/species/fish/shiner/facts.htm). The species is known to occur in the following watersheds (http://www.epa.gov/fedrgstr/EPA-SPECIES/1998/December/Day-15/e33100.htm) (see Figure 2.3):

> Kansas: Kansas River Basin (Smoky Hill, Big Blue, and Lower Kansas watersheds); Arkansas River Basin (Neosho watershed)
>
> Missouri: Missouri River Basin (Missouri, Grand, Lamine, Chariton, and Des Moines watersheds)
>
> Nebraska: Elkhorn and Loup watersheds
>
> Iowa: Des Moines, Raccoon, Boone, Big Sioux, and Rock watersheds
>
> South Dakota: Big Sioux, Vermillion, and James watersheds
>
> Minnesota: Big Sioux and Rock watersheds

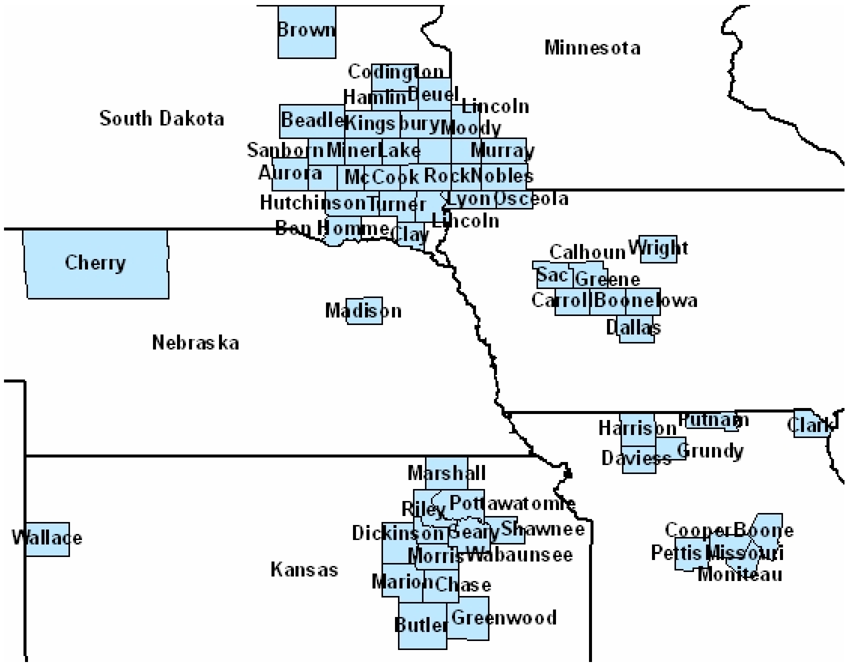


Figure 2.3. Current Known Locations (County Level) of the Topeka Shiner. County level data was obtained from U.S. FWS (2007)

2.4. Designated Critical Habitat

Effective August 26, 2004, the USFWS designated critical habitat for the Topeka shiner (USFWS, 2005: FR Vol. 69 No. 143 pp. 44735 – 44770; revised in FR Vol. 70 No. 57 pp. 15239 – 15245). Critical habitat has been designated in Iowa, Minnesota, and Nebraska. A total of 83 stream segments and 836 stream miles are included in the critical habitat. Most of the critical habitat is in Minnesota (57 stream segments and 605 stream miles) followed by Iowa (25 stream segments; 225 stream miles), then Nebraska (1 stream segment; 6 stream miles). Maps of designated critical habitat locations are in Appendix F.

'Critical habitat' is defined in the ESA as the geographic area occupied by the species at the time of the listing where the physical and biological features necessary for the conservation of the species exist, and there is a need for special management to protect the listed species. Critical habitat may also include specific areas outside the geographic area occupied by the species at the time it is listed in accordance with provisions of Section 3(5)(A) of the ESA, upon determination that such areas are essential for conservation of the species. Critical habitat receives protection under Section 7 of the ESA through prohibition against destruction or adverse modification of critical habitat with regard to actions carried out, funded, or authorized by a Federal Agency. Section 7 requires consultation on Federal actions that are likely to result in the destruction or adverse modification of critical habitat.

To be included in a critical habitat designation, the habitat must first be 'essential to the conservation of the species.' Critical habitat designations identify, to the extent known using the best scientific and commercial data available, habitat areas that provide essential life cycle needs of the species (i.e., areas on which the PCEs are found, as defined in 50 CFR 414.12(b)).

The designated critical habitat areas are considered to have the PCEs that justify critical habitat designation. Activities that may destroy or adversely modify critical habitat are those that alter the PCEs and jeopardize the continued existence of the species. Evaluation of actions related to use of atrazine that may alter the PCEs of the Topeka shiner's critical habitat form the basis of the critical habitat impact analysis. The primary constituent elements for the Topeka shiner consist of the following:

1. Streams most often with permanent flow, but that can become intermittent during dry periods;

2. Side-channel pools and oxbows either seasonally connected to a stream or maintained by groundwater inputs, at a surface elevation equal to or lower than the bankfull discharge stream elevation. The bankfull discharge is the flow at which water begins leaving the channel and flowing into the floodplain; this level is generally attained every 1 to 2 years. Bankfull discharge, while a function of the size of the stream, is a fairly constant feature related to the formation, maintenance, and dimensions of the stream channel;

3. Streams and side-channel pools with water quality necessary for unimpaired behavior, growth, and viability of all life stages. The water quality components can vary seasonally and include--temperature (1 to 30[deg]Centigrade), total suspended solids (0 to 2000 ppm), conductivity (100 to 800 mhos), dissolved oxygen (4 ppm or greater), pH (7.0 to 9.0), and other chemical characteristics;

4. Living and spawning areas for adult Topeka shiner with pools or runs with water velocities less than 0.5 meters/second (approx. 20 inches/second) and depths ranging from 0.1 to 2.0 meters (approximately 4 to 80 inches);

5. Living areas for juvenile Topeka shiners with water velocities less than 0.5 meters/second (approx. 20 inches/second) with depths less than 0.25 meters (approx. 10 inches) and moderate amounts of instream aquatic cover, such as woody debris, overhanging terrestrial vegetation, and aquatic plants;

6. Sand, gravel, cobble, and silt substrates with amounts of fine sediment and substrate embeddedness that allows for nest building and maintenance of nests and eggs by native Lepomis sunfishes (green sunfish, orangespotted sunfish, longear sunfish) and Topeka shiner as necessary for reproduction, unimpaired behavior, growth, and viability of all life stages;

7. An adequate terrestrial, semiaquatic, and aquatic invertebrate food base that allows for unimpaired growth, reproduction, and survival of all life stages;

8. A hydrologic regime capable of forming, maintaining, or restoring the flow periodicity, channel morphology, fish community composition, off-channel habitats, and habitat components described in the other primary constituent elements; and

9. Few or no nonnative predatory or nonnative competitive species present.

The analysis for listed species' direct and indirect effects provides a basis for the evaluation of potential effects to the designated critical habitat. Atrazine effects are limited to those that are linked to biologically-mediated processes. Therefore, the critical habitat analysis for atrazine is limited in a practical sense to those PCEs of the critical habitat that are biological or that can be reasonably linked to biologically mediated processes. Therefore, only PCEs Nos. 3, 5, 6, and 7 above are assessed with respect to potential effects from labeled use of atrazine.

2.5 Action Area

For listed species assessment purposes, the action area is considered to be the area affected by the federal action and not merely the immediate area involved in the action (50 CFR 402.02). It is recognized that the overall action area for the national registration of atrazine uses is likely to encompass considerable portions of the United States based on the large array of both agricultural and non-agricultural uses. Based on the available atrazine monitoring data (discussed further in Section 3.2.5) and the toxicity data for the most sensitive non-vascular aquatic plant, the Agency's LOCs are likely to be exceeded for at least one taxonomic group in many watersheds that are in proximity to or downstream of atrazine use sites. Therefore, the overall action area for atrazine is likely to include many watersheds of the United States that co-occur and/or are in proximity to agricultural and non-agricultural atrazine use sites. However, in order to focus this assessment, the scope limits consideration of the overall action area to those geographic portions that may be applicable to the protection of the Topeka shiner included in this assessment. Based on the available information on potential atrazine use sites, none of the streams and rivers that are within the range of the Topeka shiner could be excluded from the action area. Therefore, the portion of the atrazine action area that is assessed as part of this ESA includes the area within the boundary of the watersheds that drain to known current locations of the Topeka shiner.

The Topeka shiner is known to currently exist in a wide geographic range from the western corn belt in Iowa and Missouri to the central and northern great plains in Kansas, Nebraska, and South Dakota. In general, the species is found in headwater streams (e.g. 1st and 2nd order streams by the Strahler classification system) throughout the region. Historically, the Topeka shiner is presumed to have ranged over a much broader area; however, this assessment focuses on the current range of the species. In many instances, the location information obtained from U.S FWS (1998) and NatureServe (www.natureserve.org, accessed on May 3, 2007) for the Topeka shiner is non-specific and has therefore been identified as county-level occurrence. The Nature Serve information has been augmented with county-level occurrence information provided by USFWS (V. Tabor, USFWS, personal communication, 2007). Both sets of county-level information were compiled, and these data have been used to identify watersheds for inclusion as occupied stream miles. The "action area" is the overall geographic scope where effects may occur. However, because this assessment is limited to evaluation of the potential effects of atrazine use to the Topeka shiner, the action area is defined as the geographic scope where effects may occur, either directly or indirectly, to the Topeka shiner or its designated critical habitat. Therefore, the initial definition of the action area for this species is defined by the watersheds that drain to the known current range and designated critical habitats of the Topeka shiner.

As shown in Figure 2.4, the action area for the Topeka shiner represents a patchwork of watersheds stretching from southeastern North Dakota south through Iowa and into Missouri and Kansas, with isolated portions in western Kansas and Nebraska. Deriving the geographical extent of this portion of the action area is the product of consideration of the types of effects atrazine may be expected to have on the environment, the exposure levels to atrazine that are associated with those effects, and the best available information concerning the use of atrazine and its fate and transport within the area identified in Figure 2.4.

Specifically, a map was created using ESRI's ArcMap GIS. Each of the counties where the Topeka shiner is reportedly located was added to the map using the geographical location information from the Nature Serve website (http://www.natureserve.org/explorer/). Additional locations not included in the Nature Serve data were provided by the USFWS (V. Tabor, USFWS, personal communication, 2007). These locations were assigned to a watershed (HUC8, or USGS hydrologic unit code) and added to the map. The next step in defining the action area was to assume that all waters, within or draining to the identified watersheds, are part of the action area. Areas draining to the specified watersheds were defined by identifying all watersheds located upstream of the known species' locations using the USGS' hydrologic unit code (HUC) watersheds. In this case, USGS cataloging unit watersheds, or HUC8 watersheds, were used to define the extent of the action area.

More detail on the USGS' HUC classification scheme may be found at the following website:

http://water.usgs.gov/GIS/huc.html

The results of the screening level assessment suggest that effects on aquatic plants are possible anywhere within the defined area. In general, available monitoring data for the action area show that peak concentrations are consistent with modeling and are above the Agency's screening levels of concern for indirect effects (see Section 3.2).

Longer term exposures from monitoring data are difficult to assess relative to the Agency's LOCs. Preliminary analysis of the Ecological Monitoring Program data (Appendix B), which is targeted for watersheds most vulnerable to atrazine runoff, suggests that longer-term exposures (e.g. 30-day average concentrations) in selected watersheds exceed the Agency's LOCs. However, these samples are collected from 2^{nd} and 3^{rd} order streams, which may or may not be representative of some flow regimes (e.g. headwater streams with limited flow and side pools of low-order streams) in which the Topeka shiner resides. For monitoring data that is not specifically targeted to highly vulnerable areas (described further in Appendix B), the limited sampling frequency precludes a direct comparison of longer-term exposures (e.g. 30-day average concentrations) with modeling.

In addition, an evaluation of use information was conducted to determine whether any or all of the area described above should be included in the action area. As part of this effort, current labels were reviewed and local use information was evaluated to determine which atrazine uses could potentially be present within the defined area. This data suggest that extensive agricultural uses are present within the defined area and that the existence of non-agricultural uses cannot be precluded. Finally, local land cover data were considered to refine the characterization of potential atrazine use in the areas defined above. The overall conclusion of this analysis was that while certain agricultural uses (e.g., guava, macadamia nuts, sugarcane) could likely be excluded and some non-agricultural uses of atrazine were unlikely, none of the full extent depicted in Figure 2.4 could be excluded from the final action area based on usage and land cover data.

The environmental fate properties of atrazine were also evaluated to determine which routes of transport are likely to have an impact on the listed species included in this assessment. Review of the environmental fate data, as well as physico-chemical properties of atrazine, suggest that transport via runoff and spray drift are likely to be the dominant routes of exposure. In addition, long-range atmospheric transport of pesticides could potentially contribute to atrazine concentrations in the aquatic habitat used by the Topeka shiner. Given the physico-chemical profile for atrazine and data showing that atrazine has been detected in both air and rainfall samples, the potential for long range transport from outside the area defined above cannot be precluded. However, the contribution of atrazine via long-range atmospheric transport is not expected to approach the concentrations predicted by modeling (see Section 3.2).

Atrazine transport away from the site of application by both spray drift and volatilization has been documented. Spray drift is addressed as a localized route of transport from the application site in the exposure assessment. However, quantitative models are currently unavailable to address the longer-range transport of pesticides from application sites. The environmental fate profile of atrazine, coupled with the available monitoring data, suggest that long-range transport of volatilized atrazine is a possible route of exposure to non-target organisms; therefore, the full extent of the action area could be influenced by this route of exposure. However, given the amount of direct use of atrazine within the immediate area surrounding the species, the magnitude of documented exposures in rainfall at or below available surface water and groundwater monitoring data (as well as modeled estimates for surface water), and the lack of modeling tools to predict the impact of long range transport of atrazine, the extent of the action area is defined by the transport processes of runoff and spray drift for the purposes of this assessment.

Based on this analysis, the action area for atrazine as it relates to the Topeka shiner is defined by the entire watersheds depicted in Figure 2.4.

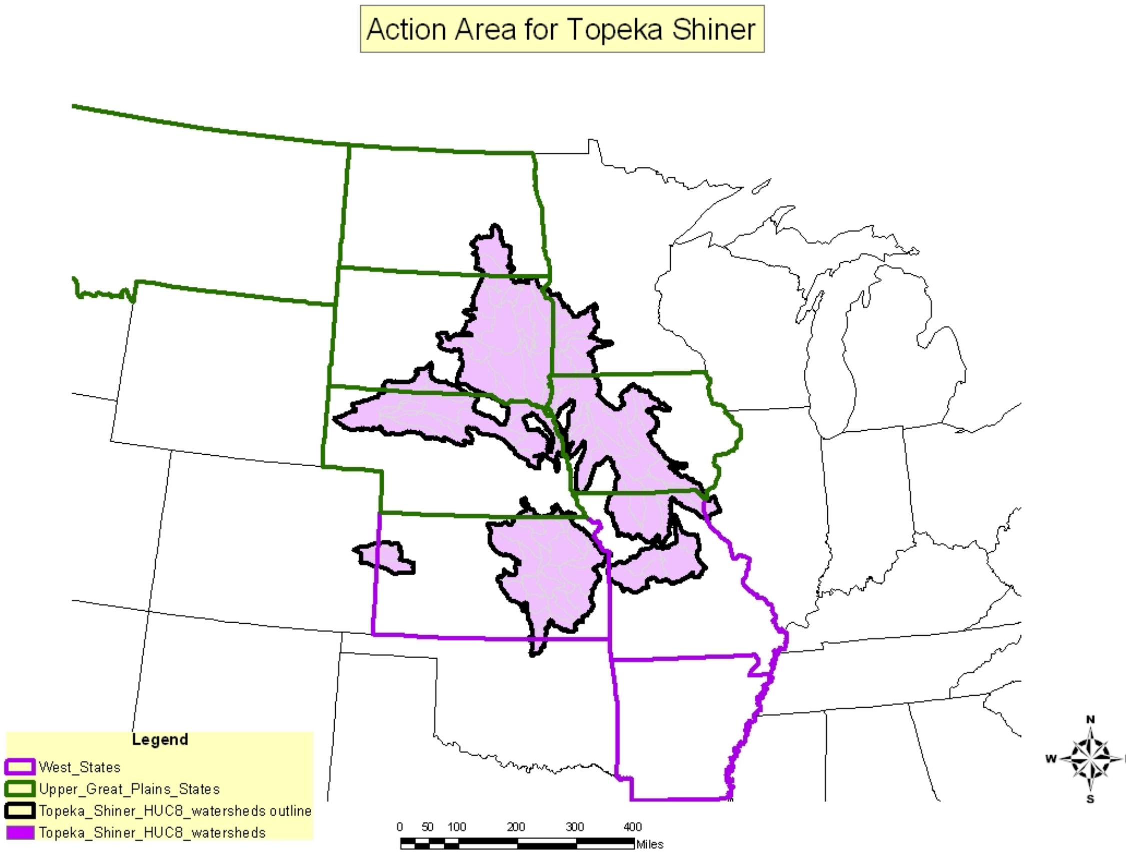


Figure 2.4 Topeka Shiner Action Area Defined by Hydrologic Unit Code (HUC8) Watersheds

2.6. Assessment Endpoints and Measures of Ecological Effect

Assessment endpoints are defined as "explicit expressions of the actual environmental value that is to be protected."[1] Selection of the assessment endpoints is based on valued entities (i.e., Topeka shiner and PCEs of designated critical habitat), the ecosystems potentially at risk (i.e., streams and rivers of Topeka shiner), the migration pathways of atrazine (i.e., runoff and spray drift), and the routes by which ecological receptors are exposed to atrazine-related contamination (i.e., direct contact).

Assessment endpoints include direct toxic effects on the survival, reproduction, and growth of individuals, as well as indirect effects, such as reduction of the prey base and/or modification of its habitat. In addition, potential destruction and/or adverse modification of critical habitat is evaluated via potential effects to PCEs, which are components of the habitat areas that provide essential life cycle needs (Section 2.3). Each assessment endpoint requires one or more "measures of ecological effect," which

[1] From U.S. EPA (1992). *Framework for Ecological Risk Assessment.* EPA/630/R-92/001.

are defined as changes in the attributes of an assessment endpoint or changes in a surrogate entity or attribute in response to exposure to a pesticide. Specific measures of ecological effect are evaluated based on a variety of data sources including registrant-submitted studies and information from the open literature. Acute and chronic toxicity information from registrant-submitted guideline tests are required to be conducted on a limited number of organisms. Additional ecological effects data from the open literature, including effects data on aquatic freshwater microcosm and mesocosm data, were also considered.

Measures of effect from microcosm and mesocosm data provide an expanded view of potential indirect effects of atrazine on aquatic organisms, their populations and communities in the laboratory, in simulated field situations, and in actual field situations. With respect to the microcosm and mesocosm data, threshold concentrations were determined from realistic and complex time variable atrazine exposure profiles (chemographs) for modeled aquatic community structure changes. Methods were developed to estimate ecological community responses for monitoring data sets of interest based on their relationship to micro- and mesocosm study results, and thus to determine whether a certain exposure profile within a particular use site and/or action area may have exceeded community-level threshold concentrations. Ecological modeling with the Comprehensive Aquatic Systems Model (CASM) (Bartell et al., 2000; Bartell et al., 1999; and DeAngelis et al., 1989) was used to integrate direct and indirect effects of atrazine to indicate changes to aquatic community structure and function.

A complete discussion of all the toxicity data available for this risk assessment, including use of CASM and associated aquatic community-level threshold concentrations, and the resulting measures of ecological effect selected for each taxonomic group of concern, is included in Section 4 of this document. A summary of the assessment endpoints and measures of ecological effect selected to characterize potential Topeka shiner risks associated with exposure to atrazine are provided in Table 2.4.

Table 2.4 Summary of Assessment Endpoints and Measures of Ecological Effect for Topeka shiner

Assessment Endpoint	Measures of Ecological Effect
1. Survival, growth, and reproduction of the Topeka shiner via direct effects resulting from atrazine exposure or via indirect effects to other fish needed for spawning habitat (e.g., sunfish).	1a. Freshwater fish acute LC_{50} 1b. Freshwater fish life-cycle NOAEC
2. Survival, growth, and reproduction of the Topeka shiner individuals via indirect effects on food source (i.e., aquatic invertebrates, aquatic plants, fish)	2a. Freshwater fish, invertebrate, and aquatic plant EC_{50} or LC_{50} 2b. Freshwater fish and invertebrate NOAEC 2c. Microcosm/mesocosm threshold concentrations showing aquatic primary productivity community-level effects.
3. Survival, growth, and reproduction of the Topeka shiner via indirect effects on habitat and/or primary productivity (i.e., aquatic plant community)	3a. Vascular plant (duckweed) acute EC_{50} 3b. Non-vascular plant (freshwater algae) acute EC_{50} 3c. Microcosm/mesocosm threshold concentrations showing aquatic primary productivity community-level effects

4. Survival, growth, and reproduction of the Topeka shiner via indirect effects on terrestrial vegetation (riparian habitat) required to maintain acceptable water quality and habitat	4a. Monocot and dicot seedling emergence EC_{25} 4b. Monocot and dicot vegetative vigor EC_{25}

Assessment endpoints and measures of ecological effect selected to characterize potential designated critical habitat modification associated with exposure to atrazine are provided in Table 2.5. As previously discussed, the basis of the designated critical habitat analysis is protection of the PCEs identified for the designated critical habitat. PCEs that are identified as assessment endpoints are limited to those that are of a biological nature (i.e., the biological resource requirements for the listed species associated with the critical habitat) and those PCEs for which atrazine effects data are available. Therefore, abiotic PCEs, such as flow regime, pH, and hardness are not evaluated because there is no perceived link between the biotic assessment endpoints and the abiotic PCEs (i.e., atrazine in surface water is unlikely to impact flow, pH, and hardness levels). In addition, the PCE related to the presence of competitive or predacious nonnative species is also not evaluated because there is no ecotoxicity data to differentiate native versus non-native species sensitivity to atrazine.

Table 2.5 Summary of Assessment Endpoints and Measures of Ecological Effect for Primary Constituent Elements of Designated Critical Habitat[a]

Assessment Endpoint	Measures of Ecological Effect
Streams and side-channel pools with water quality necessary for unimpaired behavior, growth, and viability of all life stages. The water quality components can vary seasonally and include--temperature (1 to 30[deg]Centigrade), total suspended solids (0 to 2000 ppm), dissolved oxygen (4 ppm or greater), and other chemical characteristics	1a. Monocot and dicot seedling emergence EC_{25} 1b. Monocot and dicot vegetative vigor EC_{25} 1c. Vascular and non-vascular plant (freshwater algae) acute EC_{50} 1d. Microcosm/mesocosm threshold concentrations showing aquatic primary productivity community-level effects
Living areas for juvenile Topeka shiners with water velocities less than 0.5 meters/second (approx. 20 inches/second) with depths less than 0.25 meters (approx. 10 inches) and moderate amounts of instream aquatic cover, such as woody debris, overhanging terrestrial vegetation, and aquatic plants;	
Sand, gravel, cobble, and silt substrates with amounts of fine sediment and substrate embeddedness that allows for nest building and maintenance of nests and eggs by native Lepomis sunfishes (green sunfish, orangespotted sunfish, longear sunfish) and Topeka shiner as necessary for reproduction, unimpaired behavior, growth, and viability of all life stages	3a. Monocot and dicot seedling emergence EC_{25} 3b. Monocot and dicot vegetative vigor EC_{25}
An adequate terrestrial, semiaquatic, and aquatic invertebrate food base that allows for unimpaired growth, reproduction, and survival of all life stages.	4a. Terrestrial and aquatic invertebrate EC50s 4b. Terrestrial and freshwater invertebrate NOAEC

[a] Water quality parameters including pH and hardness are also included in this PCE; however these components of water quality are not evaluated because there is no perceived link between the risk assessment biotic endpoints and water pH and hardness.

2.7. Conceptual Model

2.7.1 Risk Hypotheses

Risk hypotheses are specific assumptions about potential adverse effects (i.e., changes in assessment endpoints) and may be based on theory and logic, empirical data, mathematical models, or probability models (U.S. EPA, 1998). For this assessment, the risk is stressor-linked, where the stressor is the release of atrazine to the environment. Based on the results of the 2003 atrazine IRED (U.S. EPA, 2003a), the following risk hypotheses are presumed for this endangered species risk assessment:

- Atrazine in surface water and/or runoff/drift from treated areas within the action area may directly affect the Topeka shiner by causing mortality or adversely affecting growth or fecundity;
- Atrazine in surface water and/or runoff/drift from treated areas within the action area may indirectly affect the Topeka shiner by reducing or changing the composition of food supply and/or perturbing fish required for reproduction habitat of the Topeka shiner;
- Atrazine in surface water and/or runoff/drift from treated areas within the action area may indirectly affect the Topeka shiner by reducing or changing the composition of the aquatic plant community in the waters of the species' current range, thus affecting primary productivity and/or cover;
- Atrazine in surface water and/or runoff/drift from treated areas within the action area may indirectly affect the Topeka shiner by reducing or changing the composition of the terrestrial plant community (i.e., riparian habitat) required to maintain acceptable water quality and habitat in the rivers and streams comprising the species' current range;
- Atrazine in surface water and/or runoff/drift from treated areas within the action area may adversely modify one or more of the PCEs of the designated critical habitat of the Topeka shiner.

2.7.2 Diagram

The conceptual model is a graphic representation of the structure of the risk assessment. It specifies the stressor (atrazine), release mechanisms, abiotic receiving media, biological receptor types, and effects endpoints of potential concern. The conceptual models for the atrazine endangered species risk assessment for the Topeka shiner and designated critical habitat are shown in Figure 2.5. Exposure routes shown in dashed lines are not quantitatively considered because the resulting exposures are expected to be sufficiently low such that they are not expected to measurably contribute to potential adverse effects to the Topeka shiner and/or designated critical habitat.

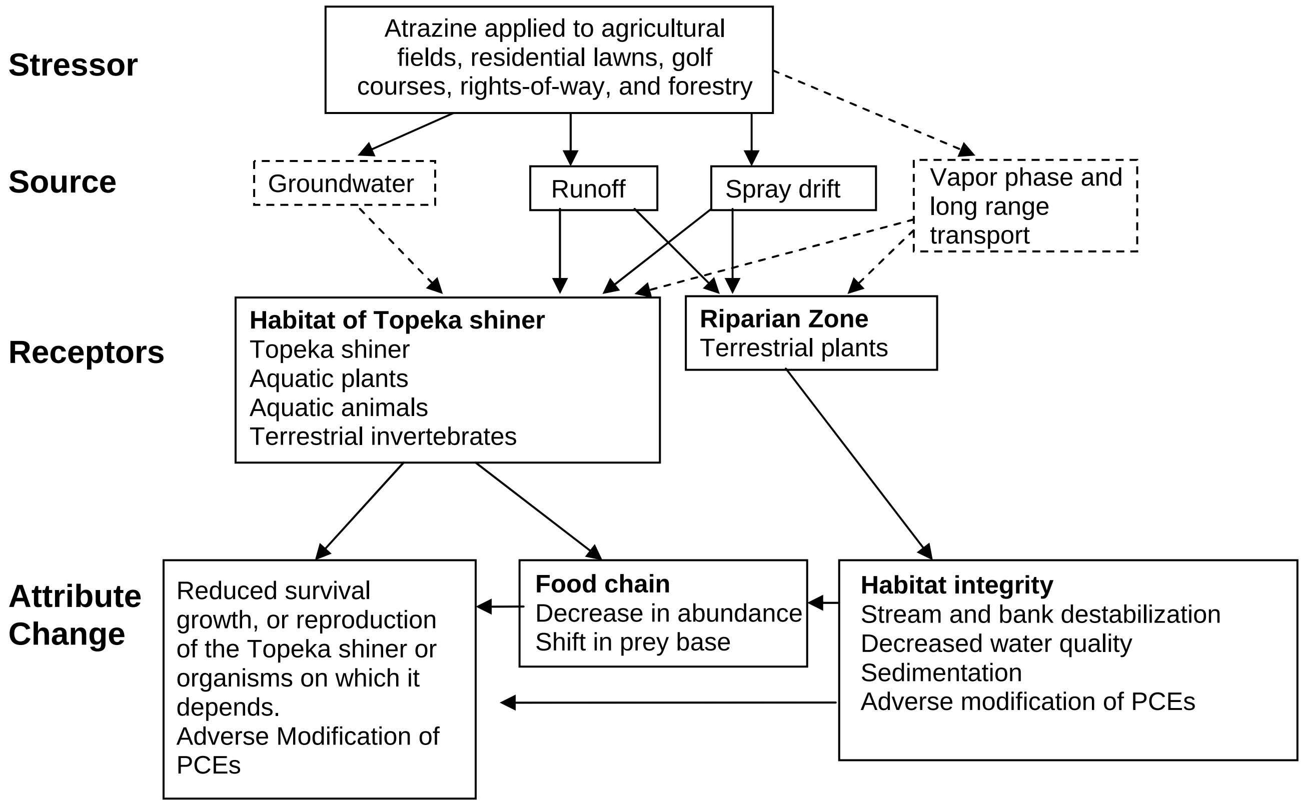


Figure 2.5 Conceptual Model for Topeka Shiner

The conceptual model provides an overview of the expected exposure routes for the Topeka shiner and its designated critical habitat within the atrazine action area previously described in Section 2.5. In addition to the Topeka shiner, other aquatic receptors that may be potentially exposed to atrazine include freshwater invertebrates and aquatic plants. Designated critical habitat may also be adversely modified based on alteration of the PCEs, which are those habitat components that support feeding, sheltering, and reproduction of the Topeka shiner. For freshwater vertebrate and invertebrate species, including the Topeka shiner, the major routes of exposure are considered to be via the respiratory surface (gills) or the integument. Direct uptake and adsorption are the major routes of exposure for aquatic plants. Direct effects to freshwater invertebrates and aquatic plants resulting from exposure to atrazine may indirectly affect the Topeka shiner and/or adversely modify its designated critical habitat via reduction and/or alteration in food and habitat (i.e., substrate, water quality including oxygen content) availability necessary for normal behavior, growth, and viability of all life stages. The available data indicate that atrazine is not likely to bioconcentrate in aquatic food items at levels of concern; fish bioconcentration factors (BCFs) range from 2 to 8.5 (U.S. EPA, 2003c).

In addition to aquatic receptors, terrestrial invertebrates and plants may also be exposed to spray drift and runoff from atrazine use in the vicinity of streams that comprise the current range and designated critical habitat for the Topeka shiner. Detrimental changes in the riparian vegetation adjacent to the Topeka shiner's current habitat and designated critical habitat may cause adverse effects to water quality (i.e., temperature and turbidity), stream bank stability, substrate composition, sediment loading, and spawning habitat.

The source and mechanism of release of atrazine into surface water are applications via foliar spray and coated fertilizer granules for agricultural (i.e., corn, sorghum, and fallow/idle land) and non-agricultural uses (i.e., golf courses, residential lawns, rights-of-way, and forestry). Surface water runoff from the areas of atrazine application is assumed to follow topography, resulting in direct runoff to the rivers and streams within the action area. Spray drift and runoff of atrazine may also affect the foliage and seedlings of terrestrial plants that comprise the riparian habitat that may be adjacent to the habitat including designated critical habitat. Additional release mechanisms include spray drift and atmospheric transport via volatilization, which may potentially transport site-related contaminants to the surrounding air. Atmospheric transport is not considered as a significant route of exposure for this assessment because the magnitude of documented exposures in rainfall are at or below available surface water and monitoring data, as well as modeled estimates of exposure.

2.8. Analysis Plan

The structure of this risk assessment is based on guidance contained in U.S. EPA's *Guidance for Ecological Risk Assessment* (U.S. EPA, 1998), the Services' *Endangered Species Consultation Handbook* (USFWS/NMFS, 1998), and is consistent with procedures and methodology outlined in the Overview Document (U.S. EPA, 2004).

2.8.1. Scope of Assessment

Atrazine is currently registered as an herbicide in the U.S. to control annual broadleaf and grass weeds in corn, sorghum, sugarcane, and other crops. In addition to food crops, atrazine is also used on a variety of non-food crops, forests, residential/industrial uses, golf course turf, recreational areas, and rights-of-way.

In accordance with the Overview Document, provisions of the Endangered Species Act (ESA), and the Services' *Endangered Species Consultation Handbook*, the assessment of effects of the FIFRA regulatory action is based on a defined action area and the extent of association of this action area with locations of the Topeka shiner and its designated critical habitat. It is acknowledged that the action area for a national-level FIFRA regulatory decision involving a potentially widely used pesticide may potentially involve numerous areas throughout the United States and its Territories. However, for the purposes of his assessment, attention will be focused on those parts of the action area with the potential to be associated with locations of the Topeka shiner and its designated critical habitat.

The end result of the EPA pesticide registration process is an approved product label. The label is a legal document that stipulates how and where a given pesticide may be used. Product labels (also known as end-use labels) describe the formulation type, acceptable methods of application, approved use sites, and any restrictions on how applications may be conducted. Thus, the use or potential use of atrazine in accordance with the approved product labels is "the action" being assessed.

This ecological risk assessment is for currently registered uses of atrazine in portions of the action area reasonably assumed to be biologically relevant to the Topeka shiner and its designated critical habitat. Further discussion of the action area(s) and designated critical habitat is provided in Section 2.4 and 2.5.

Degradates of atrazine include hydroxyatrazine (HA), deethylatrazine (DEA), deisopropylatrazine (DIA), and diaminochloroatrazine (DACT). Comparison of available toxicity information for the degradates of atrazine indicates lesser aquatic toxicity than the parent for fish, aquatic invertebrates, and aquatic plants. Specifically, the available degradate toxicity data for HA indicate that it is not toxic to freshwater fish and invertebrates at the limit of its solubility in water. In addition, no adverse effects were observed in fish or daphnids at DACT concentrations up to 100 mg/L. Acute toxicity values for DIA are 8.5- and 36-fold less sensitive than acute toxicity values for atrazine in fish and daphnids, respectively. In addition, available aquatic plant degradate toxicity data for HA, DEA, DIA, and DACT report non-definitive EC_{50} values (i.e., 50% effect was not observed at the highest test concentrations) at concentrations that are at least 700 times higher than the lowest reported aquatic plant EC_{50} value for parent atrazine. Although degradate toxicity data are not available for terrestrial plants, lesser or equivalent toxicity is assumed, given the available ecotoxicological information for other taxonomic groups including aquatic plants and the likelihood that the degradates of atrazine may lose efficacy as an herbicide. Therefore, given the lesser toxicity of the degradates as compared to the parent, and the relatively small proportion of the degradates expected to be in the environment and available for exposure relative to atrazine, the focus of this assessment is parent atrazine. Additional details on available toxicity data for the degradates are provided in Section 4 and Appendix A.

The Agency does not routinely include an evaluation of mixtures of active ingredients (either those mixtures of multiple active ingredients in product formulations or those in the applicator's tank) in its risk assessments. In the case of product formulations of active ingredients (registered product containing more than one active ingredient) each active ingredient is subject to an individual risk assessment for regulatory decision regarding the active ingredient on a particular use site. If effects data are available for a formulated product containing more than one active ingredient, they may be used qualitatively or quantitatively in accordance with the Agency's Overview Document and the Services' Evaluation Memorandum (U.S. EPA, 2004; USFWS/NMFS, 2004).

Atrazine has registered products that contain multiple active ingredients. Analysis of the available open literature and acute oral mammalian LD_{50} data for multiple active ingredient products relative to the single active ingredient is provided in Appendix G. The results of this analysis show that an assessment based on the toxicity of the single active ingredient of atrazine is appropriate.

The results of available toxicity data for environmental mixtures of atrazine with other pesticides are presented in Section A.6 of Appendix A. According to the available data, other pesticides may combine with atrazine to produce synergistic or additive toxic effects. Based on the results of the available data, study authors claim that synergistic effects with atrazine may occur for a number of organophosphate insecticides including diazinon, chlorpyrifos, and methyl parathion, as well as herbicides including alachlor. If chemicals that show synergistic effects with atrazine are present in the environment in combination with atrazine, the toxicity of atrazine may be increased, offset by other environmental factors, or even reduced by the presence of antagonistic contaminants if they are also present in the mixture. The variety of chemical interactions presented in the available data set suggests that the toxic effect of atrazine, in combination with other pesticides used in the environment, can be a function of many factors including but not necessarily limited to: (1) the exposed species, (2) the co-contaminants in the mixture, (3) the ratio of atrazine and co-contaminant concentrations, (4) differences in the pattern and duration of exposure among contaminants, and (5) the differential effects of other physical/chemical characteristics of the receiving waters (e.g., organic matter present in sediment and suspended water). Quantitatively predicting the combined effects of all these variables on mixture toxicity to any given taxa with confidence is beyond the capabilities of the available data. However, a qualitative discussion of implications of the available pesticide mixture effects data involving atrazine on the confidence of risk assessment conclusions for the Topeka shiner is addressed as part of the uncertainty analysis for this effects determination.

In this assessment, potential direct and indirect effects to the Topeka shiner and potential adverse modification to critical habitat are evaluated in accordance with the methods (both screening and species-specific refinements) described in the Agency's Overview Document (U.S. EPA, 2004).

2.8.2. Analysis of Toxicity

Analysis of potential sensitivity of the Topeka shiner to atrazine is evaluated using the most sensitive available acute and chronic endpoints reported from either registrant submitted studies or the open literature. For acute effects, the most sensitive reliable acute LC50 from the available submitted and open literature studies are used. For chronic effects, the most sensitive NOAEC from submitted life-cycle studies and the open literature are used. The open literature contains numerous studies. Only studies that produced reliable toxicity values that are based on toxicological endpoints that are directly correlated with survival or reproduction of the Topeka shiner are used for RQ calculations.

Potential sensitivity of species on which the Topeka shiner may depend for survival and reproduction (invertebrates, aquatic and terrestrial plants, and other fish) is also evaluated using the most sensitive acute and chronic toxicity value from the most sensitive species tested. If LOCs are exceeded based on the most sensitive toxicity value, then other factors, including the potential magnitude of effect and the biology and behavior of the Topeka shiner, are considered in the effects determination.

Potential risk to aquatic plant communities utilizes more refined data than is generally available for ecological risk assessment. Specifically, a robust set of microcosm and mesocosm data and aquatic ecosystem models are available for atrazine that allowed for a refinement of the indirect effects associated with potential aquatic community-level effects (via aquatic plant community structural change and subsequent habitat modification). Use of such information is consistent with the guidance provided in the Overview Document (U.S. EPA, 2004), which specifies that "the assessment process may, on a case-by-case basis, incorporate additional methods, models, and lines of evidence that EPA finds technically appropriate for risk management objectives" (Section V, page 31 of U.S. EPA, 2004).

2.8.3. Analysis of Exposure

Atrazine has been subject to a number of monitoring studies. Preliminary data are available from an ongoing monitoring study that was designed to detect high end atrazine concentrations in vulnerable watersheds. These data, together with other monitoring studies and PRZM/EXAMS modeling are used to evaluate potential exposures of atrazine to the Topeka shiner.

2.8.4. Analysis of Risk

As part of the effects determination, the Agency will reach one of the following three conclusions regarding the potential for FIFRA regulatory actions regarding atrazine to directly or indirectly affect Topeka shiner individuals and/or result in the destruction or adverse modification of designated critical habitat:

- "No effect";
- "May affect, but not likely to adversely affect" ("NLAA"); or
- "May affect and likely to adversely affect" ("LAA").

If the results of the initial baseline assessment show no LOC exceedances to the Topeka shiner or any species on which the Topeka shiner may depend for survival or reproduction, a "no effect" determination is made for the FIFRA regulatory action. If, however, LOC exceedances suggest that potential direct or indirect effects to individuals are anticipated and/or effects may impact the PCEs of the designated critical habitat, the Agency concludes a preliminary "may affect" determination for the FIFRA regulatory action regarding atrazine.

If a determination is made that use of atrazine within the action area "may affect" individual Topeka shiners and/or designated critical habitat, additional information is considered to refine the potential for exposure at the predicted levels and for effects to the Topeka shiner and other taxonomic groups upon which the species depends (i.e., freshwater fish and invertebrates, aquatic plants, riparian vegetation). Additional information including further evaluation of the potential impact of atrazine on the PCEs is also used to determine whether destruction or adverse modification to designated critical habitat may occur. Based on the refined information, the Agency uses the best available information to distinguish those actions that "may affect, but are not likely to adversely affect" ("NLAA") from those actions that are "likely to adversely affect" ("LAA") the Topeka shiner and/or PCEs of designated critical habitat. This information is presented as part of the Risk Characterization in Section 5.

2.9. Previous Assessments and Status of Forthcoming Data

Atrazine has been the subject of a number of ecological risk assessments conducted by U.S. EPA. Several assessments have recently been conducted on the potential for atrazine to affect a number of listed species as part of the Natural Resources Defense Counsel settlement agreement and one listed species included in a second settlement agreement with the Center for Biological Diversity and Save Our Springs Alliance. These effects determinations, which are available on the web at www.epa.gov/espp, review atrazine's potential direct and indirect effects to the following listed species:

1) Barton Springs salamander (*Eurycea sosorum*) (U.S. EPA, 2006c);
2) Shortnose sturgeon (*Acipenser brevirostrum*), dwarf wedgemussel (*Alasmidonta heterodon*), loggerhead turtle (*Caretta caretta*), Kemp's ridley turtle (*Lepidochelys kempii*), leatherback turtle *(Dermochelys coriacea*), and green turtle (*Chelonia mydas*) in the Chesapeake Bay (U.S. EPA, 2006d);
3) Alabama sturgeon (*Scaphirhynchus suttkusi*) (U.S. EPA, 2006e).
4) Pink mucket pearly mussel, Rough pigtoe mussel, Shiny pigtoe pearly mussel, Fine-rayed pigtoe mussel, Heavy pigtoe mussel, Ovate clubshell mussel, Southern clubshell mussel, and Stirrupshell mussel (U.S. EPA, 2007).

In addition, the Agency completed a refined ecological risk assessment for potential aquatic impacts of atrazine use in January 2003 (U.S. EPA, 2003a). This assessment was based on laboratory ecotoxicological data as well as microcosm and mesocosm field studies found in publicly available literature, a substantial amount of monitoring data for freshwater streams, lakes, reservoirs, and estuarine areas, and incident reports of adverse effects on aquatic and terrestrial organisms associated with the use of atrazine.
The results of the Agency's ecological assessments for atrazine are fully discussed in the January 31, 2003, Interim Reregistration Eligibility Decision (IRED)[2]. The assessment identified the need for the following information related to potential ecological risks was established: 1) a monitoring program to identify and evaluate potentially vulnerable waterbodies in corn, sorghum, and sugarcane use areas; and 2) further information on potential amphibian gonadal developmental responses to atrazine. On October 31, 2003, EPA issued an addendum that updated the IRED issued on January 31, 2003 (U.S. EPA, 2003b). This addendum described new scientific developments pertaining to monitoring of watersheds and potential effects of atrazine on endocrine-mediated pathways of amphibian gonadal development. As of the writing of this assessment, preliminary data from the ecological monitoring study have been submitted and are used to characterize potential exposures. However, analyses of the data are ongoing.

[2] The 2003 Interim Reregistration Eligibility Decision for atrazine is available at the following Web site: http://www.epa.gov/oppsrrd1/REDs/0001.pdf.

Finally, On August 1, 2003, EPA released an assessment of the potential effects of atrazine to 26 listed Environmentally Significant Units (ESUs) of Pacific salmon and steelhead. That assessment concluded that registered uses of atrazine would have "no effect", directly or indirectly to the 26 ESUs nor to designated critical habitat. While potential effects to riparian vegetation were noted, the extent of atrazine use in the large geographic areas comprising the relevant watersheds, lead to a conclusion that use would have no effect on the species from any potential effects to riparian areas.

As discussed in the October 2003 IRED, the Agency also conducted an evaluation of the submitted studies regarding the potential effects of atrazine on amphibian gonadal development and presented its assessment in the form of a white paper for external peer review to a FIFRA Scientific Advisory Panel (SAP) in June 2003[3]. In the white paper dated May 29, 2003, the Agency summarized seventeen studies consisting of both open literature and registrant-submitted laboratory and field studies involving both native and non-native species of frogs (U.S. EPA, 2003d). The Agency concluded that none of the studies fully accounted for environmental and animal husbandry factors capable of influencing endpoints that the studies were attempting to measure. The Agency also concluded that the current lines-of-evidence did not show that atrazine produced consistent effects across a range of exposure concentrations and amphibian species tested.

Based on this assessment, the Agency concluded and the SAP concurred that there was sufficient evidence to formulate a hypothesis that atrazine exposure may impact gonadal development in amphibians, but there were insufficient data to confirm or refute the hypothesis (http://www.epa.gov/oscpmont/sap/2003/June/junemeetingreport.pdf). Because of the inconsistency and lack of reproducibility across studies and an absence of a dose-response relationship in the currently available data, the Agency determined that the data did not alter the conclusions reached in the January 2003 IRED regarding uncertainties related to atrazine's potential effects on amphibians. The SAP supported EPA in seeking additional data to reduce uncertainties regarding potential risk to amphibians. Subsequent data collection has followed the multi-tiered process outlined in the Agency's white paper to the SAP (U.S. EPA, 2003d). In addition to addressing uncertainty regarding the potential use of atrazine to cause these effects, these studies are expected to characterize the nature of any potential dose-response relationship. A data call-in for the first tier of amphibian studies was issued in 2005. The results of these studies, as well as other recent open literature data which focus on the potential effects of atrazine on amphibian gonadal development, are being reviewed. This information will be presented and discussed as part of a second SAP to be held in October 2007.

3. Exposure Assessment

3.1 Label Application Rates and Intervals

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[3] The Agency's May 2003 White Paper on Potential Developmental Effects of Atrazine on Amphibians is available at http://www.epa.gov/oscpmont/sap/2003/june/finaljune2002telconfreport.pdf.

Atrazine labels may be categorized into two types: labels for manufacturing uses (including technical grade atrazine) and end-use products. Technical products, which contain atrazine of high purity, are not labeled for environmental release, but for making formulated products, which can be applied in specific areas to control weeds. The formulated product labels legally limit atrazine's potential use to only those sites that are specified on the labels and under the conditions of use (rate, timing, etc.) specified on the label.

In the January and October 2003 IREDs (U.S. EPA, 2003a and b), EPA stipulated numerous changes to the use of atrazine including label restrictions and other mitigation measures designed to reduce risk to human health and the environment. Specifically pertinent to this assessment, are provisions of a Memorandum of Agreement (MOA) between the Agency and atrazine registrants. In the MOA, the Agency stipulated that certain label changes must be implemented on all manufacturing-use product labels for atrazine and on all end-use product labels for atrazine prior to the 2005 growing season. These label changes included cancellation of certain uses, reduction in application rates, and requirements for harmonization across labels including setbacks from waterways. Specifically, the label changes prohibit atrazine use within 50 feet of sinkholes, 66 feet of intermittent and perennial streams, and 200 feet of lakes and reservoirs.

While these setbacks were required to reduce atrazine deposition to water bodies as a result of spray drift, it is expected that they will also result in a reduction in loading due to runoff across the setback zone; however, current models do not address this reduction quantitatively. Therefore, these restrictions are not quantitatively evaluated in this assessment. A qualitative discussion of the potential impact of these setbacks on estimated environmental concentrations of atrazine for the Topeka shiners is discussed further in Section 3.2.3. Table 3.1 provides a summary of label application rates for atrazine uses evaluated in this assessment.

Currently registered non-agricultural uses of atrazine within the action area include residential areas such as playgrounds and home lawns, turf (golf courses and recreational fields), rights-of-way, and forestry. Agricultural uses within the action area include corn, sorghum, and fallow/idle land[4]. Other agricultural uses (macadamia nut, guava, and sugarcane) are not present in the action area.

Atrazine is formulated as liquid, wettable powder, dry flowable and granular formulations. Application methods for the agricultural uses includes ground application (the most common application method), aerial application, band treatment, and incorporated treatment, and applications using various sprayers (low-volume, hand held, directed, and spreaders for granular applications). Risks from ground boom and aerial applications are considered in this assessment because they are expected to result in the

[4] Fallow or idle land is defined by the Agency as arable land not under rotation that is set at rest for a period of time ranging from one to five years before it is cultivated again, or land usually under permanent crops, meadows or pastures, which is not being used for that purpose for a period of at least one year. Arable land, which is normally used for the cultivation of temporary crops, but which is temporarily used for grazing, is also included.

highest off-target levels of atrazine due to generally higher spray drift levels. Ground boom and aerial modes of application tend to use lower volumes applied in finer sprays than applications coincident with sprayers and spreaders, and thus have a higher potential for off-target movement via spray drift.

Table 3.1 Atrazine Label Application Information for the Topeka Shiner Assessment[a]

Scenario	Maximum Application Rate (lbs/acre)	Maximum Number of Applications	Formulation	Method of Application	Interval Between Applications
Forestry	4.0	1	Liquid	Aerial and Ground	NA
Residential	2.0	2	Granular	Ground	30 days
Residential	1.0	2	Liquid	Ground	30 days
Rights-of-Way	1.0	1	Liquid	Ground	NA
Fallow/ Idle land	2.25	1	Liquid	Ground and Aerial	NA
Corn	2.5[b]	2	Liquid	Ground and Aerial	NA
Sorghum	2.0	1	Liquid	Ground and Aerial	NA
Turf	2.0	2	Granular	Ground	30 days
Turf	1.0	2	Liquid	Ground	30 days

[a] Based on 2003 IRED and Label Change Summary Table memorandum dated June 12, 2006 (U.S. EPA, 2006b).

3.2 Aquatic Exposure Assessment

3.2.1 Introduction

As discussed in Section 2.3, the Topeka shiner resides principally in headwater streams in the mid-continent of the United States. It is found primarily in low-order streams in Minnesota, Missouri, Iowa, Kansas, Nebraska, and South Dakota. The action area includes the entire watershed of streams and rivers in the areas defined above and are presented graphically in Figure 2.4.

The assessment of exposure within the action area is dependent upon a combination of modeling and monitoring data. In accordance with the Overview Document (U.S. EPA, 2004), baseline exposures were based on modeling which assumes a static water body. Available monitoring data for atrazine were also evaluated and incorporated into the exposure assessment.

For this assessment, baseline modeling using a static water body indicates long-term (e.g. 60-day average) exposure concentrations that are similar to the estimated peak value and considerably higher than concentrations seen in most monitoring data. However, the Topeka shiner's habitat includes headwater streams and side pools with low to negligible annual flow. The standard ecological water body is considered to represent headwater streams adjacent to treated fields; therefore, the static water body EECs are considered representative of high-end estimates of potential exposure for the Topeka shiner. In addition, because the Topeka shiner resides in shallow waters with volumes lower than assumed by PRZM/EXAMS, the estimated acute exposures could be underestimated by PRZM/EXAMS. However, the lower volume of water could be offset by other factors. Previous atrazine endangered species assessments (U.S. EPA 2006c,d,e) have included a refinement to exposure modeling with the static water body by incorporating flowing water into the assessment. However, because the Topeka shiner resides in headwater streams with low flow and in side pools of streams (Figure 3.1), no refinement to account for flowing water has been conducted for this assessment.

Figure 3.1. Example habitat of the Topeka shiner in Minnesota (Image obtained from Minnesota Department of Natural Resources, 2006).

Atrazine has been the subject of a number of monitoring studies. Targeted monitoring data (monitoring study specifically correlated with atrazine use in vulnerable watersheds) has recently been completed for atrazine in streams throughout the Midwest atrazine use area. These data are considered to provide context to potential atrazine levels in some Topeka shiner habitats because samples were collected from low (2^{nd} and 3^{rd}) order streams. However, the Topeka shiner also resides in 1st order streams and in side pools of low-order streams. These types of habitats are not typically included in monitoring studies. Therefore, the representativeness of the monitoring data to Topeka shiner habitats is uncertain.

In addition to targeted monitoring studies, a number of non-targeted (i.e., monitoring data in which the study design was not specifically targeted to detect atrazine in high use areas) monitoring studies are also available, which suggest a similar pattern of exposure as the targeted data. However, many of these sites are located in the most vulnerable areas represented by the targeted data; therefore, similar exposure patterns would be expected to occur.

As summarized below, baseline EECs based on the PRZM/EXAMS static water body are used in the risk estimation to derive initial RQs and distinguish between "no effect" and may affect" determinations. Although the monitoring data provide context to these modeled EECs, it is uncertain if the monitoring data or the modeling exercises provide exposure estimates that are more relevant to the Topeka shiner's habitat. Therefore, both are used to characterize potential exposures to the Topeka shiner. The monitoring data has been described in detail in previous endangered species assessments (U.S. EPA, 2006a,c,d,e); therefore, a summary of the monitoring data is presented in this assessment, and additional detail is provided in Appendix B.

3.2.2 Modeling Approach

The general conceptual model of exposure for this assessment is that the highest exposures are expected to occur in the headwater streams adjacent to agricultural fields and non-agricultural use sites (residential, right-of-way, turf, and forestry). The Topeka shiner is known to inhabit headwater streams, and the EECs derived for this assessment are relevant to habitats that are in close proximity to atrazine use sites. The action area was divided into representative regions and modeling scenarios were selected to represent each area. These areas (described in more detail in Section 3.2.3) represent the western tier (Missouri and Kansas) and the upper great plains tier (Iowa, Nebraska, South Dakota, and Minnesota) (Figure 3.2).

Figure 3.2 Regionalization of Topeka shiner Action Area

Available usage data (Kaul, et al., 2005) suggest that the heaviest usage of atrazine relative to the action area is likely to be in a band stretching from western Illinois across Iowa to central Nebraska with decreasing intensity south and north of this area. As noted above, the action area was segmented into regions to allow for modeling that covers the expected range of runoff vulnerability. All existing PRZM scenarios were evaluated, and a subset was selected for use in this assessment. The scenarios were selected to provide a spatial context to predicted exposures.

Currently a suite of 63 PRZM standard scenarios and 7 Barton Springs scenarios (recently developed for use in the Barton Springs salamander endangered species risk assessment (U.S. EPA, 2006c), are available for use in ecological risk assessments representing predominantly agricultural uses. Each scenario is intended to represent a high-end exposure setting for a particular crop. Each scenario location is selected based on various factors including crop acreage, runoff and erosion potential, climate, and agronomic practices. Once a location is selected, a scenario is developed using locally specific soil, climatic, and agronomic data. Each PRZM scenario is assigned a specific climatic weather station providing 30 years of daily weather values.

Specific scenarios were selected for use in this assessment using two criteria. First, an evaluation of all available PRZM scenarios was conducted, and those scenarios that represent atrazine uses (e.g. Ohio corn) were selected for modeling. Weather information was assigned to these scenarios at development. Second, an additional suite of scenarios was identified to represent both agricultural and non-agricultural uses for which scenarios within the action area is not available (e.g. residential). These scenarios were used in the assessment as surrogates for atrazine uses without current scenarios (e.g. Oregon Christmas tree as surrogate for forestry) and to provide geographic coverage where no current scenario exists (e.g. Ohio corn scenario modeled using Springfield, Missouri weather data).

Each scenario selected as a surrogate for this assessment is considered to be a conservative representation of exposure in the action area because the surrogate scenarios (Oregon Christmas tree and Kansas sorghum) were developed using a hydrologic group C soil with relatively high curve numbers and moderate slopes. These are the most important parameters within a PRZM scenario for generating runoff coupled with rainfall, which is higher within the action area than the areas where the scenarios were originally developed. In addition, the curve numbers and slopes are expected to be higher than those present in the action area, which generally have lower slopes and less runoff prone soils.

Further description (metadata) and copies of the existing PRZM scenarios may be found at the following websites.

http://www.epa.gov/oppefed1/models/water/index.htm#przmexamsshell

http://www.epa.gov/oppefed1/models/water/przmenvironmentdisclaim.htm

For this assessment, available PRZM weather stations were associated with watersheds highly vulnerable to atrazine runoff. As shown in Figure 3.3**,** weather stations associated with Sioux City, Iowa and Springfield, Missouri was selected to represent highly vulnerable locations for modeling surrogate scenarios (both agricultural and non-agricultural). As such, surrogate scenarios used to model this region were run using weather data from these locations to represent exposures within the entire region.

For this assessment, the following corn scenarios were modeled to represent all the various regions of the action area: North Dakota (this is a standard scenario using weather data from Fargo) representative of corn use in the upper great plains states and the Ohio scenario using the Springfield, Missouri weather data is representative of the western states. The Kansas sorghum scenario (the only existing sorghum scenario) was modeled with local weather stations including Topeka, Kansas (western states) and Sioux City, Iowa (upper great plain states).

Currently, the only non-agricultural scenarios available for use in aquatic exposure assessment are those developed specifically for the Barton Springs Salamander

Endangered Species Risk Assessment (U.S. EPA, 2006c). For the Barton Springs assessment, a suite of non-agricultural scenarios was developed including a residential, impervious (to be used in tandem with the residential scenario), and rights-of-way scenarios. These scenarios were used in this assessment in a manner similar to the agricultural scenarios described above. Each scenario was modeled using a representative weather station for each region. For example, the residential scenario was modeled using the Sioux City, Iowa weather data to represent the upper great plains states and the Springfield, Missouri weather data to represent the western states. There is some uncertainty associated with using a scenario developed for a given geographic area with climatic data from another area. However, runoff is driven primarily by hydrologic soil type (defining the curve number) and the rainfall. Thus, a scenario that represents a similar hydrologic soil type as would be found in the area being assessed and representative weather data for that region should yield high end exposures. Figure 3.3 shows the locations of these weather stations relative to the action area. A summary of all the modeled scenarios along with associated weather information is included in Table 3.2.

Both the agricultural and non-agricultural scenarios were used within the standard framework of PRZM/EXAMS modeling using the standard graphical user interface (GUI) shell, PE4v01.pl.

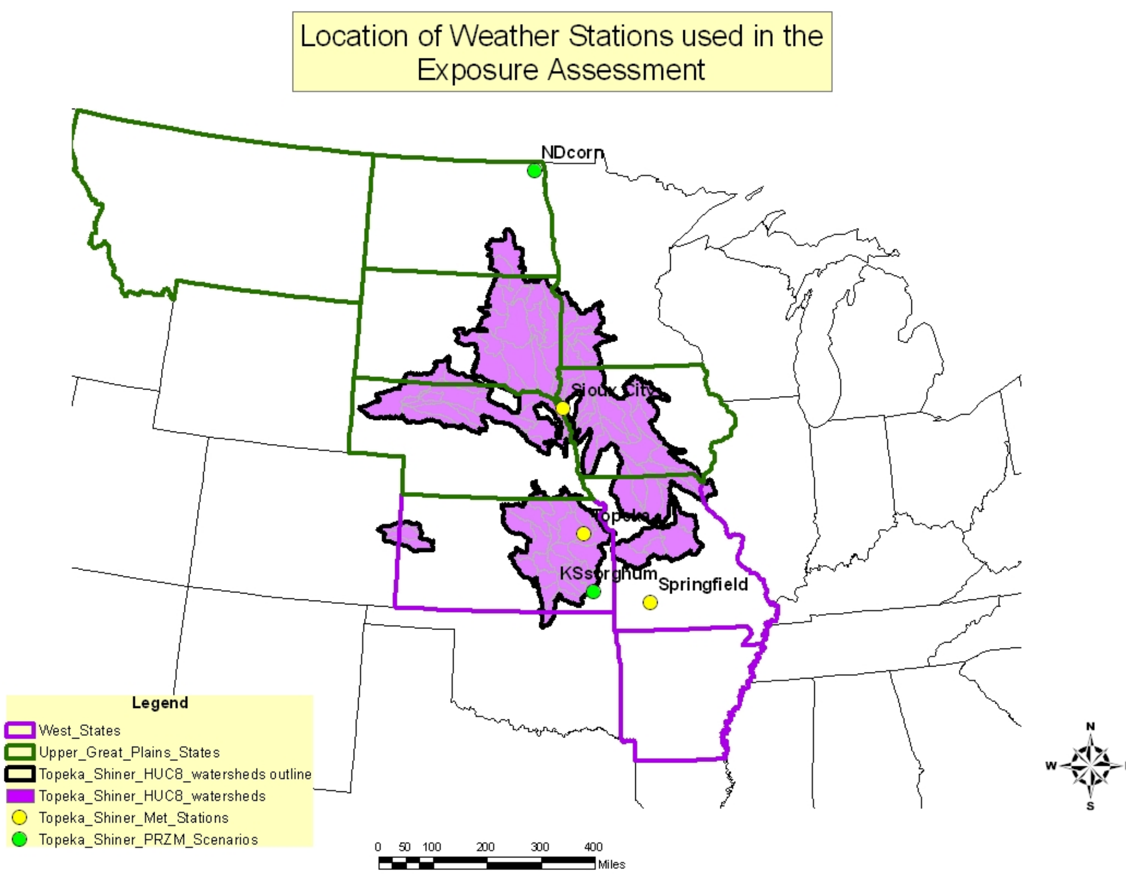

Figure 3.3 Location of Various Weather Stations Used to Model Non-Agricultural Uses (Residential, Right-of-Way, Turf, and Forestry)

Table 3.2 Summary of PRZM Scenarios

Region	Use	Scenario	First Application	Weather Station (WBAN #)
West	Corn	IL corn	April 15	Springfield, MO (13995)
	Sorghum	KS sorghum	May 1	Topeka, KS (13996)
	Fallow	BSS meadow	November 1	Springfield, MO (13995)
	Residential	BSS residential	April 15	Springfield, MO (13995)
	Right-of-way	BSS row	June 1	Springfield, MO (13995)
	Forestry	OR Christmas tree	June 1	Springfield, MO (13995)
	Turf	BSS turf	April 15	Springfield, MO (13995)
Upper Great Plains	Corn	ND corn	April 1	Fargo, ND (14914)
	Sorghum	KS sorghum	May 1	Sioux City, SD (14943)
	Fallow	BSS meadow	November 1	Sioux City, SD (14943)
	Residential	BSS residential	May 1	Sioux City, SD (14943)
	Right-of-way	BSS row	June 1	Sioux City, SD (14943)
	Forestry	OR Christmas tree	June 1	Sioux City, SD (14943)
	Turf	BSS turf	May 1	Sioux City, SD (14943)

[a] BSS scenarios developed for Barton Springs Salamander (BSS) Endangered Species Risk Assessment (U.S. EPA, 2006c).

Peak concentrations, as well as 90th percentile rolling time-weighted averages of 14 days, 21 days, 30 days, 60 days, and 90 days were derived for comparison with the appropriate ecotoxicity endpoints (including the community-level threshold concentrations) for atrazine (see Section 4). The 30-year time series output file was used to recalculate the peak, 14-day, 21-day, 30-day, 60-day, and 90-day rolling averages at the 90th percentile. All model outputs were post-processed manually using Microsoft Excel to provide the equivalent of the standard one in ten year return frequency exposures, as predicted by PRZM/EXAMS. A sample of how this post-processing was conducted may be found in the previous atrazine assessments for the Chesapeake Bay and Alabama Sturgeon (U.S. EPA 2006c,d,e).

Additional information on the modeling approach for the non-agricultural residential, rights-of-way, and forestry use scenarios may be found in the previous atrazine endangered species risk assessments (U.S. EPA, 2006c,d).

3.2.3 Model Inputs

The estimated water concentrations from surface water sources were calculated using Tier II PRZM (Pesticide Root Zone Model) and EXAMS (Exposure Analysis Modeling System). PRZM is used to simulate pesticide transport as a result of runoff and erosion from a standardized watershed, and EXAMS estimates environmental fate and transport of pesticides in surface waters. The linkage program shell (PE4v01.pl) that incorporates the site-specific scenarios was used to run these models.

Scenarios used in this assessment consist of agricultural scenarios for corn and sorghum developed previously for other geographic areas. Scenarios developed for the Barton Springs Salamander assessment (U.S. EPA, 2006c) not specific to watersheds included in the action area, are used in this assessment for one agricultural use (fallow/idle land) and several non-agricultural uses (residential, turf, forestry, and rights-or-way). All scenarios were modeled using local weather data as described above. Linked use site-specific scenarios and meteorological data were used to estimate exposure as a result of specific use for each modeling scenario. The PRZM/EXAMS model was used to calculate concentrations using the standard ecological water body scenario in EXAMS. Weather and agricultural practices were simulated over 30 years so that the 1 in 10 year exceedance probability at the site was estimated for the standard ecological water body.

One outcome of the 2003 IRED process was a modification to all existing atrazine labels that requires setback distances around intermittent/perennial streams and lakes/reservoirs. The label changes specify setback distances of 66 feet and 200 feet for atrazine applications surrounding intermittent/perennial streams and lakes/reservoirs, respectively. The Agency incorporated these distances into this assessment and has modified the standard spray drift assumptions accordingly using U.S. EPA's AgDrift model (http://www.agdrift.com/AgDRIFt2/Download.htm) to estimate the impact of a setback distance of 66 feet on the fraction of drift reaching a surface water body. The revised spray drift percentages, which are incorporated into the PRZM/EXAMS modeling, are 0.6% for ground applications and 6.5% for aerial applications.

Models to estimate the effect of setbacks on load reduction for runoff are not currently available. It is well documented that vegetated setbacks can result in a substantial reduction in pesticide load to surface water (USDA, NRCS, 2000). Specifically for atrazine, data reported in the USDA study indicate that well vegetated setbacks have been documented to reduce atrazine loading to surface water by as little as 11% and as much as 100% of total runoff compared to the loading without a setback. It is expected that the presence of a well-vegetated setback between the site of atrazine application and receiving water bodies would result in reduction in loading. Therefore, the aquatic EECs presented in this assessment are likely to over-estimate exposure in areas with well-vegetated setbacks.

The date of first application was developed based on several sources of information including data provided by the Biological and Economic Analysis Division (BEAD) and

Crop Profiles maintained by the USDA. More detail on the crop profiles may be found at:

http://pestdata.ncsu.edu/cropprofiles/cropprofiles.cfm

The appropriate PRZM input parameters were selected from the environmental fate data submitted by the registrant and in accordance with US EPA-OPP EFED water model parameter selection guidelines, Guidance for Selecting Input Parameters in Modeling the Environmental Fate and Transport of Pesticides, Version 2.3, February 28, 2002. These parameters are consistent with those used in both the 2003 IRED (U.S. EPA, 2003a) and the cumulative triazine risk assessment (U.S. EPA, 2006a) and are summarized in Table 3.3. More detail on these assessments may be found at:

http://www.epa.gov/oppsrrd1/REDs/atrazine_ired.pdf

http://www.epa.gov/pesticides/cumulative/common_mech_groups.htm#chloro

Table 3.3 Summary of PRZM/EXAMS Environmental Fate Data Used for Aquatic Exposure Inputs for Atrazine Topeka shiner Assessment

Fate Property	Value	MRID[a] (or source)
Molecular Weight	215.7 g/mole	MRID 41379803
Henry's constant	2.58×10^{-9}	MRID 41379803
Vapor Pressure	3×10^{-7}	MRID 41379803
Solubility in Water	33 mg/l	MRID 41379803
Photolysis in Water	335 days	MRID 42089904
Aerobic Soil Metabolism Half-lives	152 days	MRID 40431301 MRID 40629303 MRID 42089906
Hydrolysis	stable	MRID 40431319
Aerobic Aquatic Metabolism (water column)	304 days	2x aerobic soil metabolism rate constant
Anaerobic Aquatic Metabolism (benthic)	608 days	MRID 40431323
Koc	88.78 ml/g	MRID 40431324 MRID 41257901 MRID 41257902 MRID 41257904 MRID 41257905 MRID 41257906
Application Efficiency	95 % for aerial 99 % for ground	Default value[c]
Spray Drift Fraction[b]	6.5 % for aerial 0.6 % for ground	AgDrift adjusted values based on label restrictions

Fate Property	Value	MRID[a] (or source)
[a] Master Record Identification (MRID) is record tracking system used within OPP to manage data submissions to the Agency. Each data submission if given a unique MRID number for tracking purposes. [b] Spray drift not included in final EEC due to edge-of-field estimation approach. [c] Inputs determined in accordance with EFED "*Guidance for Chemistry and Management Practice Input Parameters for Use in Modeling the Environmental Fate and Transport of Pesticides*" dated February 28, 2002.		

3.2.4 Modeling Results

As noted above, a total of seven scenarios were evaluated in this assessment. Of these, four were developed as part of the Barton Springs salamander endangered species risk assessment (U.S. EPA, 2006c). Two of the Barton Springs scenarios (residential and rights-of-way) were used in tandem with an impervious scenario, while two (fallow/idle land and turf) are standard PRZM/EXAMS scenarios. The remaining three scenarios (corn, sorghum, and Christmas trees as surrogate for forestry) were taken from existing scenarios developed for other regions of the United States and modeled using local weather data. No new scenarios were developed specifically for this assessment. The results of the modeling are summarized in Table 3.4.

In general, these EECs show a pattern of exposure for all durations that is influenced by the persistence of the compound and the lack of flow through the static water body. Predicted atrazine concentrations, though high across durations of exposure for a single year, do not increase across the 30-year time series; therefore accumulation is not a concern.

Table 3.4 Summary of PRZM/EXAMS Output Baseline EECs for all Modeled Scenarios
(Using the Standard Water Body)

Region	Use Site (see Table 3.2 for Scenarios Used)	Application Rate (lbs/acre)	No. of Applications	90th Percentile of 30 Years of Output					
				Peak EEC (µg/L)	14-day EEC (µg/L)	21-day EEC (µg/L)	30-day EEC (µg/L)	60-day EEC (µg/L)	90-day EEC (µg/L)
West	Corn[a]	2.0	2 (not to exceed 2.5 lbs/year)	92.8	91.7	91.4	90.7	88.0	85.4
Upper Great Plains	Corn[a]	2.0	2 (not to exceed 2.5 lbs/year)	84.8	84.0	83.6	83.5	82.3	80.8
West	Sorghum	2.0	1	60.1	59.4	58.9	58.4	57.3	56.3
Upper Great Plains	Sorghum	2.0	1	57.2	56.6	56.3	55.8	54.4	52.8
West	Fallow	2.25	1	103.4	103.1	103.1	103.1	103.0	103.0
Upper Great Plains	Fallow	2.25	1	49.2	49.1	49.1	49.1	49.1	48.8
West	Residential[b] Granular	2.0	2 (not to exceed 4.0 lbs/year)	11.9	11.8	11.7	11.6	11.3	11.0
Upper Great Plains	Residential[b] Granular	2.0	2 (not to exceed 4.0 lbs/year)	10.9	10.9	10.9	10.8	10.8	10.8
West	Residential[b] Liquid	1.0	2 (not to exceed 2.0 lbs/year)	9.9	9.7	9.7	9.6	9.3	9.1
Upper Great Plains	Residential[b] Liquid	1.0	2 (not to exceed 2.0 lbs/year)	8.2	8.1	8.1	8.0	7.8	7.6
West	Rights-of-way	1.0	1	3.8	3.8	3.8	3.8	3.6	3.5
Upper Great Plains	Rights-of-way[v]	1.0	1	3.3	3.2	3.2	3.2	3.1	3.0

Region	Use Site (see Table 3.2 for Scenarios Used)	Application Rate (lbs/acre)	No. of Applications	90th Percentile of 30 Years of Output					
				Peak EEC (µg/L)	14-day EEC (µg/L)	21-day EEC (µg/L)	30-day EEC (µg/L)	60-day EEC (µg/L)	90-day EEC (µg/L)
West	Forestry	4.0	1	27.4	26.9	26.8	26.5	25.6	24.8
Upper Great Plains	Forestry	4.0	1	64.5	61.0	60.7	60.2	58.3	56.5
West	Turf Granular	2.0	2 (not to exceed 4.0 lbs/year)	7.2	7.1	7.0	7.0	6.7	6.5
Upper Great Plains	Turf Granular	2.0	2 (not to exceed 4.0 lbs/year)	10.1	10.1	10.1	10.1	10.0	9.9
West	Turf Liquid	1.0	2 (not to exceed 2.0 lbs/year)	7.6	7.5	7.5	7.5	7.4	7.2
Upper Great Plains	Turf Liquid	1.0	2 (not to exceed 2.0 lbs/year)	8.2	8.1	8.1	8.0	8.0	7.9

[a] Actual labeled maximum rates are 2.0 lb/acre for a single application with no more than 2.5 lbs/acre per year. The rate and number of applications reported in this table are an approximation of the label maximum given the current limitation in the Agency's PRZM/EXAMS graphical user interface (GUI) PE4v01.pl. Currently, PE4v01.pl allows multiple applications but the rate cannot be varied from one application to the next. The impact of this assumption was assessed using an interim version of the GUI and yielded an approximately 6% increase in concentration. The corn EECs has been adjusted upwards by 6% for each duration of exposure to reflect this issue.
[b] Assumes 1% overspray of atrazine to the impervious surfaces.
[c] Assumes only 10% of any watershed is in right-of-way.

3.2.5 Existing Monitoring Data

The second step in the process of characterizing EECs used for risk estimation was to compare the modeling results with available surface water monitoring data. A fairly robust set of surface water monitoring data exists for atrazine from a variety of targeted and non-targeted studies. Targeted studies are those studies whose design is specifically tailored to the use pattern for a specific compound. Sample location, number of samples, frequency of sampling, and when the samples are collected are designed specifically to capture exposures for the target compound. Non-targeted monitoring is typically more general in nature and is not designed for a specific compound. The study design for non-targeted studies are typically broad with the intent of capturing as many compounds as possible but not necessarily focused on the main exposure period for a single compound.

Data from a number of monitoring programs are available, including data from the USGS NAWQA program (http://water.usgs.gov.nawqa), Watershed Regression for Pesticides (WARP), Heidelberg College, Community Water System (CWS) data from drinking water sources, published USGS studies, other published data, and recently submitted data collected by the registrant of atrazine (Ecological Stream Monitoring Program). In general, relevance of the available monitoring data is uncertain given that the Topeka shiner resides in headwater streams with low flow and in side pools of low order streams, while the bulk of the monitoring data (including the targeted ecological stream monitoring) represents samples collected from 3rd order streams and higher, typically from mid-stream sampling stations. Therefore, only a summary of the available monitoring studies is presented in this assessment. Additional data can be obtained from Appendix B.

The available monitoring data typically report consistent information. The recent Ecological Monitoring Program Data are summarized below. Other monitoring studies, including USGS NAWQA, USGS Watershed Regression of Pesticides (WARP) Data, Heidelberg College Data, and other open literature sources report atrazine levels and patterns that are similar to those reported in the targeted ecological monitoring program. However, the targeted data are considered to be more robust due to its targeted nature. Details on both the targeted and the non-targeted studies may be found in Appendix B.

Overall, the targeted monitoring data suggest a similar pattern of atrazine exposure in surface water as in the other data sets evaluated as part of this assessment. In the targeted study, atrazine was detected in a total of 2,979 out of 3,601 samples for an overall frequency of detection of 79%. The frequency of detection ranged across all watersheds and years from a maximum of 100% to a minimum of 11%. The maximum concentration detected from all watersheds was 208.8 µg/L from the Indiana 11 site in 2005. The mean annual concentrations ranged from a maximum of 9.5 µg/L from the Missouri 01 site in 2004 to a low of 0.1 µg/L for the Nebraska 06 site in 2006, while the median values ranged from 4.2 µg/L for the Missouri 02 site in 2004 to 0.1 µg/L for the Ohio 03 site in 2004. It should be noted that a number of watersheds, particularly in Nebraska, experienced dry periods where scheduled sampling did not take place; therefore, the statistics for those watersheds may not represent actual conditions expected in normal or wetter years.

Patterns observed in the other monitoring studies were consistent with those reported in the targeted ecological monitoring data. Details on all available monitoring studies are in Appendix B.

3.2.6 Comparison of Modeling and Monitoring Data

Modeling with the static water body provides screening-level EECs for use in risk estimation (Section 5.1). In this case, the listed species' habitat includes headwater streams with low flow and in side pools of low-order streams. Therefore, the modeled static water body EECs used for risk estimation are considered to be a reasonable approximation of high end exposure which the Topeka shiner may be exposed. Both monitoring data targeted to atrazine use and non-targeted data provide context to these modeled exposures.

The peak EECs are relatively consistent across modeling and targeted and non-targeted monitoring studies (highest maximum peaks detected across the studies are typically 100 to 200 ug/L). However, monitoring studies suggest that longer duration EECs are considerably lower than the highest detected peak concentrations. The Topeka shiner habitat includes small pools connected to low order streams with low flow rates (see Section 2.3. and 3.1). The monitoring studies may not represent these types of habitats. Therefore, the modeled longer-duration EECs will be used for RQ calculations. In addition, because the Topeka shiner resides in shallow waters with volumes lower than assumed by PRZM/EXAMS, the estimated acute exposures could be underestimated by PRZM/EXAMS. However, the lower volume of water could be offset by other factors.

3.2.7. Impact of Typical Usage Information on Exposure Estimates

A final piece of the exposure characterization includes an evaluation of usage information. Label application information was provided by EPA's Biological and Economic Analysis Division and summarized in Table 2.2. This information suggests that atrazine use on agricultural crops (non-agricultural usage data is not available as part of this analysis) ranges from 0.6 lbs/acre for sweet corn and wheat to 1.2 lbs/acre for sorghum in the states considered within the action area of this assessment. This suggests that if typical application rates were used in modeling as opposed to maximum label rates, atrazine exposures would be reduced below those modeled by roughly 40% depending on the use pattern. Typically usage information is not incorporated into these assessments, but does provide context to the exposures predicted. Caution is used when evaluating "typical" application rate information because this represents the average of all reported applications and thus roughly 50% of the time higher application rates are being applied. Also, typical application rates would not alter EECs from monitoring studies.

3.3 Terrestrial Plant Exposure Assessment

Terrestrial plants in riparian areas may be exposed to atrazine residues carried from application sites via surface water runoff or spray drift. Exposures can occur directly to seedlings breaking through the soil surface and through root uptake or direct deposition onto foliage to more mature plants. Riparian vegetation is important to the water and stream quality of the Topeka shiner because it serves as a buffer and filters out sediment, nutrients, and contaminants before they enter the watersheds associated with Topeka shiner habitat. Riparian vegetation has been shown to be essential in the maintenance of a stable stream (Rosgen, 1996). Destabilization of the stream can have an adverse effect on habitat quality by increasing sedimentation within the watershed.

Concentrations of atrazine on the riparian vegetation were estimated using OPP's TerrPlant model (U.S. EPA, 2007; Version 1.2.2), considering use conditions likely to occur in the watersheds associated with the action area. The TerrPlant model evaluates exposure to plants via runoff and spray drift and is EFED's standard tool for estimating exposure to non-target plants. The runoff loading of TerrPlant is estimated based on the solubility of the chemical and assumptions about the drainage and receiving areas. As previously discussed in Section 3.1 (model inputs), the standard spray drift assumptions were modified using AgDrift to estimate the impact of a setback distance of 66 feet on the fraction of drift reaching a surface water body. These revised spray drift percentages were also incorporated into the TerrPlant model, assuming that non-target terrestrial plants adjacent to atrazine use sites would receive the same percentage of spray drift as an adjacent surface water body. The revised spray drift percentages are 0.6% for ground applications and 6.5% for aerial applications.

Although TerrPlant calculates exposure values for terrestrial plants inhabiting two environments (i.e., dry adjacent areas and semi-aquatic areas), only the exposure values from the dry adjacent areas are used in this assessment. The 'dry, adjacent area' is considered to be representative of a slightly sloped area that receives relatively high runoff and spray drift levels from upgradient treated fields. In this assessment, the 'dry, adjacent area' scenario is used to estimate baseline exposure values for terrestrial plants in riparian areas. The 'semi-aquatic area' is considered to be representative of depressed areas that are ephemerally flooded, such as marshes, and, therefore, is not used to estimate exposure values for terrestrial riparian vegetation.

The following input values were used to estimate terrestrial plant exposure to atrazine from all uses: solubility = 33 ppm; minimum incorporation depth = 1 (TerrPlant default for incorporation depths $\leq$ 1 inch; from product labels); application methods: ground boom, aerial, and granular (from product labels). The following agricultural and non-agricultural scenarios were modeled: ground/aerial application to fallow/idle land at 2.25 lbs ai/A, corn/sorghum at 2.0 lb ai/A, and forestry at 4.0 lbs ai/A, and granular application to residential lawns at 2 lbs ai/A.

Terrestrial plant EECs are summarized in Table 3.5.

Table 3.5. Baseline Exposure Estimates for Terrestrial Plants to Atrazine

Use/ App. Rate (lbs/acre)	Application Method	Total Loading to Dry Adjacent Areas (lbs/acre)	Drift EEC (lbs/acre)
Fallow/idle land / 2.25	Aerial	0.19	0.15
	Ground	0.06	0.01
Corn and Sorghum / 2.0	Aerial	0.17	0.13
	Ground	0.05	0.01
Forestry / 4.0	Aerial	0.34	0.26
	Ground	0.10	0.02
Residential / 2.0	Granular	0.04	NA

4. Effects Assessment

This assessment evaluates the potential for atrazine to directly or indirectly affect the Topeka shiner and/or adversely modify designated critical habitat. As previously discussed in Section 2, assessment endpoints for the Topeka shiner include direct toxic effects on the survival, reproduction, and growth, as well as indirect effects, such as reduction of the prey base and/or modification of its habitat. In addition, potential destruction and/or adverse modification of critical habitat are assessed by evaluating potential effects to the PCEs, which are components of the critical habitat areas that provide essential needs to the Topeka shiner, such as water quality and food base (see Section 2.4). Toxicity data used to evaluate direct effects, indirect effects, and adverse modification to critical habitat are summarized in Table 4.1.

Table 4.1 Summary of Toxicity Data Used to Assess Direct and Indirect Effects and Adverse Modification to Critical Habitat

Toxicity Data Used to Evaluate Assessment Endpoint	Assessment Endpoint	Comment
Acute and chronic studies in freshwater fish	**Direct effects** to the Topeka shiner **Indirect effects**: Reduction in spawning habitat; reduction in food abundance	Most sensitive toxicity values used for direct effects assessment.
Acute and chronic studies in freshwater aquatic invertebrates and terrestrial invertebrates	**Indirect effects:** reduction in food supply **Adverse Modification**: **PCE No. 7,** adequate supply of invertebrate food base.	Toxicity value from the most sensitive species tested is initially used for RQ calculation; however, data across all species tested (particularly known food items) is also used in the effects determination.
Acute studies in vascular and non-vascular aquatic plants	Indirect effects via reduction in food supply, habitat, and primary productivity Adverse Modification: **PCE No. 3,** water quality such as dissolved oxygen levels and pH; **PCE No. 5**, presence of moderate in-stream cover such as aquatic plants.	Most sensitive vascular and non-vascular aquatic plant studies initially used for baseline RQ calculations; refinements include use of threshold concentrations to predict community-level effects.
Terrestrial plant toxicity data	Indirect effects via potential effects to habitat, reproduction, and water quality **Adverse Modification**: **PCE No. 3**, water quality such as temperature and suspended solids. **PCE No. 5**, presence of moderate cover such as woody debris and overhanging terrestrial vegetation; **PCE No. 6**, Sand, gravel, cobble, and silt substrates with amounts of fine sediment and substrate embeddedness that allows for nest building and maintenance of nests and eggs by native sunfishes and Topeka shiner;	Distribution of seedling emergence and vegetative vigor terrestrial plant data used in combination with toxicity data for woody vegetation, and riparian habitat characteristics.

Acute (short-term) and chronic (long-term) toxicity information is characterized based on registrant-submitted studies and a comprehensive review of the open literature on atrazine, consistent with the Overview Document (U.S. EPA, 2004). In addition to registrant-submitted and open literature toxicity information, indirect effects to the Topeka shiner, via impacts to aquatic plant community structure and function are also evaluated based on community-level threshold concentrations. Other sources of information, including use of the acute probit dose response relationship to establish the probability of an individual effect and reviews of the Ecological Incident Information System (EIIS), are conducted to further refine the characterization of potential ecological effects associated with exposure to atrazine.

A summary of the available freshwater and terrestrial organism ecotoxicity information, the community-level endpoints, use of the probit dose response relationship, and the incident information for atrazine are provided in Sections 4.1 through 4.9 . A summary of the available data directly used in this assessment is presented. A more comprehensive discussion of the available toxicity data are included in Appendix A of this assessment.

Atrazine degradates have been shown to be less toxic to aquatic organisms than atrazine. As shown in Table 4.2, comparison of available toxicity information for HA, DIA, and DACT indicates lesser aquatic toxicity than the parent for freshwater fish, invertebrates, and aquatic plants.

Table 4.2 Comparison of Acute Freshwater Toxicity Values for Atrazine and Degradates

Substance Tested	Fish LC_{50} (µg/L)	Daphnid EC_{50} (µg/L)	Aquatic Plant EC_{50} (µg/L)
Atrazine	5,300	3,500	1
HA	>3,000 (no effects at saturation)	>4,100 (no effects at saturation)	>10,000
DACT	>100,000	>100,000	No data
DIA	17,000	126,000 (NOAEC: 10,000)	2,500
DEA	No data	No data	1,000

Although degradate toxicity data are not available for terrestrial plants, lesser toxicity is assumed, given the available ecotoxicological information for other taxonomic groups including aquatic plants and the likelihood that the atrazine degradates are expected to lose efficacy as an herbicide.

Therefore, given the lesser toxicity of the degradates, as compared to the parent, concentrations of the atrazine degradates are not assessed, and the focus of this assessment is limited to parent atrazine. The available information also indicates that aquatic organisms are more sensitive to the technical grade (TGAI) than the formulated products of atrazine; therefore, the focus of this assessment is on the TGAI. A detailed summary of the available ecotoxicity information for all atrazine degradates and formulated products is presented in Appendix A.

As previously discussed in the problem formulation, the available toxicity data show that other pesticides may combine with atrazine to produce synergistic, additive, and/or antagonistic toxic interactions. The results of available toxicity data for mixtures of atrazine with other pesticides are presented in Section A.6 of Appendix A. Potential synergistic effects with atrazine have been demonstrated for a number of organophosphate insecticides including diazinon, chlorpyrifos, and methyl parathion, as well as herbicides including alachlor. If chemicals that show synergistic effects with atrazine are present in the environment in combination with atrazine, the toxicity of the atrazine mixture may be increased relative to the toxicity of each individual chemical, offset by other environmental factors, or even reduced by the presence of antagonistic contaminants if they are also present in the mixture. The variety of chemical interactions presented in the available data set suggest that the toxic effect of atrazine, in combination with other pesticides used in the environment, can be a function of many factors including but not necessarily limited to (1) the exposed species, (2) the co-contaminants in the mixture, (3) the ratio of atrazine and co-contaminant concentrations, (4) differences in the pattern and duration of exposure among contaminants, and (5) the differential effects of other physical/chemical characteristics of the receiving waters (e.g. organic matter present in sediment and suspended water). Quantitatively predicting the combined effects of all these variables on mixture toxicity to any given taxa with confidence is beyond the capabilities of the available data. However, a qualitative discussion of implications of the available pesticide mixture effects data involving atrazine on the confidence of risk assessment conclusions is addressed as part of the uncertainty analysis for this effects determination.

4.1 Ecotoxicity Study Data Sources

Toxicity endpoints are established based on data generated from guideline studies submitted by the registrant, and from open literature studies that meet the criteria for inclusion into the ECOTOX database maintained by EPA/Office of Research and Development (ORD) (U.S. EPA, 2004). Open literature data presented in this assessment were obtained from the 2003 atrazine IRED as well as ECOTOX information obtained on May 31, 2007. The May 2007 ECOTOX search included all open literature data for atrazine (i.e., pre- and post-IRED). In order to be included in the ECOTOX database, papers must meet the following minimum criteria:

- the toxic effects are related to single chemical exposure;
- the toxic effects are on an aquatic or terrestrial plant or animal species;
- there is a biological effect on live, whole organisms;
- a concurrent environmental chemical concentration/dose or application rate is reported; and
- there is an explicit duration of exposure.

Meeting the minimum criteria for inclusion in ECOTOX does not necessarily mean that the data are suitable for use in risk estimation. Data that pass the ECOTOX screen are evaluated along with the registrant-submitted data, and may be incorporated qualitatively or quantitatively into this endangered species risk assessment. In general, only effects data in the open literature that are more conservative than the registrant-submitted data are considered. Based on the results of the 2003 IRED for atrazine, potential adverse effects on sensitive aquatic plants and non-target aquatic organisms including their populations and communities, are not likely to occur if concentrations in water do not exceed approximately 10 to 20 μg/L on a recurrent basis or over a prolonged period of time (U.S. EPA, 2003a). Given the large amount of microcosm/mesocosm and field study data for atrazine, only effects data that are less than the 10 μg/L aquatic-community effect level identified in the 2003 atrazine IRED were considered. The degree to which open literature data are quantitatively or qualitatively characterized is dependent on whether the information is relevant to the assessment endpoints (i.e., maintenance of survival, reproduction, and growth; alteration of PCEs in the critical habitat impact analysis) identified in the problem formulation. For example, endpoints such as biochemical modifications are not likely to be used to calculate risk quotients unless it is possible to quantitatively link these endpoints with reduction in survival, reproduction, or growth (e.g., the magnitude of effect on the biochemical endpoint needed to result in effects on survival, growth, or reproduction is known).

Citations of all open literature not considered as part of this assessment because it was either rejected by the ECOTOX screen or accepted by ECOTOX but not used (e.g., the endpoint is less sensitive and/or not appropriate for use in this assessment) are included in Appendix E. Appendix E also includes a rationale for rejection of those studies that did not pass the ECOTOX screen and those that were not evaluated as part of this ESA.

As described in the Agency's Overview Document (U.S. EPA, 2004), the most sensitive endpoint for each taxa is used for RQ calculation. For this assessment, evaluated taxa include freshwater fish, freshwater aquatic invertebrates, freshwater aquatic plants, terrestrial plants, and terrestrial invertebrates. Table 4.3 summarizes the most sensitive ecological toxicity endpoints for the Topeka shiner and its designated critical habitat, based on an evaluation of both the submitted studies and the open literature, as previously discussed. Toxicity information used in this assessment are further described in Sections 4.2 to 4.9. Additional information on the available submitted and open literature toxicity studies is provided in Appendix A. Appendix A also includes ecotoxicity data for taxonomic groups that are not relevant to this assessment (i.e., birds, estuarine/marine organisms) because the Agency is completing endangered species risk assessments for other species concurrently with this assessment.

Table 4.3 Freshwater Aquatic and Terrestrial Plant Toxicity Profile for Atrazine

Assessment Endpoint	Species	Toxicity Value Used in Risk Assessment	Citation MRID # (Author & Date)	Comment
Direct Toxicity to Topeka Shiner; indirect effect via reduction in food supply; indirect effect via reduction in spawning habitat (fish, such as sunfish provide spawning habitat for the Topeka shiner)[a]	Rainbow Trout	96-hour LC_{50} = 5,300 µg/L **Probit slope = 2.72**	00024716 (Beliles and Scott, 1965)	Acceptable study
	Brook Trout	NOAEC = 65 µg/L LOAEC = 120 µg/L	00024377 (Macek et al., 1976)	Acceptable life-cycle study: 7.2% reduction in length; 16% reduction in weight occurred at the LOAEC
Indirect effects: reduction in food supply Adverse Modification: PCE No. 7, adequate supply of invertebrate food base.	Midge	LC50: 720 µg/L	00024377 Macek *et al*. 1976	Supplemental
	Scud	NOAEC = 60 µg/L LOAEC = 120 µg/L	00024377 (Macek et al., 1976)	Acceptable: 25 % reduction in development of F_1 to seventh instar at the LOAEC
Indirect effects via reduction in habitat and primary productivity; reduction in food supply Adverse Modification of critical habitat: PCE No. 3, water quality such as dissolved oxygen levels and pH; PCE No. 5, presence of moderate cover such as aquatic plants.	Freshwater algae	7-day EC_{50} = 1 µg/L	00023544 (Torres & O'Flaherty, 1976)	Supplemental study
	Duckweed	14-day EC_{50} = 37 µg/L	43074804 (Hoberg, 1993)	Supplemental study

Assessment Endpoint	Species	Toxicity Value Used in Risk Assessment	Citation MRID # (Author & Date)	Comment
Indirect Effects to Topeka Shiner resulting from potential effects to riparian habitat Adverse modification of critical habitat: PCE Nos. 3 and 5 as described for aquatic plants; PCE No. 6, Substrates with amounts of fine sediment and substrate embeddedness that allows for nest building and maintenance of nests and eggs by native sunfishes and Topeka shiner.	Oat (monocot)	Tier II Seedling Emergence EC_{25} = 0.004 lb ai/A	42041403 (Chetram, 1989)	Acceptable: EC_{25} based on reduction in dry weight
	Carrot (dicot)	Tier II Seedling Emergence EC_{25} = 0.003 lb ai/A	42041403 (Chetram, 1989)	Acceptable: EC_{25} based on reduction in dry weight

a Sunfish data are also used to characterize potential indirect effects to the Topeka shiner because sunfish are known to provide spawning habitat. Sunfish data are described in Section 5 and in Appendix A.

Toxicity to fish and aquatic invertebrates is categorized using the system shown in Table 4.4 (U.S. EPA, 2004). Toxicity categories for aquatic plants have not been defined.

Table 4.4 Categories of Acute Toxicity for Aquatic Organisms

LC/EC_{50} (mg/L)	Toxicity Category
< 0.1	Very highly toxic
> 0.1 - 1	Highly toxic
> 1 - 10	Moderately toxic
> 10 - 100	Slightly toxic
> 100	Practically nontoxic

4.2. Toxicity to Freshwater Fish

4.2.1. Acute Exposure (Mortality) Studies

Freshwater fish acute toxicity studies were used to assess potential direct effects to the Topeka shiner. Atrazine toxicity has been evaluated in numerous freshwater fish species, including rainbow trout, brook trout, bluegill sunfish, fathead minnow, tilapia, zebrafish, goldfish, and carp. The results of these studies demonstrate a wide range of sensitivity. The range of acute freshwater fish LC_{50} values for atrazine spans one order of magnitude, from 5,300 to 60,000 µg/L; therefore, atrazine is categorized as moderately (>1,000 to 10,000 µg/L) to slightly (>10,000 to 100,000 µg/L) toxic to freshwater fish on an acute basis. The freshwater fish acute LC_{50} value of 5,300 µg/L is based on a static 96-hour toxicity test using rainbow trout (*Oncorhynchus mykiss*) (MRID 00024716).

Sunfish data are also used to evaluate potential indirect effects to the Topeka shiner because sunfish are known to provide spawning habitat to the Topeka shiner. Sunfish LC50s range from >8,000 ug/L (00024377) to 57,000 ug/L (MRID 00147125). Details of these studies along with a complete list of all available freshwater fish toxicity data considered for this assessment is provided in Appendix A.

4.2.2. Chronic Exposure (Growth/Reproduction) Studies

Chronic freshwater fish toxicity studies were used to assess potential direct effects to the Topeka shiner via potential effects to growth and reproduction. Freshwater fish life-cycle studies for atrazine are available and summarized in Table A-12 of Appendix A. Following 44 weeks of exposure to atrazine in a flow-through system, statistically significant reductions in brook trout mean length (7.2%) and body weight (16%) were observed at a concentration of 120 µg/L, as compared to the control (MRID 00024377). The corresponding NOAEC for this study is 65 µg/L. Although the acute toxicity data for atrazine show that rainbow trout are the most sensitive freshwater fish, available chronic rainbow trout toxicity data indicate that it is less sensitive to atrazine, on a chronic exposure basis than the brook trout with respective LOAEC and NOAEC values of 1,100 µg/L and 410 µg/L. Further information on chronic freshwater fish toxicity data for atrazine is provided in Section A.2.2 of Appendix A.

Sunfish data are also used to evaluate potential indirect effects to the Topeka shiner because sunfish are known to provide spawning habitat to the Topeka shiner. A life-cycle NOAEC of 95 ug/L was reported in sunfish. Details of these studies along with a complete list of all available freshwater fish toxicity data considered for this assessment is provided in Appendix A.

4.2.3. Sublethal Effects and Additional Open Literature Information

In addition to registrant submitted studies, data were located in the open literature that report sublethal effect levels to freshwater fish that are less than the selected measures of effect summarized in Table 4.2. Although these studies report potentially sensitive endpoints, effects on survival, growth, or reproduction were not observed in the available life-cycle studies at concentrations that induced the reported sublethal effects described below and in Appendix A.

Reported sublethal effects in rainbow trout show increased plasma vitellogenin levels in both female and male fish and decreased plasma testosterone levels in male fish at atrazine concentrations of approximately 50 µg/L (Wieser and Gross, 2002 [MRID 456223-04]). Vitellogenin (Vtg) is an egg yolk precursor protein expressed normally in female fish and dormant in male fish. The presence of Vtg in male fish is used as a molecular marker of exposure to estrogenic chemicals. It should be noted, however, that there is a high degree of variability with the Vtg effects in these studies, which confounds the ability to resolve the effects of atrazine on plasma steroids and vitellogenesis.

Effects of atrazine on freshwater fish behavior, including a preference for the dark part of the aquarium following one week of exposure (Steinberg et al., 1995 [MRID 452049-10]) and a reduction in grouping behavior following 24-hours of exposure (Saglio and Trijase, 1998 [MRID 452029-14]), have been observed at atrazine concentrations of 5 µg/L. In addition, alterations in rainbow trout kidney histology have also been observed at atrazine concentrations of 5 µg/L and higher (Fischer-Scherl et al., 1991 [MRID 452029-07]).

In salmon, atrazine effects on gill physiology and endocrine-mediated olfactory functions have been studied. Data from Waring and Moore (2004; ECOTOX #72625) suggest that salmon smolt gill physiology, represented by changes in Na-K-ATPase activity and increased sodium and potassium levels, was altered at 1 μg/L atrazine and higher. However, the Topeka shiner occurs in freshwater habitats; therefore, seawater survival is not a relevant endpoint for this assessment. Moore and Lower (2001; ECOTOX #67727) reported that endocrine-mediated functions of male salmon parr were affected at 0.5 μg/L atrazine. The reproductive priming effect of the female pheromone prostaglandin $F_{2\alpha}$ on the levels of expressible milt in males was reduced after exposure to atrazine at 0.5 μg/L. Although the hypothesis was not tested, the study authors suggest that exposure of smolts to atrazine during the freshwater stage may potentially affect olfactory imprinting to the natal river and subsequent homing of adults. However, no quantitative relationship is established between reduced olfactory response of male epithelial tissue to the female priming hormone in the laboratory and reduction in salmon reproduction (i.e., the ability of male salmon to detect, respond to, and mate with ovulating females). A negative control was not included as part of the study design; therefore, potential solvent effect cannot be evaluated. Furthermore, the study did not determine whether the decreased response of olfactory epithelium to specific chemical stimuli would likely impair similar responses in intact fish.

Tierney et al. (2007) studied the effect of 30 minute exposure to atrazine on behavioral and neurophysiological responses of juvenile rainbow trout to an amino acid odorant (L-histidine at 10^{-7} M). L-histidine was chosen because it has been shown to elicit an avoidance response in salmonids; however, control fish exposed to L-histidine at 10^{-7} M showed a slight preference (1.2 response ratio). Although the study authors conclude that L-histidine preference behavior was altered by atrazine at exposures $\geq$ 1 ug/L, no significant decreases in preference behavior were observed at 1 ug/L. Furthermore, no dose response relationship was observed in the behavioral response following pesticide exposure. At 1 and 100 ug/L, non-significant decreases in L-histidine preference were observed; however a statistically significant avoidance of L-histidine was observed at 10 ug/L, but not 100 ug/L. Hyperactivity (measured as the number of times fish crossed the centerline of the tank) was observed in trout exposed to 1 and 10 ug/L atrazine. In the study measuring neurophysiological responses following atrazine exposure, electro-olfactogram (EOG) response was significantly reduced (EOG measures changes in nasal epithelial voltage due to response of olfactory sensory neurons). Although this study produced a more sensitive effects endpoint for freshwater fish, the data were not used quantitatively in the risk assessment because of the following reasons: 1) A negative control was not used; therefore, potential solvent effects cannot be evaluated; 2) The study did not determine whether the decreased response of olfactory epithelium to specific chemical stimuli would likely impair similar responses in intact fish; and 3) A quantitative relationship between the magnitude of reduced olfactory response to an amino acid odorant in the laboratory and reduction in trout imprinting and homing, alarm response, and reproduction (i.e., the ability of trout to detect, respond to, and mate with ovulating females) in the wild is not established.

Although these studies raise questions about the effects of atrazine on plasma steroid levels, behavior modifications, gill physiology, and endocrine-mediated functions in freshwater and anadromous fish, it is not possible to quantitatively link these sublethal effects to the selected assessment endpoints for the Topeka shiner (i.e., survival, growth, and reproduction of individuals). Also, effects on survival, growth, or reproduction were not observed in the available life-cycle studies at concentrations that induced these reported sublethal effects. Therefore, potential sublethal effects on fish are not used as part of the quantitative risk characterization. Further detail on sublethal effects to fish is provided in Sections A.2.4a and A.2.4b of Appendix A.

4.3 Toxicity to Freshwater Invertebrates

The Topeka shiner is an opportunistic omnivore, which means they typically eat what is available to them. However, a predominant component of its diet has been documented to be aquatic invertebrates (Dahle, 2001). Toxicity data for the most sensitive freshwater invertebrate tested are used to assess: (1) potential indirect effects of atrazine to the Topeka shiner via reduction in available food; and (2) potential effects to designated critical habitat (PCE No. 7, adequate supply of invertebrate food base).

4.3.1. Acute Exposure Studies

Atrazine is classified as highly toxic to slightly toxic to aquatic invertebrates. A wide range of EC_{50}/LC_{50} values have been reported for freshwater invertebrates with values ranging from 720 to >33,000 μg/L. The lowest freshwater LC_{50} value of 720 μg/L is based on an acute 48-hour static toxicity test for the midge, *Chironomus tentans* (MRID 000243-77). Further evaluation of the available acute toxicity data for the midge shows high variability with the LC_{50} values, ranging from 720 to >33,000 μg/L. With the exception of the midge, reported acute toxicity values for the other five freshwater invertebrates tested (including the water flea, scud, stonefly, leech, and snail) are 3,500 μg/L and higher. Further evaluation of the available acute toxicity data for the water flea also shows high variability similar to other freshwater invertebrates with LC_{50} values ranging from 3,500 to >30,000 μg/L. All of the available acute toxicity data for freshwater invertebrates are provided in Section A.2.5 and Table A-18 of Appendix A. The LC_{50}/EC_{50} distribution for freshwater invertebrates is graphically represented in Figure 4.1. The columns represent the lowest reported value for each species, and the positive y error bar represents the maximum reported value. Values in parentheses represent the number of studies included in the analyses.

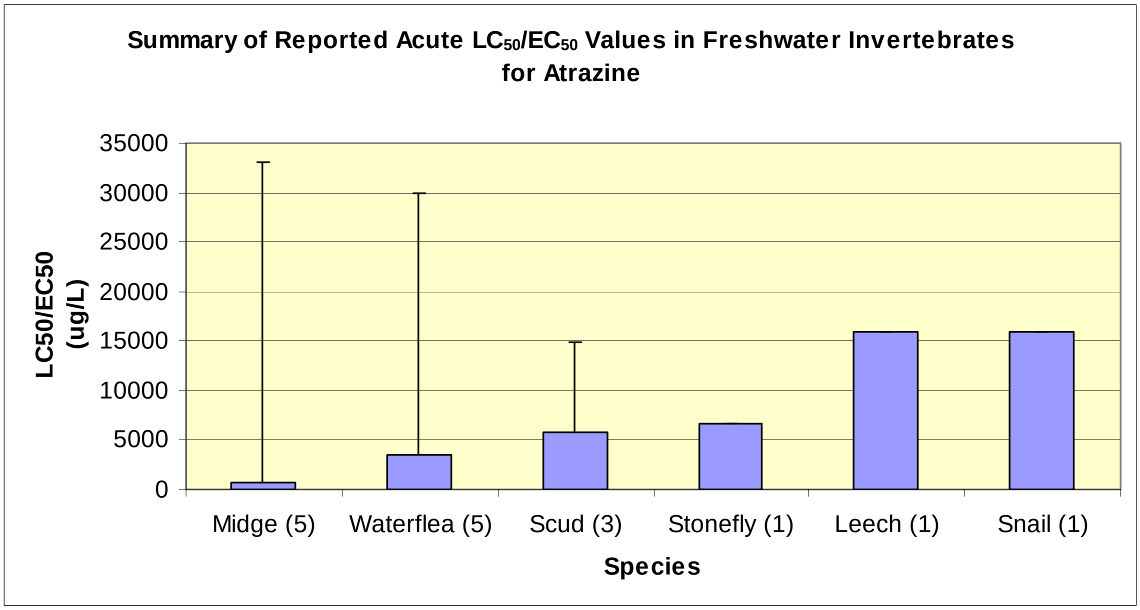

Figure 4.1 Summary of Reported Acute LC_{50}/EC_{50} Values in Freshwater Invertebrates for Atrazine

4.3.2 Chronic Exposure Studies

The most sensitive chronic endpoint for freshwater invertebrates is based on a 30-day flow-through study on the scud (*Gammarus fasciatus*), with respective NOAEC and LOAEC values of 60 and 140 µg/L, based on a 25% reduction in the development of F_1 to the seventh instar (MRID 00024377) (see Section 4.1.1.2). Although the acute toxicity data for atrazine show that the midge (*Chironomus tentans*) is the most sensitive freshwater invertebrate, available chronic midge toxicity data indicate that it is less sensitive to atrazine, on a chronic exposure basis, than the scud, with respective LOAEC and NOAEC values of 230 µg/L and 110 µg/L. Additional information on the chronic toxicity of atrazine to freshwater invertebrates is provided in Section A.2.6 and Table A-20 of Appendix A.

4.4 Toxicity to Aquatic Plants

Aquatic plant toxicity studies were used as one of the measures of effect to evaluate whether atrazine may affect primary production. Aquatic plants may also serve as a dietary item of the Topeka shiner. In addition, freshwater vascular and non-vascular plant data are used to evaluate a number of the PCEs associated with the critical habitat impact analysis. The following PCEs are evaluated using aquatic plant toxicity data:

- Streams and side-channel pools with water quality necessary for unimpaired behavior, growth, and viability of all life stages. The water quality components can vary seasonally and include--temperature (1 to 30[deg]Centigrade), total suspended solids (0 to 2000 ppm), conductivity (100 to 800 mhos), dissolved oxygen (4 ppm or greater), pH (7.0 to 9.0), and other chemical characteristics;

- Living areas for juvenile Topeka shiners with water velocities less than 0.5 meters/second (approx. 20 inches/second) with depths less than 0.25 meters (approx. 10 inches) and moderate amounts of instream aquatic cover, such as woody debris, overhanging terrestrial vegetation, and aquatic plants;

Two types of studies were used to evaluate the potential of atrazine to affect primary productivity. Laboratory studies were used to determine whether atrazine may cause direct effects to aquatic plants. In addition, the community-level effect threshold concentrations, described in Section 4.7, were used to further characterize potential community-level effects resulting from potential effects to aquatic plants. A summary of the laboratory data and field data for aquatic plants is provided in Sections 4.4.1 and 4.4.2.

4.4.1. Laboratory Data

Numerous aquatic plant toxicity studies have been submitted to the Agency. A summary of the data for freshwater vascular and non-vascular plants is provided below. Section A.4.2 and Tables A-40 and A-41 of Appendix A include a more comprehensive description of these data.

The Tier II results for freshwater aquatic plants produced EC_{50} values for four different species of freshwater algae at concentrations as low as 1 μg/L, based on data from a 7-day acute study (MRID 00023544). Vascular plants are less sensitive to atrazine than freshwater non-vascular plants with an EC_{50} value of 37 μg/L, based on reduction in duckweed growth (MRID 43074804).

Comparison of atrazine toxicity levels for three different endpoints in algae suggests that the endpoints in decreasing order of sensitivity are cell count, growth rate and oxygen production (Stratton, 1984). Walsh (1983) exposed *Skeletonema costatum* to atrazine and concluded that atrazine is only slightly algicidal at relatively high concentrations (i.e., 500 and 1,000 μg/L). Caux et al. (1996) compared the cell count IC_{50} and fluorescence LC_{50} and concluded that atrazine is algicidal at concentrations affecting cell counts.

Abou-Waly et al. (1991) measured growth rates on days 3, 5, and 7 for two algal species. The pattern of atrazine effects on growth rates differs sharply between the two species. Atrazine had a strong early effect on *Anabaena flos-aquae* followed by rapid recovery in clean water (i.e., EC_{50} values for days 3, 5, and 7 are 58, 469, and 766 µg/L, respectively). The EC_{50} values for *Selenastrum capricornutum* continued to decline from day 3 through 7 (i.e., 283, 218, and 214 µg/L, respectively). Based on these results, it appears that the timing of peak effects for atrazine may differ depending on the test species.

It should be noted that recovery from the effects of atrazine and the development of resistance to the effects of atrazine in some vascular and non-vascular aquatic plants have been reported and may add uncertainty to these findings. However, reports of recovery are often based on differing interpretations of recovery. Thus, before recovery can be considered as an uncertainty, an agreed upon interpretation is needed. For the purposes of this assessment, recovery is defined as a return to pre-exposure levels for the *affected population*, not for a replacement population of more tolerant species. Further research would be necessary in order to quantify the impact that recovery and resistance would have on aquatic plants.

4.4.2. Freshwater Field Studies

Microcosm and mesocosm studies with atrazine provide measurements of primary productivity that incorporate the aggregate responses of multiple species in aquatic plant communities. Because plant species vary widely in their sensitivity to atrazine, the overall response of the plant community may be different from the responses of the individual species measured in laboratory toxicity tests. Mesocosm and microcosm studies allow observation of population and community recovery from atrazine effects and of indirect effects on higher trophic levels. In addition, mesocosm and microcosm studies, especially those conducted in outdoor systems, incorporate partitioning, degradation, and dissipation, factors that are not usually accounted for in laboratory toxicity studies, but that may influence the magnitude of ecological effects.

Atrazine has been the subject of many mesocosm and microcosm studies in ponds, streams, lakes, and wetlands. The durations of these studies have ranged from a few weeks to several years at exposure concentrations ranging from 0.1 µg/L to 10,000 µg/L. Most of the studies have focused on atrazine effects on phytoplankton, periphyton, and macrophytes; however, some have also included measurements on animals.

As described in the 2003 IRED for atrazine (U.S. EPA, 2003a), potential adverse effects on sensitive aquatic plants and non-target aquatic organisms including their populations and communities are likely to be greatest when atrazine concentrations in water equal or exceed approximately 10 to 20 µg/L on a recurrent basis or over a prolonged period of time. A summary of all the freshwater aquatic microcosm, mesocosm, and field studies that were reviewed as part of the 2003 IRED is included in Section A.2.8a and Tables A-22 through A-24 of Appendix A. Given the large amount of microcosm and mesocosm and field study data for atrazine, only effects data less than or more conservative than the

10 µg/L aquatic community effect level identified in the 2003 IRED were considered from the open literature search that was completed in October 2006. Based on the selection criteria for review of new open literature, all of the available studies show effects levels to freshwater fish, invertebrates, and aquatic plants at concentrations greater than 10 µg/L.

It should be noted that the 10 to 20 µg/L community effect level has been further refined, since completion of the 2003 IRED. The community-level effects thresholds for various durations of exposure from 14 to 90 days are described in further detail in Section 4.2. In summary, the potential for atrazine to induce community-level effects depends on both atrazine concentration and duration. As the exposure duration increases, atrazine concentrations that may produce community level effects decrease. For example, 14-day atrazine concentrations of 38 µg/L or lower are not considered likely to result in aquatic community level effects, whereas 90-day atrazine concentrations of 12 µg/L or lower are not expected to produce community level effects.

Community-level effects to aquatic plants that are likely to result in indirect effects to the rest of the aquatic community are evaluated based on threshold concentrations. These threshold concentrations, which are discussed in greater detail in Section 4.2, incorporate the available micro- and mesocosm data included in the 2003 IRED (U.S. EPA, 2003a) as well as additional information gathered following completion of the 2003 atrazine IRED (U.S. EPA, 2003e).

4.5. Toxicity to Terrestrial Plants

Terrestrial plant toxicity data are used to evaluate the potential for atrazine to affect riparian zone vegetation within the action area. Riparian zone effects may impact water quality characteristics, which could impact the Topeka shiner. In addition, several PCEs associated with designated critical habitat are associated with the presence of riparian vegetation.

- Streams and side-channel pools with water quality necessary for unimpaired behavior, growth, and viability of all life stages. The water quality components can vary seasonally and include--temperature (1 to 30[deg]Centigrade), total suspended solids (0 to 2000 ppm), conductivity (100 to 800 mhos), dissolved oxygen (4 ppm or greater), pH (7.0 to 9.0), and other chemical characteristics;

- Living areas for juvenile Topeka shiners with water velocities less than 0.5 meters/second (approx. 20 inches/second) with depths less than 0.25 meters (approx. 10 inches) and moderate amounts of instream aquatic cover, such as woody debris, overhanging terrestrial vegetation, and aquatic plants;

- Sand, gravel, cobble, and silt substrates with amounts of fine sediment and substrate embeddedness that allows for nest building and maintenance of nests and eggs by native Lepomis sunfishes (green sunfish, orangespotted sunfish, longear sunfish) and Topeka shiner as necessary for reproduction, unimpaired behavior, growth, and viability of all life stages;

Plant toxicity data from both registrant-submitted studies and studies in the scientific literature were reviewed for this assessment. Registrant-submitted studies are conducted under conditions and with species defined in EPA toxicity test guidelines. Sub-lethal endpoints such as plant growth, dry weight, and biomass are evaluated for both monocots and dicots, and effects are evaluated at both seedling emergence and vegetative life stages. Guideline studies generally evaluate toxicity to ten crop species. A drawback to these tests is that they are conducted on herbaceous crop species only, and extrapolation of effects to other species, such as the woody shrubs and trees and wild herbaceous species, contributes uncertainty to risk conclusions. Atrazine is labeled for use on conifers and softwoods; therefore, effects to evergreens would not be anticipated at exposure concentrations less than the application rate. In addition, preliminary data submitted to the Agency (discussed below) suggests that sensitive woody plant species exist; however, damage to most woody species at labeled application rates of atrazine is not expected.

Commercial crop species have been selectively bred, and may be more or less resistant to particular stressors than wild herbs and forbs. The direction of this uncertainty for specific plants and stressors, including atrazine, is largely unknown. Homogenous test plant seed lots also lack the genetic variation that occurs in natural populations; therefore, the range of effects seen from these tests is likely to be smaller than would be expected from wild populations.

Based on the results of the submitted terrestrial plant toxicity tests, it appears that seedlings are more sensitive to atrazine via soil/root uptake exposure than emerged plants via foliar routes of exposure. However, all tested plants, with the exception of corn in the seedling emergence and vegetative vigor tests and ryegrass in the vegetative vigor test, exhibited adverse effects following exposure to atrazine. Tables 4.5 and 4.6 summarize the respective seedling emergence and vegetative vigor terrestrial plant toxicity data used to derive risk quotients in this assessment.

In Tier II seedling emergence toxicity tests, the most sensitive monocot and dicot species are oats and carrots, respectively. EC_{25} values for carrots and oats, which are based on a reduction in dry weight, are 0.003 and 0.004 lb ai/A, respectively; NOAEC values for both species are 0.0025 lb ai/A. Dry weight was the most sensitive parameter evaluated; emergence was not significantly affected at any level tested.

For Tier II vegetative vigor studies, the most sensitive dicot and monocot species are the cucumber and onion, respectively. In general, dicots appear to be more sensitive than monocots via foliar routes of exposure with all tested dicot species showing a significant reduction in dry weight at EC_{25} values ranging from 0.008 to 0.72 lb ai/A. In contrast, two of the four tested monocots showed no effect to atrazine (corn and ryegrass), while EC_{25} values for onion and oats were 0.61 and 2.4 lb ai/A, respectively.

Table 4.5 Non-target Terrestrial Plant Seedling Emergence Toxicity (Tier II) Data (Chetram, 1989; MRID 42041403)

Surrogate Species	% ai	EC_{25} / NOAEC (lbs ai/A)	Endpoint Affected	Study Classification
Monocot - Corn (*Zea mays*)	97.7	> 4.0 / > 4.0	No effect	Acceptable
Monocot - Oat (*Avena sativa*)	97.7	**0.004 / 0.0025**	red. in dry weight	Acceptable
Monocot - Onion (*Allium cepa*)	97.7	0.009 / 0.005	red. in dry weight	Acceptable
Monocot - Ryegrass (*Lolium perenne*)	97.7	0.004 / 0.005	red. in dry weight	Acceptable
Dicot - Root Crop - Carrot (*Daucus carota*)	97.7	**0.003 / 0.0025**	red. in dry weight	Acceptable
Dicot - Soybean (*Glycine max*)	97.7	0.19 / 0.025	red. in dry weight	Acceptable
Dicot - Lettuce (*Lactuca sativa*)	97.7	0.005 / 0.005	red. in dry weight	Acceptable
Dicot - Cabbage (*Brassica oleracea alba*)	97.7	0.014 / 0.01	red. in dry weight	Acceptable
Dicot - Tomato (*Lycopersicon esculentum*)	97.7	0.034 / 0.01	red. in dry weight	Acceptable
Dicot - Cucumber (*Cucumis sativus*)	97.7	0.013 / 0.005	red. in dry weight	Acceptable

Table 4.6 Non-target Terrestrial Plant Vegetative Vigor Toxicity (Tier II) Data (Chetram, 1989; MRID 42041403)

Surrogate Species	% ai	EC_{25} / NOAEC (lbs ai/A)	Endpoint Affected	Study Classification
Monocot - Corn	97.7	> 4.0 / > 4.0	No effect	Acceptable
Monocot - Oat	97.7	2.4 / 2.0	red. in dry weight	Acceptable
Monocot - Onion	97.7	**0.61 / 0.5**	red. in dry weight	Acceptable
Monocot - Ryegrass	97.7	> 4.0 / > 4.0	No effect	Acceptable
Dicot - Carrot	97.7	1.7 / 2.0	red. in plant height	Acceptable
Dicot - Soybean	97.7	0.026 / 0.02	red. in dry weight	Acceptable
Dicot - Lettuce	97.7	0.33 / 0.25	red. in dry weight	Acceptable
Dicot - Cabbage	97.7	0.014 / 0.005	red. in dry weight	Acceptable
Dicot - Tomato	97.7	0.72 / 0.5	red. in plant height	Acceptable
Dicot - Cucumber	97.7	**0.008 / 0.005**	red. in dry weight	Acceptable

In addition, a report on the toxicity of atrazine to woody plants (Wall et al., 2006; MRID 46870401) was reviewed by the Agency. A total of 35 species were tested at application rates ranging from 1.5 to 4.0 lbs ai/A. Twenty-eight species exhibited either no or negligible phytotoxicity. Seven of 35 species exhibited >10% phytotoxicity. However, further examination of the data indicate that atrazine application was clearly associated with severe phytotoxicity in only one species (Shrubby Althea). These data suggest that, although sensitive woody plants exist, atrazine exposure to most woody plant species at application rates of 1.5 to 4.0 lbs ai/A is not expected to cause adverse effects. A summary of the available woody plant data is provided in Table A-39b of Appendix A.

4.6. Toxicity to Terrestrial Invertebrates

Terrestrial invertebrate toxicity data are used to evaluate potential indirect effects to the Topeka shiner and to adversely modify designated critical habitat (PCE 7 - an adequate terrestrial, semiaquatic, and aquatic invertebrate food base that allows for unimpaired growth, reproduction, and survival of all life stages). A summary of the available terrestrial insect data is summarized in Table 4.7 below. Additional details on the data are included in Appendix A.

Atrazine is practically non-toxic to honey bees (LD50: 97 ug/bee). It also did not cause adverse effects in fruit flies exposed to 15 ug/fly. LC50 values in earthworms ranged from 273 to 926 ppm soil (Mosleh et al., 2003; Haque and Ebing, 1983). Atrazine did not produce statistically significant ($p<0.05$) adverse effects in studies on several beetle species at any level tested, which ranged from application rates of approximately 1 lb a.i./Acre to 8 lbs a.i./Acre (Kegel, 1989; Brust, 1990; Samsoe-Petersen, 1995).

The most sensitive terrestrial invertebrate species tested was the springtail (*Onychiurus apuanicus* and *O. armatus*). Exposure to *O. apuanicus* at 2.5 ppm resulted in 18% mortality, and exposure to *O. armatus* at 20 ppm resulted in 51% mortality (Mola et al., 1987); lower levels were not tested. These soil concentrations are associated with an application rate of approximately 1 lb a.i./Acre and 7 lbs a.i./Acre, respectively, assuming a soil density of 1.3 grams/cm^3 and a soil depth of 3 cm. Additional details on these studies may be found in Appendix A.

Available terrestrial insect toxicity data are summarized in Table 4.7.

Table 4.7. Summary of Available Terrestrial Invertebrate Toxicity Studies

Species	Toxicity Summary	Comment	Citation
Beetles	NOAECs ranged from 0.8 lbs a.i./Acre to 8 lbs a.i./Acre	Soil sprayed with atrazine at levels that ranged from 0.8 to 8 lbs a.i./Acre did not result in statistically significant ($p<0.05$) reductions in survival. LOAEC: Not achieved	Kegel, 1989 Ecotox No. 64007 Brust, 1990 Ecotox No. 70406 Samsoe-Petersen, 1995 Ecotox No. 63490
Earthworms	28-day LC50: 381 mg/kg soil 14-Day LC50: 273- 926 mg/kg soil	Spiked soil studies; endpoints included mortality and body mass	Mosleh et al., 2003 Ecotox No. 77549 Haque and Ebing, 1983 Ecotox No. 40493
Micro arthropods	NOAEC: 0.9 – 1.8 lbs/Acre LOAEC: 5.4 lbs a.i./Acre	The LOAEC was based on reduced abundance from a field study (Fretello et al., 1985); it could not be determined if reduced abundance was caused by migration (repellency), by toxic effects, or both.	Cortet et al., 2002 Ecotox No. 75784 Fratello et. al., 1985 Ecotox No. 59428
Springtails	30-Day LD50: 17 ppm to 20 ppm (approximately 7 lbs a.i./Acre)[a] LOAEC: 2.5 - 20 ppm soil (approx. 1 – 7 lbs/Acre)[a]	Exposure occurred via treated soil; mortality rate at 2.5 and 20 was 18% and 51%, respectively, compared with 0% in controls.	Mola et al., 1987. Ecotox No. 71417
Fruit flies *Drosphilia*	NOAEC: 15 ug/fly	No increased mortality occurred in groups exposed to atrazine alone relative to controls.	Lichtenstein et al., 1973 Ecotox No. 2939
Honey bees	LD50: >97 ug/bee	5% mortality occurred at the highest dose tested (97 ug/bee)	MRID 00036935
Earthworm Wire worm Springtail	LOAEC: 8 lb/acre NOAEC: Not achieved	Field study examining the impacts of several herbicides on soil invertebrate populations. The endpoint measured was abundance of several species. Study authors suggested that reduced abundance was likely caused by repellency and not direct toxicity.	Fox, 1964 Ecotox No. 36668

a Application rate was estimated from soil concentration by assuming a soil density of 1.3 grams/cm^3 and a soil depth of 3 cm.

4.7 Community-Level Endpoints: Threshold Concentrations

Direct and indirect effects to the Topeka shiner are evaluated in accordance with the screening level methodology described in the Agency's Overview Document (U.S. EPA, 2004). If aquatic plant RQs exceed the Agency's non-listed species LOC (because the Topeka shiner does not have an obligate relationship with any one particular plant species, but rather rely on multiple plant species), based on available EC_{50} data for vascular and non-vascular plants, risks to individual aquatic plants are assumed.

It should be noted, however, that the indirect effects and components of the critical habitat impact analyses in this assessment are unique, in that the best available information for atrazine-related effects on aquatic communities is significantly more extensive than for other pesticides. Hence, atrazine effects determinations can utilize more refined data than is generally available to the Agency. Specifically, a robust set of microcosm and mesocosm data and aquatic ecosystem models are available for atrazine that allowed EPA to refine the indirect effects and critical habitat impact analysis associated with potential aquatic community-level effects (via aquatic plant community structural change and subsequent habitat modification) to the Topeka shiner. Use of such information is consistent with the guidance provided in the Overview Document (U.S. EPA, 2004), which specifies that "the assessment process may, on a case-by-case basis, incorporate additional methods, models, and lines of evidence that EPA finds technically appropriate for risk management objectives" (Section V, page 31 of EPA, 2004). This information, which represents the best scientific data available, is described in further detail below and in previous effects determinations for atrazine (U.S. EPA 2006c,d,e). This information is also considered a refinement of the 10-20 µg/L range reported in the 2003 IRED (U.S. EPA, 2003a).

The Agency has selected an atrazine level of concern (LOC) in the 2003 IRED (U.S. EPA, 2003a and b) that is consistent with the approach described in the Office of Water's (OW) draft atrazine aquatic life criteria (U.S. EPA, 2003c). Through these previous analyses (U.S. EPA, 2003a, b, and c), which reflect the current best available information, predicted or monitored aqueous atrazine concentrations can be interpreted to determine if a water body is likely to be significantly affected via indirect effects to the aquatic community. Potential impacts of atrazine to plant community structure and function that are likely to result in indirect effects to the rest of the aquatic community, including the Topeka shiner, are evaluated as described below.

As described further in U.S. EPA (2006c,d,e), responses in microcosms and mesocosms exposed to atrazine were evaluated to differentiate no or slight, recoverable effects from significant, generally non-recoverable effects (U.S. EPA, 2003e). Because effects varied with exposure duration and magnitude, there was a need for methods to predict relative differences in effects for different types of exposures. The Comprehensive Aquatic Systems Model (CASM) (Bartell et al., 2000; Bartell et al., 1999; DeAngelis et al., 1989) was selected as an appropriate tool to predict these relative effects, and was configured to provide a simulation for the entire growing season of a 2nd and 3rd order Midwestern stream as a function of atrazine exposure. CASM simulations conducted for the concentration/duration exposure profiles of the micro- and mesocosm data showed that CASM seasonal output, represented as an aquatic plant community similarity index, correlated with the micro- and mesocosm effect scores, and that a 5% change in this index reasonably discriminated micro- and mesocosm responses with slight versus significant effects. The CASM-based index was assumed to be applicable to more diverse exposure conditions beyond those present in the micro- and mesocosm studies.

To avoid having to repeatedly run CASM, simulations were conducted for a variety of actual and synthetic atrazine chemographs to determine 14-, 30-, 60-, and 90-day average concentrations that discriminated among exposures that were unlikely to exceed the CASM-based index (i.e., 5% change in the index). It should be noted that the average 14-, 30-, 60-, and 90-day concentrations were originally intended to be used as screening values to trigger a CASM run (which is used as a tool to identify the 5% index change LOC), rather than actual thresholds to be used as an LOC (U.S. EPA, 2003e). The following threshold concentrations for atrazine were identified (U.S. EPA, 2003e):

- 14-day average = 38 µg/L
- 30-day average = 27 µg/L
- 60-day average = 18 µg/L
- 90-day average = 12 µg/L

Effects of atrazine on aquatic plant communities that have the potential to subsequently pose indirect effects to the Topeka shiner and its designated critical habitat are best addressed using the robust set of micro- and mesocosm studies available for atrazine and the associated risk estimation techniques (U.S. EPA, 2003a, b, c, and e). The 14-, 30-, 60-, and 90-day threshold concentrations developed by EPA (2003e) are used to evaluate potential indirect effects to aquatic communities for the purposes of this ESA. Use of these threshold concentrations is considered appropriate because: (1) the CASM-based index meets the goals of the defined assessment endpoints for this assessment; (2) the threshold concentrations provide a reasonable surrogate for the CASM index; and (3) the additional conservatism built into the threshold concentration, relative to the CASM-based index, is appropriate for an endangered species risk assessment (i.e., the threshold concentrations were set to be conservative, producing a low level (1%) of false negatives relative to false positives). Therefore, these threshold concentrations are used to identify potential indirect effects (via aquatic plant community structural change) to the Topeka shiner and its designated critical habitat. If modeled atrazine EECs exceed the 14-, 30-, 60- and 90-day threshold concentrations following refinements of potential atrazine concentrations with available monitoring data, CASM could be employed to further characterize the potential for indirect effects. A step-wise data evaluation scheme incorporating the use of the threshold concentrations is provided in Figure 4.2.

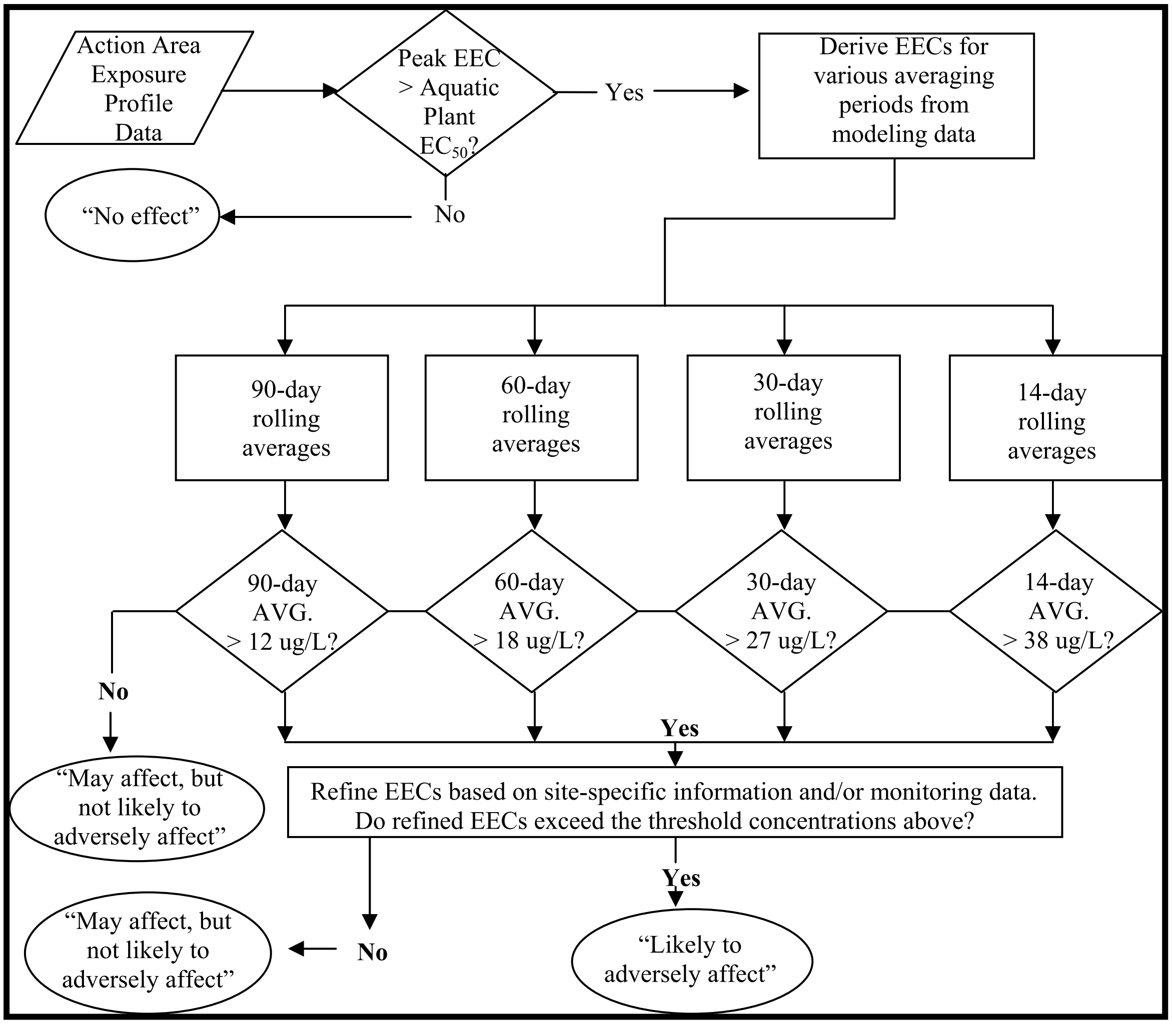

Figure 4.2 Use of Threshold Concentrations in Endangered Species Assessment

4.8 Use of Probit Slope Dose-Response Relationship to Provide Information on the Endangered Species Levels of Concern

The Agency uses the probit dose-response relationship as a tool for providing additional information on the potential for acute direct effects to individual listed species and aquatic animals that may indirectly affect the listed species of concern (U.S. EPA, 2004). As part of the risk characterization, an interpretation of acute RQ for listed species is discussed. This interpretation is presented in terms of the chance of an individual event (i.e., mortality or immobilization) should exposure at the EEC actually occur for a species with sensitivity to atrazine on par with the acute toxicity endpoint selected for RQ calculation. To accomplish this interpretation, the Agency uses the slope of the dose response relationship available from the toxicity study used to establish the acute toxicity measures of effect for each taxonomic group that is relevant to this assessment. The individual effects probability associated with the acute RQ is based on the mean estimate of the slope and an assumption of a probit dose response relationship. In addition to a single effects probability estimate based on the mean, upper and lower estimates of the effects probability are also provided to account for variance in the slope, if available.

The upper and lower bounds of the effects probability are based on available information on the 95% confidence interval of the slope. Studies with good probit fit characteristics (i.e., statistically appropriate for the data set) are associated with a high degree of confidence. Conversely, a low degree of confidence is associated with data from studies that do not statistically support a probit dose response relationship. In addition, confidence in the data set may be reduced by high variance in the slope (i.e., large 95% confidence intervals), despite good probit fit characteristics. In the event that dose response information is not available to estimate a slope, a default slope assumption of 4.5 (lower and upper bounds of 2 to 9) (Urban and Cook, 1986) is used.

Individual effect probabilities are calculated using an Excel spreadsheet tool IECV1.1 (Individual Effect Chance Model Version 1.1) developed by the U.S. EPA, OPP, Environmental Fate and Effects Division (June 22, 2004). The model allows for such calculations by entering the mean slope estimate (and the 95% confidence bounds of that estimate) as the slope parameter for the spreadsheet. In addition, the acute RQ is entered as the desired threshold.

The following probit slopes were used (probability of individual mortality calculations are presented in Section 5.2):

Fish: Probit slope = 2.7 (95% C.I. of 1.6 – 3.9), rainbow trout – MRID 00024716

Aquatic Invertebrate: Probit slope = 4.4, scud – MRID 45202917

Slope information on the most sensitive aquatic invertebrate (midge) is not available. Therefore, the probability of an individual effect was calculated using the probit slope of 4.4, which is the only technical grade atrazine value reported across invertebrate studies; 95% confidence intervals could not be calculated based on the available data (MRID 45202917; Table A-18).

4.9 Incident Database Review

A number of incidents have been reported in which atrazine has been associated with some type of environmental effect. Incidents are maintained and catalogued by EFED in the Ecological Incident Information System (EIIS). Each incident is assigned a level of certainty from 0 (unrelated) to 4 (highly probable) that atrazine was a causal factor in the incident. As of the writing of this assessment, 358 incidents are in EIIS for atrazine spanning the years 1970 to 2005. Most (309/358, 86%) of the incidents involved damage to terrestrial plants, and most of the terrestrial plant incidences involved damage to crops treated directly with atrazine. Of the remaining 49 incidents, 47 involved aquatic animals and 2 involved birds. Because the species included in this effects determination are aquatic species, incidents involving aquatic animals assigned a certainty index of 2 (possible) or higher (N=33) were re-evaluated. Results are summarized below, and additional details are provided in Appendix C. The 33 aquatic incidents were divided into three categories:

1. Aquatic incidents in which atrazine concentrations were confirmed to be sufficient to either cause or contribute to the incident, including directly via toxic

effects to aquatic organisms or indirectly via effects to aquatic plants, resulting in depleted oxygen levels;

2. Aquatic incidents in which insufficient information is available to conclude whether atrazine may have been a contributing factor – these may include incidents where there was a correlation between atrazine use and a fish kill, but the presence of atrazine in the affected water body was not confirmed; and

3. Aquatic incidents in which causes other than atrazine exposure are more plausible (e.g., presence of substance other than atrazine confirmed at toxic levels).

The presence of atrazine at levels thought to be sufficient to cause either direct or indirect effects was confirmed in 3 (9%) of the 33 aquatic incidents evaluated. Atrazine use was also correlated with 11 (33%) additional aquatic incidents where its presence in the affected water was not confirmed, but the timing of atrazine application was correlated with the incident. Therefore, a definitive causal relationship between atrazine use and the incident could not be established. The remaining 19 incidents (58%) were likely caused by some factor other than atrazine. Other causes primarily included the presence of other pesticides at levels known to be toxic to affected animals. Although atrazine use was likely associated with some of the reported incidents for aquatic animals, they are of limited utility to this assessment for the following reasons:

- No incidents in which atrazine is likely to have been a contributing factor have been reported after 1998. A number of label changes, including cancellation of certain uses, reduction in application rates, and harmonization across labels to require setbacks for applications near waterbodies, have occurred since that time. For example, several incidents occurred in ponds that are adjacent to treated fields. The current labels require a 66-foot buffer between application sites and water bodies.

- The habitat of the assessed species is not consistent with environments in which incidents have been reported. For example, no incidents in streams or rivers were reported.

Although the reported incidents suggest that high levels of atrazine may result in impacts to aquatic life in small ponds that are in close proximity to treated fields, the incidents are of limited utility to the current assessment. However, the lack of recently reported incidents in flowing waters does not indicate that effects have not occurred. Further information on the atrazine incidents and a summary of uncertainties associated with all reported incidents are provided in Appendix C.

5. Risk Characterization

Risk characterization is the integration of the exposure and effects characterizations to determine the potential ecological risk from varying atrazine use scenarios within the action area and likelihood of direct and indirect effects on the Topeka shiner and its designated critical habitat. The risk characterization provides an estimation (Section 5.1) and a description (Section 5.2) of the likelihood of adverse effects; articulates risk assessment assumptions, limitations, and uncertainties; and synthesizes an overall conclusion regarding the likelihood of adverse effects to the Topeka shiner and/or its designated critical habitat (i.e., "no effect," "likely to adversely affect," or "may affect, but not likely to adversely affect"). In accordance with the Agency's Overview Document (U.S. EPA, 2004), RQs derived in the risk estimation are based on baseline EECs using the PRZM-EXAMS static water body modeling. In the risk description, atrazine exposures are refined by considering additional lines of evidence available regarding habitat information and exposure and effects information used in this assessment.

5.1 Risk Estimation

Risk was estimated by calculating the ratio of the PRZM/EXAMS estimated environmental concentration (EEC) (Table 3.4) and the appropriate toxicity endpoint (Table 4.3). This ratio is the risk quotient (RQ), which is then compared to pre-established acute and chronic levels of concern (LOCs) for each category evaluated (Appendix D). Screening-level RQs are based on the most sensitive effects endpoints and the PRZM/EXAMS EECs listed in Table 3.4.

The highest PRZM/EXAMS EEC (fallow land) was initially used to derive risk quotients. In cases where LOCs were not exceeded based on the highest EEC, additional RQs were not derived because it was assumed that RQs for lower EECs would also not exceed LOCs. However, if LOCs were exceeded based on the highest EEC, use/region-specific RQs were also derived.

In cases where the baseline RQ exceeds one or more LOCs (i.e., "may affect"), additional factors, including the Topeka shiner life history characteristics, refinement of the baseline EECs using site-specific information, available monitoring data, and consideration of community-level threshold concentrations, are considered and used to characterize the potential for atrazine to adversely affect the Topeka shiner and its designated critical habitat. Risk quotients used to evaluate potential direct and indirect effects to the Topeka shiner and to designated critical habitat are in Sections 5.1.1. and 5.1.2. RQs are described and interpreted in the context of an effects determination in Section 5.2 (risk description).

5.1.1 Direct Effects

Direct effects to the Topeka shiner associated with acute and chronic exposure to atrazine are based on the most sensitive toxicity data available for freshwater fish. RQs used to estimate acute and chronic direct effects to the Topeka shiner are in Tables 5.1 and 5.2, respectively.

Table 5.1 Summary of Acute RQs Used to Estimate Direct Effects to the Topeka Shiner

Effect	Surrogate Species	Toxicity Value (µg/L)	EEC (µg/L)	RQ	Probability of Individual Effect	LOC (0.05) Exceedance
Direct acute effects to the Topeka shiner	Rainbow trout	LC_{50} = 5,300[a]	Peak = 103[b]	0.02	1 in 5.2E+05 (1 in 249 to 1 in 5.2E+10)[c]	No[d]

[a] Based on a 96-hour LC_{50} value of 5,300 µg/L for the rainbow trout (MRID #000247-16).
[b] Based on peak fallow land baseline EEC (Table 3.4).
[c] Based on a probit slope value of 2.72 for the rainbow trout with 95% confidence intervals of 1.56 and 3.89 (MRID 00024716).
[d] RQ < acute endangered species LOC of 0.05.

Table 5.2 Summary of Chronic RQs Used to Estimate Direct Effects to the Topeka Shiner

Effect to Topeka shiner	Use (appl. Method; rate; # appl.; interval between appl.)	Range of 60-day EECs (µg/L)	Freshwater Fish Chronic RQ (NOAEC= 65 µg/L)[a]	LOC (1.0) Exceeded
Chronic Direct Toxicity	Fallow/Idle land (aerial liquid; 2.25 lb ai/A; 1 appl.)	West: 103 Great Plains: 49	**1.6** 0.75	Yes (West region)
	Corn (aerial liquid; 2.5 lb ai/A; 2 appl.)	West: 88 Great Plains: 82	**1.4** **1.3**	Yes (both regions)
	Forestry	West: 26 Great Plains: 58	0.40 0.89	No
	Sorghum (aerial liquid; 2 lb ai/A; 1 appl.)	West: 57 Great Plains: 54	0.88 0.83	No
	All other uses	≤12	≤0.18	No

[a] Based on a 44-week NOAEC value of 65 µg/L for the brook trout (MRID 00024377).

Based on the highest baseline EEC modeled for atrazine use patterns within the action area, acute direct effects RQs do not exceed the endangered species LOC of 0.05. Therefore, atrazine is not expected to result in acute direct effects to the Topeka shiner within the action area. However, chronic RQs for fallow land and corn exceeded the chronic LOC of 1. These RQs are further characterized in the context of the effects determination in Section 5.2.

5.1.2 Indirect Effects

This section presents RQs used to evaluate the potential for atrazine to induce indirect effects. Pesticides have the potential to exert indirect effects upon listed species by inducing changes in structural or functional characteristics of affected communities. Perturbation of forage or prey availability and alteration of the extent and nature of habitat are examples of indirect effects. A number of these indirect effects are also considered as part of the critical habitat adverse modification evaluation. In conducting a screen for indirect effects, direct effects LOCs for each taxonomic group (i.e., freshwater fish, invertebrates, aquatic plants, and terrestrial plants) are employed to make inferences concerning the potential for indirect effects upon listed species that rely upon non-listed organisms in these taxonomic groups as resources critical to its life cycle (U.S. EPA, 2004). This approach used to evaluate indirect effects to listed species is endorsed by the Services (USFWS/NMFS, 2004b). If no direct effect listed species LOCs are exceeded for organisms on which the Topeka shiner depends for survival or reproduction, indirect effects to the Topeka shiner are not expected to occur.

If LOCs are exceeded for organisms on which the Topeka shiner depends for survival or reproduction, dose-response analysis is used to estimate the potential magnitude of effect associated with an exposure equivalent to the EEC. The greater the probability that exposures will produce effects on a taxa, the greater the concern for potential indirect effects for listed species dependant upon that taxa (U.S. EPA, 2004).

As an herbicide, indirect effects to the Topeka shiner from potential effects on primary productivity of aquatic plants are a principle concern. If plant RQs fall between the endangered species and non-endangered species LOCs, a no effect determination for listed species that rely on multiple plant species to successfully complete their life cycle (termed plant dependent species) is determined. If plant RQs are above non-endangered species LOCs, this could be indicative of a potential for adverse effects to those listed species that rely either on a specific plant species (plant species obligate) or multiple plant species (plant dependant) for some important aspect of their life cycle (U.S. EPA, 2004). Based on the information provided in Section 2.3, the Topeka shiner does not have any known obligate relationship with a specific species of aquatic plant.

Direct effects to riparian zone vegetation may also indirectly affect the Topeka shiner by reducing water quality and available spawning habitat via increased sedimentation. Direct impacts to the terrestrial plant community (i.e., riparian habitat) are evaluated using submitted terrestrial plant toxicity data. If terrestrial plant RQs exceed the Agency's LOC for direct effects to non-endangered plant species, based on EECs derived using EFED's Terrplant model (Version 1.2.1) and submitted guideline terrestrial plant toxicity data, a conclusion that atrazine may affect the Topeka shiner via potential indirect effects to the riparian habitat (and resulting impacts to habitat due to increased sedimentation) is made. Further analysis of the potential for atrazine to affect the Topeka shiner via reduction in riparian habitat includes a description of the importance of riparian vegetation to the assessed species and types of riparian vegetation that may potentially be impacted by atrazine use within the action area.

RQs used to evaluate the potential for atrazine to induce indirect effects to the Topeka shiner are in Table 5.3 below. These RQs suggest that potential indirect effects to the Topeka shiner from reduction in food availability, primary productivity, and spawning habitat could occur as indicated by LOC exceedances. Highest RQs occurred for the corn, sorghum, fallow, and forestry uses, although LOCs were exceeded for aquatic plants for all uses assessed. These RQs were based on the most sensitive surrogate species tested across aquatic invertebrate, fish, and aquatic plant species tested. Discussion of these RQs in the context of this effects determination is presented in Section 5.2.

Table 5.3. RQs used to evaluate the potential for atrazine to induce indirect effects to the Topeka shiner.

Indirect Effect	Taxa	Toxicity Value (ug/L)	Corn, sorghum, fallow, and forestry		Residential, rights of ways, and turf uses		LOC Exceedances
			EEC	RQ	EEC	RQ	
Reduction in Food Supply	Aquatic Invertebrate	LC50: 720 NOAEC: 60	Peak (ug/L): 27 - 103 21-Day (ug/L): 27 - 103	0.04 - **0.14** 0.45 **- 1.7**	Peak (ug/L): 3.3 - 12 21-Day (ug/L): 3.2 - 12	<0.02 <0.2	Acute and chronic RQs exceed the endangered species acute (0.05) and chronic LOC (1.0) for **corn, and fallow** uses. The acute RQ was also exceeded for the **sorghum** and **forestry** use. LOCs were not exceeded for residential, rights of ways, or turf uses.
	Terrestrial Invertebrate	LC50: approx. 7 lbs a.i./Acre[b]	2 – 4 lbs a.i./Acre	**0.29– 0.57**	1 - 2 lbs a.i./Acre	**0.14 – 0.29**	Interim LOC for terrestrial invertebrates of 0.05 was exceeded for all uses.
Reduction in food supply; Primary productivity	Vascular Aquatic Plants	EC50: 37	Peak (ug/L): 27 - 103	0.73 – **2.8**	Peak (ug/L): 3.3 - 12	<=0.32	RQs exceed the LOC (1.0) for **corn, sorghum, forestry, and fallow** uses. LOCs were not exceeded for residential, rights of ways, or turf uses.
	Non-Vascular Aquatic Plants	EC50: 1	Peak (ug/L): 27 - 103	**27 - 103**	Peak (ug/L): 3.3 - 12	**3.3 - 12**	LOCs were exceeded for **all uses.**
Reduction in food supply; reduction in suitable spawning habitat	Rainbow trout LC50	LC50: 5300	Peak (ug/L): 103	0.03	Peak (ug/L): 3.3 - 12	<0.01	No LOCs were exceeded.
	Brook trout NOAEC[a]	NOAEC: 65	60-Day (ug/L): 27 – 103	0.42 – **1.6**	<12	<=0.18	Chronic LOC was exceeded for the **corn and fallow,** uses.

a The direct effects RQs presented in Tables 5.1 and 5.2 were also used to characterize potential chronic risks to freshwater fish. However, sunfish are a predominant species that provides spawning habitat to the Topeka shiner.
b LC50 is an empirical value that was not statistically derived; 51% mortality occurred at 20 ppm soil (Mola et al., 1987; Ecotox No. 71417). Assuming a soil depth of 3 cm and a soil density of 1.3 g/cm^3, an application rate of 7 lbs a.i./Acre would be associated with a soil concentration of 20 ppm. This calculation assumes no foliar interception (e.g., direct spraying of bare ground) and is, therefore, conservative.

Potential indirect effects to the Topeka shiner resulting from direct effects on riparian vegetation were assessed using RQs from terrestrial plant seedling emergence and vegetative vigor EC_{25} data as a screen. Based on the results of the submitted terrestrial plant toxicity tests, it appears that emerging seedlings are more sensitive to atrazine via soil/root uptake than emerged plants via foliar routes of exposure. However, all tested plants, with the exception of corn in the seedling emergence and vegetative vigor tests, and ryegrass in the vegetative vigor test, exhibited adverse effects following exposure to atrazine. The results of these tests indicate that a variety of terrestrial plants that may inhabit riparian zones may be sensitive to atrazine exposure. RQs used to estimate potential indirect effects to the Topeka shiner from seedling emergence and vegetative vigor effects on terrestrial plants within riparian areas are summarized in Tables 5.4 and 5.5, respectively.

As shown in Table 5.4, terrestrial plant RQs are above the Agency's LOC for all species except corn. For species with LOC exceedances, RQ values based on aerial application of atrazine to forestry at 4.0 lb ai/A range from 1.8 to 113; the maximum RQ value based on an equivalent ground application is 35, approximately a three-fold reduction as compared to aerial applications. Granular application of atrazine to residential lawns at 2.0 lb ai/A may also impact terrestrial plants exposed to atrazine via runoff with RQs ranging from <1 (corn and soybeans) to 13 (carrots). Monocots and dicots show similar sensitivity to atrazine; therefore, RQs are similar across both taxa.

Table 5.4 Non-target Terrestrial Plant Seedling Emergence RQs

Surrogate Species	EC_{25} (lbs ai/A)[a]	EEC Dry adjacent areas[b]	RQ Dry adjacent areas[b]
Monocot - Corn	> 4.0	Aerial: 0.17 – 0.34 Ground: 0.05 – 0.10 Granular: 0.04	<LOC
Monocot - Oat	0.004	Aerial: 0.17 – 0.34 Ground: 0.05 – 0.10 Granular: 0.04	**Aerial: 43 - 85** **Ground: 13 - 26** **Granular: 10**
Monocot - Onion	0.009	Aerial: 0.17 – 0.34 Ground: 0.05 – 0.10 Granular: 0.04	**Aerial: 19 - 38** **Ground: 5.8 - 12** **Granular: 4.4**
Monocot - Ryegrass	0.004	Aerial: 0.17 – 0.34 Ground: 0.05 – 0.10 Granular: 0.04	**Aerial: 43 - 85** **Ground: 13 - 26** **Granular: 10**
Dicot - Carrot	0.003	Aerial: 0.17 – 0.34 Ground: 0.05 – 0.10 Granular: 0.04	**Aerial: 57 - 113** **Ground: 17 - 35** **Granular: 13**
Dicot - Soybean	0.19	Aerial: 0.17 – 0.34 Ground: 0.05 – 0.10 Granular: 0.04	**Aerial: < LOC – 1.8** Ground: < LOC Granular: < LOC
Dicot - Lettuce	0.005	Aerial: 0.17 – 0.34 Ground: 0.05 – 0.10 Granular: 0.04	**Aerial: 34 - 68** **Ground: 10 - 21** **Granular: 8**
Dicot - Cabbage	0.014	Aerial: 0.17 – 0.34 Ground: 0.05 – 0.10 Granular: 0.04	**Aerial: 12 - 24** **Ground: 3.7 – 7.4** **Granular: 2.9**
Dicot - Tomato	0.034	Aerial: 0.17 – 0.34 Ground: 0.05 – 0.10 Granular: 0.04	**Aerial: 5.0 - 10** **Ground: 1.5 – 3.1** **Granular: 1.2**
Dicot - Cucumber	0.013	Aerial: 0.17 – 0.34 Ground: 0.05 – 0.10 Granular: 0.04	**Aerial: 13 - 26** **Ground: 4.0 – 8.0** **Granular: 3.1**

[a] From Chetram (1989); MRID 420414-03.
[b] Range of EECs and RQs based on use scenarios presented in Table 3.4 (i.e., aerial and ground: forestry, fallow/idleland, corn, sorghum; and granular residential).

Terrestrial plants are more sensitive to the seedling emergence test than to vegetative vigor test. As shown in Table 5.5, vegetative vigor RQs exceed the Agency's LOC for three dicot species (soybeans, cabbage, and cucumber), based on aerial application of atrazine at 2 to 4 lb ai/A, with RQs ranging from 5 to 33. For ground applications, LOCs are exceeded for two dicot species, cabbage and cucumber, with RQs ranging from 1.5 to 3. Vegetative vigor RQs do not exceed LOCs for any of the tested monocot species.

Table 5.5 Non-target Terrestrial Plant Vegetative Vigor Toxicity RQs

Surrogate Species	EC_{25} (lbs ai/A)[a]	Drift EEC (lbs ai/A)[b]	Drift RQ[b]
Monocot - Corn	> 4.0	Aerial: 0.13 – 0.26 Ground: 0.01 – 0.02	<LOC
Monocot - Oat	2.4	Aerial: 0.13 – 0.26 Ground: 0.01 – 0.02	<LOC
Monocot - Onion	0.61	Aerial: 0.13 – 0.26 Ground: 0.01 – 0.02	<LOC
Monocot - Ryegrass	> 4.0	Aerial: 0.13 – 0.26 Ground: 0.01 – 0.02	<LOC
Dicot - Carrot	1.7	Aerial: 0.13 – 0.26 Ground: 0.01 – 0.02	<LOC
Dicot - Soybean	0.026	Aerial: 0.13 – 0.26 Ground: 0.01 – 0.02	**Aerial: 5.0 - 10** Ground: <LOC
Dicot - Lettuce	0.33	Aerial: 0.13 – 0.26 Ground: 0.01 – 0.02	<LOC
Dicot - Cabbage	0.014	Aerial: 0.13 – 0.26 Ground: 0.01 – 0.02	**Aerial: 9.3 - 19** **Ground:** <LOC **– 1.7**
Dicot - Tomato	0.72	Aerial: 0.13 – 0.26 Ground: 0.01 – 0.02	<LOC
Dicot - Cucumber	0.008	Aerial: 0.13 – 0.26 Ground: 0.01 – 0.02	**Aerial: 16 - 33** **Ground: 1.5 – 3.0**

[a] From Chetram (1989); MRID 420414-03.
[b] Range of EECs and RQs based on use scenarios presented in Table 3.4 (i.e., aerial and ground: forestry, fallow/idleland, corn, and sorghum).

As shown in Tables 5.4 and 5.5, LOCs are exceeded for some terrestrial plant taxa, which could result in indirect effects to the Topeka shiner. These LOCs and their impact on the effects determination are described in Section 5.2.

5.2 Risk Description

The risk description synthesizes an overall conclusion regarding the likelihood of adverse impacts and/or modification leading to an effects determination (i.e., "no effect," "may affect, but not likely to adversely affect," or "likely to adversely affect") for the Topeka shiner and its designated critical habitat.

If the RQs presented in the Risk Estimation (Section 5.1) show no direct or indirect effects to the Topeka shiner, and no adverse modification to PCEs of the designated critical habitat (RQs < LOC), a "no effect" determination is made, based on baseline modeled EECs of atrazine's use within the action area. If, however, direct or indirect effects to Topeka shiner individuals are anticipated and/or effects may adversely modify the PCEs of the designated critical habitat (RQs > LOC), the Agency concludes a preliminary "may affect" determination for the FIFRA regulatory action regarding

atrazine. Following a "may affect" determination, additional information is considered to refine the potential for exposure at the predicted levels based on monitoring data, the life history characteristics (i.e., habitat range, feeding preferences, etc.) of the Topeka shiner, and potential community-level effects to aquatic plants.
Based on the best available information, refined evaluations were used to distinguish those actions that "may affect, but are not likely to adversely affect" ("NLAA") from those actions that are "likely to adversely affect" ("LAA") the Topeka shiner and designated critical habitat. The criteria used to make determinations that the effects of an action are "not likely to adversely affect" the Topeka shiner and designated critical habitat include the following:

- <u>Significance of Effect</u>: Insignificant effects are those that cannot be meaningfully measured, detected, or evaluated in the context of a level of effect where "take" occurs for even a single individual. "Take" in this context means to harass or harm, defined as the following:

    - Harm includes significant habitat modification or degradation that results in death or injury to listed species by significantly impairing behavioral patterns such as breeding, feeding, or sheltering.

    - Harass is defined as actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding, or sheltering.

- <u>Likelihood of the Effect Occurring</u>: Discountable effects are those that are extremely unlikely to occur. For example, use of dose-response information to estimate the likelihood of effects can inform the evaluation of some discountable effects.

- <u>Adverse Nature of Effect:</u> Effects that are wholly beneficial without any adverse effects are not considered adverse.

A description of the risk and effects determination for each of the established direct and indirect assessment endpoints for the Topeka shiner is in Section 5.2.1 and 5.2.2., respectively. A description of the risk and effects determination for the critical habitat impact analysis in less vulnerable watersheds is provided in Section 5.3.

5.2.1 Potential for Atrazine to Directly Affect the Topeka Shiner

5.2.1.1. Acute Exposures

All acute RQs for the most sensitive freshwater fish species tested were <=0.02. The endangered species LOC is 0.05. Therefore, no RQs exceed the endangered species LOC. At the RQ of 0.02, the probability of an individual mortality would be approximately 1 in 500,000 (95% C.I. of 1 in 249 to 1 in 5E10) based on a probit slope value of 2.72 for the rainbow trout with 95% confidence intervals of 1.56 and 3.89 (MRID 00024716).

There are a number of uncertainties in the acute risk assessment. The most sensitive freshwater fish species tested was used to calculate RQs. The Topeka shiner has not been tested in acute studies; therefore, the sensitivity of the Topeka shiner to atrazine is uncertain. However, a number of freshwater fish species have been tested in acute studies including rainbow trout, brook trout, Nile river fish, bluegill sunfish, tilapia, fathead minnow, carp, brown trout, zebra fish, and gold fish. LC50s range from 5300 ug/L to 60,000 ug/L. The Topeka shiner would need to be approximately 2-fold more sensitive than the most sensitive freshwater species tested to result in an LOC exceedance.

There is also uncertainty in the potential exposure levels to the Topeka shiner. The shiner lives in low order streams with little to negligible flow. The EECs used to calculate RQs were based on PRZM/EXAMS modeling, which suggested that peak exposures could be up to 100 ug/L. As previously discussed, recent targeted and non-targeted monitoring from highly vulnerable and less vulnerable watersheds reported peak EECs that are higher than the highest peak PRZM/EXAMS EEC used to calculate RQs. Based on the highest peak EEC reported in the recent targeted monitoring studies in vulnerable watersheds, the acute RQ would be 0.04 (highest EEC across monitoring studies of 209 μg/L / LC_{50} of 5,300 μg/L = RQ of 0.04), which is also below the acute endangered species LOC. Therefore, based on the lack of LOC exceedance from the most sensitive species tested, a conclusion of "no effect" to the Topeka shiner was made.

5.2.1.2. Chronic Exposures

Chronic RQs (presented in Table 5.2) exceed the LOC of 1.0 for corn (both regions) and fallow/idle land (west region only), with RQ values as high as 1.6 (see Table 5.2). Fish chronic RQs were based on PRZM/EXAMS 60-day EECs and the freshwater fish chronic NOAEC for brook trout of 65 μg/L.

The highest 60-day average atrazine concentration from the available targeted vulnerable watershed monitoring study was 26 ug/L. Nonetheless, Topeka shiner habitats include first order streams and small inlets or side pools within streams (Figure 5.1). However, monitoring studies typically sample mid-instream locations within a water body. Atrazine concentrations within side pools of low-order streams will depend on a number of factors that influence residence time, and longer term concentrations within these inlets may exceed those reported in both the targeted and non-targeted monitoring studies. Therefore, the PRZM/EXAMS 60-day EEC was considered an appropriate measure of exposure for the Topeka shiner.

Figure 5.1. Examples of Topeka Shiner Habitat in Minnesota. Images obtained from Minnesota Department of Natural Resources (2005, 2006)

There is also one known Topeka shiner population in an enclosed farm pond (Dehle, 2001). Therefore, the PRZM/EXAMS estimate for long-term exposures are considered appropriate for exposure estimation for this location.

The magnitude of potential effects at the highest 60-day EEC for corn and fallow uses of 88 ug/L and 103 ug/L, respectively, is uncertain. In the submitted life-cycle studies, LOAEC values ranged from 120 ug/L to 870 ug/L, which are all above the PRZM/EXAMS 60-day EECs. The LOAEC in the most sensitive study was based on growth effects; a 7.2% reduction in mean length and a 16% reduction in body weight relative to controls occurred at the LOAEC of 120 ug/L. If the Topeka shiner sensitivity to atrazine is similar to brook trout (the most sensitive species tested), then the magnitude of potential effects would be expected to be somewhat less than effects reported at the LOAEC of 120 ug/L in brook trout. Effects at the LOAEC from other studies included: reduced growth (fathead minnows at 150 ug/L); equilibrium loss (bluegill sunfish at 500 ug/L); and mortality (fathead minnows at 870 ug/L). These studies are described in Appendix A.

Chronic EECs were based on the maximum labeled application rates. Typical application rates for corn and fallow uses were 0.6 to 0.9 lbs a.i./Acre, which is >50% lower than the maximum labeled application rates. Therefore, EECs based on typical application rates would be reduced by more than 50%, which would not result in LOC exceedance.

Also, as discussed in Section 4.2.3, several open literature studies raise questions about sublethal effects of atrazine on plasma steroid levels, behavior modifications, gill physiology, and endocrine-mediated functions in freshwater and anadromous fish. These data were not used to determine if atrazine is likely to adversely affect the Topeka shiner or not for a number of reasons including (1) study design limitations, (2) lack of a quantifiable link between the sublethal effects and the assessment endpoints assessed (i.e., survival, growth, and reproduction), and (3) effects to reproduction, growth, and survival were not observed in the four submitted fish life-cycle studies at levels that produced the reported sublethal effects (Appendix A). These studies are discussed in greater detail in Sections A.2.4a and A.2.4b of Appendix A.

5.2.1.3. Summary of Conclusions

The effects determination for potential direct effects to the Topeka shiner is summarized in Table 5.7 below.

Table 5.7. Effects Determination Summary for Potential Direct Effects to the Topeka Shiner from Labeled Uses of Atrazine

Endpoint	Use	Region	Effects Determination	Basis for Conclusion
Acute direct effects	All	West, Great Plains	No effect	No acute LOCs are exceeded for the most sensitive species tested.
Chronic direct effects	Corn	West, Great Plains	Likely to adversely affect	RQs for corn and fallow were 1.3 to 1.6 based on the PRZM/EXAMS standard static pond. Based on the habitat of the Topeka shiner, the PRZM/EXAMS EECs
	Fallow	West	Likely to	

			adversely affect	were considered to be appropriate measures of exposure for this species. The LOAEC in the most sensitive life-cycle study was 7% reduction in length and 16% reduction in weight at 120 ug/L. The magnitude of potential effect to the Topeka shiner would be expected to be somewhat lower than effects observed at the most sensitive LOAEC.
	All other uses	West, Great Plains	No effect	The chronic LOC was not exceeded for these uses.

5.2.2 Potential for Atrazine to Indirectly Affect the Topeka Shiner

Indirect effects assessed include reduced food supply (invertebrates, plants, or other fish), by changes in water quality via alterations in the aquatic or terrestrial (riparian) plant community, and effects to reproductive habitat (sunfish nests provide spawning habitat for Topeka shiners). Dietary behavior of the Topeka shiner is described as a generalist omnivore. Its diet consists primarily of aquatic insects (particularly midges) and other aquatic invertebrates, but it also consumes plant material, terrestrial invertebrates, and other fish (Dahle, 2001). Therefore, the potential for atrazine to affect the Topeka shiner via reduction in available food is evaluated using RQs for aquatic invertebrates, aquatic plants, fish, and terrestrial invertebrates.

RQs presented in Section 5.1 indicate that LOCs were exceeded for some organisms that the Topeka shiner could rely on for food, reproduction, or habitat suitability/stability. These RQs are further described in sections 5.2.2.1 to 5.2.2.3 below.

5.2.2.1. Potential for Atrazine to Indirectly Affect the Topeka Shiner via Reduction in Aquatic Invertebrates as Food Items

Acute baseline RQs were based on the lowest LC_{50} value across all aquatic invertebrate taxa of 720 μg/L for the midge (*Chironomus* spp.). Consideration of all acute toxicity data for the midge shows a wide range of sensitivity within and between species of the same genus (2 orders of magnitude) with values ranging from 720 to >33,000 μg/L. The highest acute RQ for the midge was 0.14. A probit slope was not available from any of the midge studies. However, based on the most conservative (lowest) probit slope reported for freshwater invertebrates of 4.4 (scud, MRID 45202917), the probability of an individual effect at an RQ of 0.14 would be approximately 1 in 12,000.

Therefore, assuming that the Topeka shiner consumes only animals that are as sensitive as the most sensitive species tested in the most sensitive study conducted in that species, potential reduction in abundance of aquatic invertebrates as food would be approximately 0.01% (1/12,000).

Given the low magnitude of potential impact on abundance of the most sensitive aquatic invertebrate species based on the most sensitive bioassay, potential impacts to the Topeka shiner resulting from reduced availability of aquatic invertebrates as food is considered to be sufficiently low such that any potential effect to the Topeka shiner would be insignificant. Therefore, a take is not anticipated to occur from any labeled use of atrazine as a result of reduced aquatic invertebrate food base. This conclusion is further supported by the observation that LOCs were not exceeded for any aquatic invertebrate species other than the most sensitive species, the generalist feeding behavior of the assessed species, and the wide range of LC50s in the most sensitive species (720 ug/L to >33,000 ug/L).

Chronic LOCs were also exceeded for the most sensitive aquatic invertebrate (scud, NOAEC = 60 ug/L) for corn (both regions) and fallow (west region) uses. The highest 21-day EEC of 103 ug/L exceeded the NOAEC of 60 ug/L reported for the scud. The LOAEC in this study (MRID 00024377) was 120 ug/L based on 25% reduction in development of F1 to seventh instar. NOAECs were not exceeded for any other aquatic invertebrate tested including midge, daphnids, green hydra, snail, or leech. The baseline EEC of 103 ug/L did not exceed any level that elicited a response (LOAEC) in the available studies, and no LOCs were exceeded for the predominant food items (insects such as midges) of the Topeka shiner. Given the magnitude of potential impact on abundance of the most sensitive aquatic invertebrate species based on the most sensitive bioassay, potential impacts to the Topeka shiner resulting from reduced availability of aquatic invertebrates as food is considered to be sufficiently low such that any potential effect to the Topeka shiner would be insignificant or unmeasurable. Therefore, atrazine is "not likely to adversely affect" (NLAA) the Topeka shiner via reductions in aquatic invertebrate food base.

5.2.2.2. Potential for Atrazine to Adversely Affect the Topeka Shiner by Affecting Terrestrial Invertebrates

Studies that showed statistically significant ($p<0.05$) effects to terrestrial invertebrates were typically at levels that were above highest labeled application rate of 4 lbs a./Acre for forestry and 2.5 lbs a.i./Acre for corn and sorghum. The most sensitive terrestrial insect tested was the springtail (*Onychiuridae*). Mortality rate in *Onychiurus armatus* was approximately 50% at 20 ppm soil, which is associated with an application rate of 7 lbs a.i./Acre assuming a soil depth of 3 cm and a soil density of 1.3 g/cm^3. Another species of springtail, *O. armatus,* was associated with 18% mortality at soil levels associated with approximately 1 lb a.i./Acre (Mola et al., 1987), which is within the range of labeled atrazine application rates. An application rate of 5.4 lbs a.i./Acre was associated with reduced abundance of microarthropods (Fratello et. al., 1985); however, reduced abundance could have been caused by indirect effects (migration/repellency). Application rates of 0.9 and 1.8 lbs a.i./Acre did not affect abundance of microarthropods (Cortet et al., 2002; Fratello et. al., 1985).

Atrazine did not affect survival in a number of beetle species at application rates that ranged from 0.8 to 8 lbs a.i./Acre (Kegel, 1989; Brust, 1990; Samsoe-Petersen, 1995). No studies in beetles established definitive LOAEC or EC50 values. Because the studies in beetles produced free-standing NOAECs, their utility is somewhat limited; however, they do suggest that abundance would not likely be affected to an extent that would result in indirect effects to the Topeka shiner at atrazine applications up to 8 lbs a.i./Acre for ground beetles (Poecilus) and 2 lbs a.i./Acre for carabid beetles.

In addition, earthworm LC50s were 270 and 380 ppm soil (Mosleh et al., 2003; Haque and Ebing, 1983). The highest soil concentrations expected from the maximum labeled application rate (4 lbs a.i./Acre) on the treated field would be approximately 11 ppm in the top 3 cm of soil (RQ would be approximately 0.04).

Also, the acute contact LD50 in honey bees was >97 ug/bee (5% mortality occurred at the highest dose level) (MRID 00036935). A dose of 97 ug/bee corresponds to an atrazine concentration on the bee of approximately 757 ppm, assuming an adult honey bee weighs 128 mg (Mayer and Johansen, 1990). The corresponding exposure value to honey bees at an application rate of 4 lbs a.i./Acre is approximately 60 ppm. Although the resulting RQ (0.079) would be above the interim LOC for terrestrial invertebrates of 0.05, the resulting probability of an individual mortality would be approximately 1 in 3,000,000 assuming a probit slope of 4.5. The default probit slope was used because insufficient mortality occurred at the highest dose tested in the honey bee study (MRID 00036935).

Overall, the available data suggest that some species of terrestrial invertebrates could be directly or indirectly affected by atrazine at labeled application rates. However, the magnitude of such effects is not likely to result in indirect effects to the Topeka shiner. For this reason, atrazine is not likely to adversely affect the Topeka shiner by affecting terrestrial invertebrate food source.

5.2.2.3. Potential for Atrazine to Adversely Affect the Topeka Shiner by Affecting the Aquatic Plant Community

Aquatic plants may serve as food and shelter for the Topeka shiner in addition to contributing to water quality parameters essential to its habitat. RQs presented in Section 5.1 exceeded the LOC for all uses (non-vascular plants) in both the west and Great Plains regions. The vascular plant LOC was also exceeded for all agricultural uses assessed. The potential for atrazine to affect the Topeka shiner via effects to aquatic plants is initially based on the most sensitive EC50 in vascular plants (duckweed, EC50 = 37 ug/L) and non-vascular aquatic plants (algae, EC50 = 1 ug/L). As noted above LOCs were exceeded for all use scenarios for algae and for corn, sorghum, and forestry uses for vascular plants. Therefore, a preliminary "may effect" determination is made.

RQs used for the preliminary "may effect" determination were based on the most sensitive single species EC50s. In order to determine whether potential effects to individual plant species would likely result in community-level effects to the Topeka shiner's habitat, the time-weighted baseline EECs (for 14-, 30-, 60-, and 90-day averages from Table 3.4) were compared to their respective time-weighted threshold concentrations (described in Section 4). As discussed in Section 4.2, concentrations of atrazine from the exposure profile at a particular use site and/or action area that exceed any of the following time-weighted threshold concentrations indicate that changes in the aquatic plant community structure (including food items for the Topeka shiner) could be affected:

- 14-day average = 38 µg/L
- 30-day average = 27 µg/L
- 60-day average = 18 µg/L
- 90-day average = 12 µg/L

A comparison of the range of the baseline 14-, 30-, 60-, and 90-day EECs for the Topeka shiner with the atrazine threshold concentrations representing potential aquatic community-level effects is provided in Table 5.8.

Table 5.8. Summary of Modeled Scenario Time-Weighted Baseline EECs with Threshold Concentrations for Potential Community-Level Effects

Use Scenario	14-day		30-day		60-day		90-day	
	EECs (µg/L) [a]	Threshold Conc. (µg/L)	EECs (µg/L) [a]	Threshold Conc. (µg/L)	EECs (µg/L) [a]	Threshold Conc. (µg/L)	EECs (µg/L) [a]	Threshold Conc. (µg/L)
Corn	**84 - 92**	38	**84 - 91**	27	**82 - 88**	18	**81 - 85**	12
Sorghum	**57 - 59**		**56 - 58**		**54 - 57**		**53 - 56**	
Fallow / idle land	**49 - 103**		**49 - 103**		**49 - 103**		**49 - 103**	
Forestry	27 - **61**		**27 - 60**		**26 - 58**		**25 - 57**	
Residential, turf, and rights of ways	3 - 12		3 - 11		3 - 11		3 - 11	

[a] Baseline EECs from Table 3.4.

Based on the results of this comparison, estimated baseline 14- to 90-day EECs for corn, sorghum, fallow/idle land, and forestry modeled uses exceed their respective threshold concentrations for community level effects.

The recently submitted targeted monitoring data suggests that longer duration atrazine concentrations are typically considerably lower than the peak atrazine levels. For example, the median 14-day atrazine concentration across all sites was approximately 50% of the maximum (Appendix B). Nonetheless, sampling stations used for the monitoring study may not represent small side pools such as those commonly inhabited by the Topeka shiner (see Figure 5.1). For this reason, the EECs are not further refined from PRZM/EXAMS estimates and the effects determination is not changed by considering habitat characteristics of the assessed species relative to the PRZM/EXAMs standard ecological pond.

In conclusion, consideration of the community-level effects thresholds does not dramatically impact the conclusions of this assessment. EECs for corn, sorghum, fallow land, and forestry exceed at least one of the community level effects thresholds listed in Table 5.8. EECs for residential, turf, rights of ways uses do not exceed any of the community level effects thresholds.

For this reason, the effects determination for potential indirect effects to the Topeka shiner via effects to aquatic plants is “likely to adversely affect, or LAA” for agricultural and forestry uses. However, because PRZM/EXAMS EECs for turf, rights-of-ways, and residential uses were lower than the community level effects threshold concentrations, atrazine is not likely to adversely affect the Topeka shiner by impacting the plant community from these uses.

5.2.2.4. Indirect Effects via Reduction in Fish Necessary for Food and Reproduction

Spawning of the Topeka shiner occurs over gravel nests of sunfish. As described in Section 5.2.1, atrazine use is considered to have “no effect” to the Topeka shiner via acute direct toxicity. This conclusion was based on the most sensitive acute LC50 in fish available. Therefore, a conclusions of “no effect” is also made with respect to the potential for indirect effects associated with acute effects to other fish species.

However, the conclusion for the direct effects assessment for potential chronic effects to the Topeka shiner presented in Section 5.2.1 was “likely to adversely affect.” Therefore, additional analysis is needed to evaluate whether the Topeka shiner may be adversely affected by potential chronic effects to other fish species.

The highest chronic fish RQ was 1.6 (EEC = 103 ug/L, NOAEC = 65 ug/L) based on EECs for the fallow use. The most sensitive NOAEC was based on a life-cycle study in brook trout that produced a NOAEC of 65 ug/L and a LOAEC of 120 ug/L. The LOAEC was based on growth effects (7% reduction in length and a 16% reduction in weight). The highest EEC (fallow) was 103 ug/L, which is somewhat lower than the LOAEC of 120 ug/L (MRID 00024377). The Topeka shiner is known to depend on sunfish nests for spawning. Sunfish were somewhat less sensitive than brook trout to atrazine. Although the NOAEC in bluegill sunfish was 95 ug/L, which is similar to the brook trout NOAEC of 65 ug/L, the LOAEC in sunfish was 500 ug/L based on loss of equilibrium. This analysis suggests that fish could be exposed to atrazine at levels that approach the LOAEC in the most sensitive species; however, the magnitude of potential effects to fish species is expected to be sufficiently low such that indirect effects to the Topeka shiner are unlikely to occur. Therefore, atrazine is not likely to adversely affect the Topeka shiner via impacts on other fish species. This conclusion is based on significance of effect as defined in Section 5.2.

5.2.2.5. Indirect Effects via Alteration in Terrestrial Plant Community (Riparian Habitat)

As shown in Tables 5.4 and 5.5, seedling emergence or vegetative vigor RQs exceed LOCs for a number of the tested plant species. Based on exceedance of the seedling emergence LOCs for all species tested except corn, the following general conclusions can be made with respect to potential harm to riparian habitat via runoff exposures:

- Atrazine may enter riparian areas via runoff where it may be taken up through the root system of sensitive plants.

- Comparison of seedling emergence EC_{25} values to EECs estimated using TERRPLANT suggests that inhibition of new growth may occur. Inhibition of new growth could result in degradation of high quality riparian habitat over time because as older growth dies from natural or anthropogenic causes, plant biomass may be prevented from being replenished in the riparian area. Inhibition of new growth may also slow the recovery of degraded riparian areas that function poorly due to sparse vegetation because atrazine deposition onto bare soil would be expected to inhibit the growth of new vegetation.

- Because LOCs were exceeded for most species tested (9/10) in the seedling emergence studies, it is likely that many species of herbaceous plants may be potentially affected by exposure to atrazine in runoff.

Because RQs for terrestrial plants are above the Agency's LOCs, atrazine use is considered to have the potential to directly impact plants in riparian areas, potentially resulting in degradation of stream water quality via sedimentation and alteration of habitat. Therefore, an analysis of the potential for habitat degradation to affect the Topeka shiner is necessary.

Riparian plants beneficially affect water and stream quality in a number of ways in both adjacent river reaches and areas downstream of the riparian zone. Riparian vegetation provides a number of important functions in the stream/river ecosystem, including the following:

- serves as an energy source;
- provides organic matter to the watershed;
- provides streambank stability;
- provides shading, which ensures thermal stability of the stream; and
- serves as a buffer, filtering out sediment, nutrients, and contaminants before they reach the stream.

A general discussion of riparian habitat and its relevance to the Topeka shiner is provided below. Additional details are presented in Appendix H.

It is difficult to estimate the magnitude of potential impacts of atrazine use on riparian habitat and the magnitude of potential effects on stream water quality from such impacts as they relate to survival, growth, and reproduction of the Topeka shiner. The level of exposure and any resulting magnitude of effect on riparian vegetation are expected to be highly variable and dependent on many factors. The extent of runoff and/or drift into stream corridor areas is affected by the distance the atrazine use site is offset from the stream, local geography, weather conditions, and quality of the riparian buffer itself. The sensitivity of the riparian vegetation is dependent on the susceptibility of the plant species present to atrazine and composition of the riparian zone (e.g. vegetation density, species richness, height of vegetation, width of riparian area).

Quantification of risk to the Topeka shiner from potential effects to riparian areas is precluded by the following factors:

- The relationship between distance of soil input into the watershed and sediment deposition in areas critical to survival, reproduction, and growth of the Topeka shiner is not known;
- Riparian areas within the action area are highly variable in their composition and location with respect to atrazine use; therefore, their sensitivity to potential damage is also variable; and
- The action area for the Topeka shiner is a large geographic area, encompassing multiple states.

In addition, even if plant community structure was quantifiably correlated with riparian function, it may not be possible to discern the effects of atrazine on species composition separate from other agricultural actions or determine if atrazine is a significant factor in altering community structure. Plant community composition in agricultural field margins is likely to be modified by many agricultural management practices. Vehicular impact and mowing of field margins and off-target movement of fertilizer and herbicides are all likely to cause changes in plant community structure of riparian areas adjacent to agricultural fields (Jobin et al., 1997; Kleijn and Snoeijing, 1997; Schippers and Joenje, 2002). Although herbicides are commonly identified as a contributing factor to changes in plant communities adjacent to agricultural fields, some studies identify fertilizer use as the most important factor affecting plant community structure near agricultural fields (e.g. Schippers and Joenje, 2002) and community structure is expected to be affected by a number of other factors (de Blois et al., 2002). Thus, the effect of atrazine alone on riparian community structure is complicated by other multiple stressors likely to occur within the action area.

In summary, terrestrial plant RQs are above terrestrial plant LOCs for all uses; therefore, labeled use of atrazine has the potential to affect riparian vegetation within the Topeka shiner's habitats. However, water quality and sedimentation / siltation in a stream may depend on numerous factors, and determining whether atrazine use is expected to result in an overall increase in sediment/silt levels in a habitat is difficult. Until further analysis is performed on specific land management practices and sensitivity of riparian vegetation in areas surrounding Topeka shiner habitats, potential effects to riparian vegetation as indicated by terrestrial plant RQ exceedance, is presumed to potentially adversely affect the Topeka shiner and its designated critical habitat

Because woody plants are typically not sensitive to atrazine at expected exposure concentrations, riparian areas which have predominantly forested vegetation containing woody shrubs and trees are not likely to be adversely impacted by atrazine use to an extent that would be expected to result in measurable effects on the Topeka shiner. Therefore, atrazine is not likely to adversely affect populations of Topeka shiners in watersheds with predominantly forested riparian areas. However, given that the Topeka shiner's habitat is located in the Great Plains, the presence of forested riparian areas is not expected to be predominant landcover.

Therefore, habitats of the Topeka shiner that are in close proximity to potential atrazine use sites and where the riparian vegetation is comprised of sensitive grasses and non-woody plants, the effects determination is "likely to adversely affect." A graphic representation of the effects determination for this assessment endpoint, based on evaluation of the sedimentation, streambank stability, and thermal stability attributes for riparian vegetation is provided in Figure 5.2.

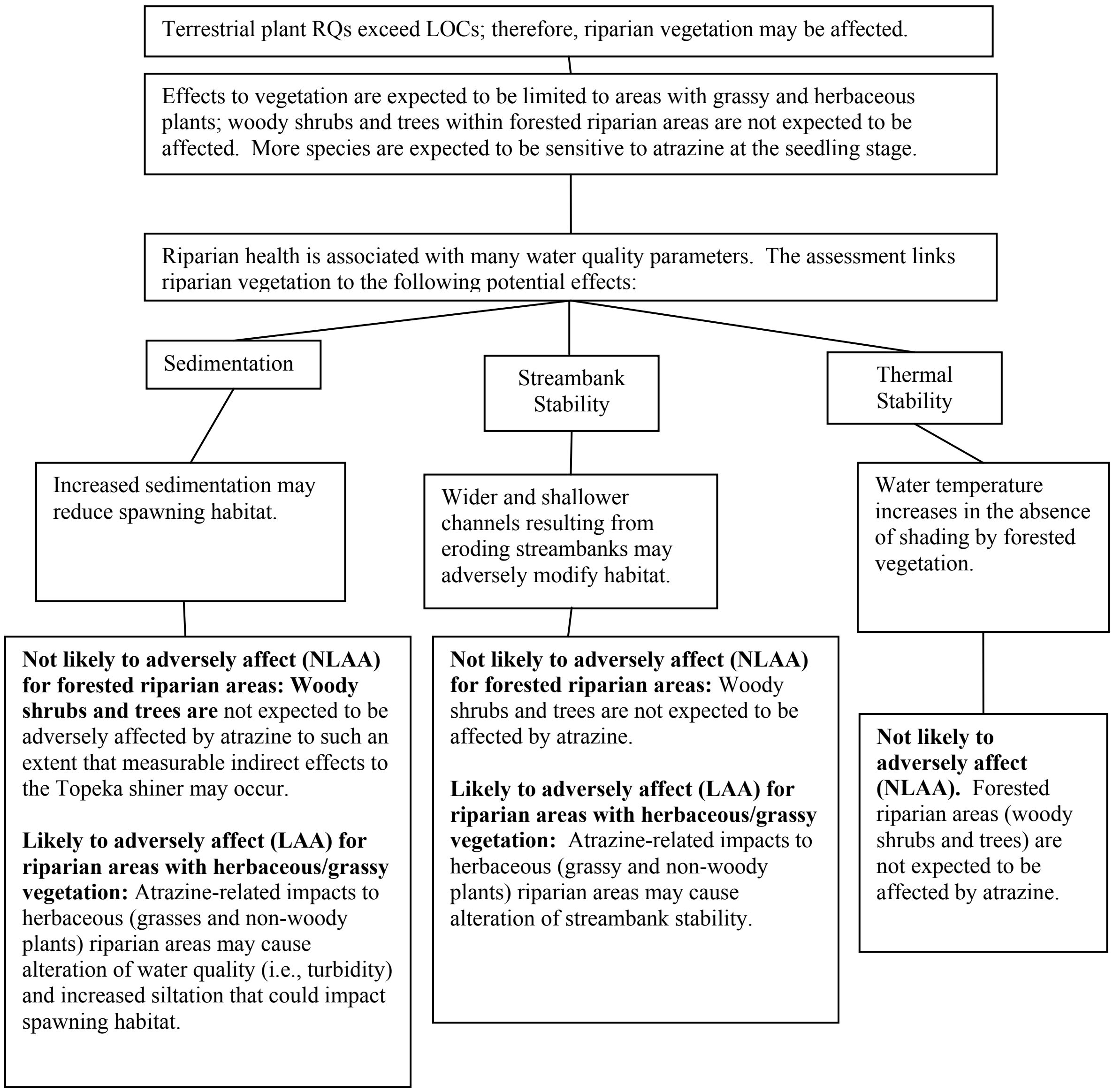

Figure 5.2 Summary of the Potential of Atrazine to Affect the Topeka shiner via Riparian Habitat Effects

5.3 Adverse Modification to Designated Critical Habitat

As previously discussed, designated critical habitat for the Topeka shiner is located in Iowa, Minnesota, and Nebraska. The potential for atrazine to adversely affect critical habitat is evaluated using adverse modification of principle constituent elements (PCEs) as defined in Section 2.6. The designated critical habitat areas are considered to have the PCEs that justify critical habitat designation. Activities that may destroy or adversely modify critical habitat are those that alter the PCEs and jeopardize the continued existence of the species. Evaluation of actions related to use of atrazine that may alter the PCEs of the Topeka shiner's critical habitat form the basis of the critical habitat impact analysis. The primary constituent elements for the Topeka shiner that may be affected by biological processes, and, thus, may be affected by use of atrazine include the following:

- Streams and side-channel pools with water quality necessary for unimpaired behavior, growth, and viability of all life stages. The water quality components can vary seasonally and include--temperature (1 to 30[deg]Centigrade), total suspended solids (0 to 2000 ppm), conductivity (100 to 800 mhos), dissolved oxygen (4 ppm or greater), pH (7.0 to 9.0), and other chemical characteristics;

- Living areas for juvenile Topeka shiners with water velocities less than 0.5 meters/second (approx. 20 inches/second) with depths less than 0.25 meters (approx. 10 inches) and moderate amounts of instream aquatic cover, such as woody debris, overhanging terrestrial vegetation, and aquatic plants;

- Sand, gravel, cobble, and silt substrates with amounts of fine sediment and substrate embeddedness that allows for nest building and maintenance of nests and eggs by native Lepomis sunfishes (green sunfish, orangespotted sunfish, longear sunfish) and Topeka shiner as necessary for reproduction, unimpaired behavior, growth, and viability of all life stages; and

- An adequate terrestrial, semiaquatic, and aquatic invertebrate food base that allows for unimpaired growth, reproduction, and survival of all life stages.

The potential for atrazine to adversely modify the aforementioned PCEs is summarized in Table 5.9. The assessment is evaluated using RQs derived for direct and indirect effects as described in Sections 5.1 and 5.2.

Table 5.9. Summary of conclusions regarding the potential for atrazine to adversely modify critical habitat PCEs

PCE	Conclusions	Basis for Conclusions (see Section 5.3. for additional information)
Streams and side-channel pools with water quality necessary for unimpaired behavior, growth, and viability of all life stages. The water quality components can vary seasonally and include--temperature (1 to 30[deg]Centigrade), total suspended solids (0 to 2000 ppm), conductivity (100 to 800 mhos), dissolved oxygen (4 ppm or greater), pH (7.0 to 9.0), and other chemical characteristics	LAA	As described in Sections 5.2.2.3 and 5.2.2.5, atrazine was concluded to likely to adversely affect the Topeka shiner by potentially aquatic and sensitive riparian plants. These potential effects could result in alteration of suspended solid levels, oxygen levels, and other chemical characteristics.
Living areas for juvenile Topeka shiners with water velocities less than 0.5 meters/second (approx. 20 inches/second) with depths less than 0.25 meters (approx. 10 inches) and moderate amounts of instream aquatic cover, such as woody debris, overhanging terrestrial vegetation, and aquatic plants	LAA	As described in Table 1.1, RQs were exceeded for aquatic and terrestrial plants (Sections 5.2.2.2 and 5.2.2.4), which suggests that "amounts of instream aquatic cover, such as woody debris, overhanging terrestrial vegetation, and aquatic plants" could be affected. Woody plant species are not expected to be adversely affected by atrazine at EECs presented in this assessment; however, other overhanging vegetation and aquatic plants could potentially be impacted in areas that are in close proximity to atrazine use.
Sand, gravel, cobble, and silt substrates with amounts of fine sediment and substrate embeddedness that allows for nest building and maintenance of nests and eggs by native Lepomis sunfishes (green sunfish, orangespotted sunfish, longear sunfish) and Topeka shiner as necessary for reproduction, unimpaired behavior, growth, and viability of all life stages	LAA	Atrazine may affect riparian vegetation of the Topeka shiner's habitats that are in close proximity to atrazine use sites. However, sedimentation / siltation in a stream may depend on numerous factors, and determining whether atrazine use is expected to result in an overall increase in sediment/silt levels in a habitat is difficult. Nonetheless, if riparian habitat is exposed to atrazine, the plant biomass of the riparian habitat could be adversely impacted primarily by reduction in biomass of exposed seeds (MRID 42041403). Until further analysis is performed on specific land management practices in areas surrounding Topeka shiner habitats, potential effects to riparian vegetation as indicated by terrestrial plant RQ exceedance, is presumed to potentially adversely affect the Topeka shiner and its designated critical habitat
An adequate terrestrial, semiaquatic, and aquatic invertebrate food base that allows for unimpaired growth, reproduction, and survival of all life stages.	NLAA	Atrazine was found to not likely adversely affect the Topeka shiner via reduction in aquatic and terrestrial invertebrates as food supply.

5.4. Environmental Baseline and Cumulative Effects

Given the "LAA" finding, the Agency has completed a summary of the environmental baseline and cumulative effects included in this assessment in Appendix I. The environmental baseline is defined as the effects of past and ongoing human induced and natural factors leading to the status of the species, its habitat, and ecosystem, within the action area. The baseline information provides a snapshot of the Topeka shiner's status at this time. A summary of all USFWS biological opinions that are relevant to the Topeka shiner that have been made available to EPA included in this assessment is also provided as part of the baseline status. Cumulative effects include the effects of future state, tribal, local, private, or other non-federal entity activities on endangered and threatened species and their critical habitat that are reasonably expected to occur in the action area.

6. Uncertainties

6.1. Exposure Assessment Uncertainties

6.1.1 Modeling Assumptions

Overall, the uncertainties addressed in this assessment cannot be quantitatively characterized. Given the available data and use of conservative modeling assumptions, it is expected that the baseline modeled EECs over-predict exposure for longer-term durations, but are within a factor of two as compared with peak monitored concentrations.

In general, the simplifying assumptions used in this assessment appear from the characterization in Section 3 to be reasonable given the analysis completed and the available monitoring data. There are also a number of assumptions that tend to result in over-estimation of exposure. Although these assumptions cannot be quantified, they are qualitatively described. For instance, modeling in this assessment for each atrazine use assumes that all applications have occurred concurrently on the same day at the exact same application rate. This is unlikely to occur in reality, but is a reasonable conservative assumption in lieu of actual data.

6.1.2 Impact of Vegetative Setbacks on Runoff

Unlike spray drift, models are currently not available to evaluate the effectiveness of a vegetative setback on runoff and loadings. The effectiveness of vegetative setbacks is highly dependent on the condition of the vegetative strip. For example, a well-established, healthy vegetative setback can be a very effective means of reducing runoff and erosion from agricultural fields (USDA, NRCS, 2000). Alternatively, a setback of poor vegetative quality or a setback that is channelized can be ineffective at reducing loadings. Until such time as a quantitative method to estimate the effect of vegetative setbacks on various conditions on pesticide loadings becomes available, the aquatic exposure predictions are likely to overestimate exposure where healthy vegetative setbacks exist and underestimate exposure where poorly developed, channelized, or bare setbacks exist.

6.1.3. Best Management Practices for Atrazine

A number of best management practices (BMPs) are recommended by State Agencies for the purpose of reducing atrazine exposure to surface waters. These include (but are not limited to) the following:

- Soil incorporation
- Crop rotation
- Use of banded applications
- Use of split applications
- Use early pre-plant applications
- Reduced application rates
- Reduce soil-applied atrazine application rates, use postemergence atrazine applications or post-emergent alternative.
- Establish vegetative and riparian buffer strips.
- Use conservation practices and structures.

If any or all of the aforementioned BMPs are in place over the predominant cropland within the watershed, then atrazine concentrations in the associated Topeka shiner habitats would be expected to be lower than EECs presented in this assessment. However, such possible reductions cannot be quantified over the entire action area.

6.1.3 PRZM Modeling Inputs and Predicted Aquatic Concentrations

In general, the linked PRZM/EXAMS model produces estimated aquatic concentrations that are expected to be exceeded once within a ten-year period. The Pesticide Root Zone Model (PRZM) is a process or "simulation" model that calculates what happens to a pesticide in a farmer's field on a day-to-day basis. It considers factors such as rainfall and plant transpiration of water, as well as how and when the pesticide is applied. It has two major components: hydrology and chemical transport. Water movement is simulated by the use of generalized soil parameters, including field capacity, wilting point, and saturation water content. The chemical transport component can simulate pesticide application on the soil or on the plant foliage. Dissolved, adsorbed, and vapor-phase concentrations in the soil are estimated by simultaneously considering the processes of pesticide uptake by plants, surface runoff, erosion, decay, volatilization, foliar wash-off, advection, dispersion, and retardation.

Uncertainties associated with each of these individual components add to the overall uncertainty of the modeled concentrations. Additionally, model inputs from the environmental fate degradation studies are chosen to represent the upper confidence bound on the mean, values that are not expected to be exceeded in the environment 90 percent of the time. Mobility input values are chosen to be representative of conditions in the environment. The natural variation in soils adds to the uncertainty of modeled values. Factors such as application date, crop emergence date, and canopy cover can also affect estimated concentrations, adding to the uncertainty of modeled values. Factors within the ambient environment such as soil temperatures, sunlight intensity, antecedent soil moisture, and surface water temperatures can cause actual aquatic concentrations to differ for the modeled values.

Additionally, the rate at which atrazine is applied and the percent of crops that are actually treated with atrazine may be lower than the Agency's default assumption of the maximum allowable application rate being used and the entire crop being treated. The geometry of a watershed and limited meteorological data sets also add to the uncertainty of estimated aquatic concentrations.

6.2 Effects Assessment Uncertainties

6.2.1 Age Class and Sensitivity of Effects Thresholds

It is generally recognized that test organism age may have a significant impact on the observed sensitivity to a toxicant. The acute toxicity data for fish are collected on juvenile fish between 0.1 and 5 grams. Aquatic invertebrate acute testing is performed on recommended immature age classes (e.g., first instar for daphnids, second instar for amphipods, stoneflies, mayflies, and third instar for midges).

Testing of juveniles may overestimate toxicity at older age classes for pesticidal active ingredients, such as atrazine, that act directly (without metabolic transformation) because younger age classes may not have the enzymatic systems associated with detoxifying xenobiotics. In so far as the available toxicity data may provide ranges of sensitivity information with respect to age class, this assessment uses the most sensitive life-stage information as measures of effect for surrogate aquatic animals, and is therefore, considered protective.

6.2.2 Impact of Multiple Stressors on the Effects Determination

The influence of length of exposure and concurrent environmental stressors to the Topeka shiner (i.e., construction of dams and locks, fragmentation of habitat, change in flow regimes, increased sedimentation, degradation of quantity and quality of water in the watersheds of the action area, predators, etc.) will likely affect the species' response to atrazine. Additional environmental stressors may increase sensitivity to the herbicide, although there is the possibility of additive/synergistic reactions. Timing, peak concentration, and duration of exposure are critical in terms of evaluating effects, and these factors are expected to vary both temporally and spatially within the action area. Overall, the effect of this variability may result in either an overestimation or underestimation of risk. However, as previously discussed, the Agency's LOCs are set to be protective given the wide range of possible uncertainties.

6.2.4 Use of Threshold Concentrations for Community-Level Endpoints

For the purposes of this ESA, threshold concentrations are used to predict potential indirect effects to the Topeka shiner and adverse modification to designated critical habitat (via aquatic plant community structural change). The conceptual aquatic ecosystem model used to develop the threshold concentrations is intended to simulate the ecological production dynamics in a 2nd or 3rd order Midwestern stream; however, the model has been correlated to the micro- and mesocosm studies, which were derived from a wide range of experimental studies (i.e., jar studies to large enclosures in lentic and lotic systems), that represent the best available information for atrazine-related community-level endpoints.

The threshold concentrations are intended to be predictive of potential atrazine-related community-level effects in aquatic ecosystems, such as those that occur in known locations for the Topeka shiner and its designated critical habitat, where the species composition may differ from those included in the micro- and mesocosm studies. Although it is not possible to determine how well the responses observed in the micro- and mesocosm studies reflect the action area watersheds for the Topeka shiner, estimated chronic atrazine exposure concentrations in less vulnerable watersheds of the action area (from modeled EECs assuming flow) are predicted to be between 5 to 12 times lower than the community-level threshold concentrations, depending on the modeled atrazine use and averaging period. However, an evaluation of targeted monitoring data from vulnerable watersheds suggests that chronic exposure concentrations of atrazine exceed these threshold concentrations in a number of areas. Given that threshold concentrations were derived based on the best available information from available community-level data for atrazine, these values are intended to be protective of the aquatic community, including the Topeka shiner and its designated critical habitat. Additional uncertainties associated with use of the thresholds to estimate community-level effects are discussed in Section B.8 of Appendix B from U.S. EPA (2006c,d,e).

6.2.5. Sublethal Effects

The assessment endpoints used in ecological risk assessment include potential effects on survival, growth, and reproduction of the Topeka shiner and organisms on which this species depend for survival and reproduction such as fish and invertebrates. A number of studies were located that evaluated potential sublethal effects to fish from exposure to atrazine. Although many of these studies reported toxicity values that were less sensitive than the submitted studies, they were not considered for use in risk estimation. In particular, fish studies were located in the open literature that reported effects on endpoints other than survival, growth, or reproduction at concentrations that were considerably lower than the most sensitive endpoint from submitted studies.

Upon evaluation of the available studies, however, the most sensitive NOAEC from the submitted full life-cycle studies was considered to be the most appropriate chronic endpoint for use in risk assessment. In the full life cycle study, fish are exposed to atrazine from one stage of the life cycle to at least the same stage of the next generation (e.g. egg to egg). Therefore, exposure occurs during the most sensitive life stages and during the entire reproduction cycle. Four life cycle studies have been submitted in support of atrazine registration. Species tested include brook trout, bluegill sunfish, and fathead minnows. The most sensitive NOAEC from these studies was 65 μg/L.

Reported sublethal effects including changes in hormone levels, behavioral effects, kidney pathology, gill physiology, and potential olfaction effects have been observed at concentrations lower than 65 μg/L (see Appendix A and Section 4.1.2.). In accordance with the Overview Document (U.S. EPA, 2004) and the Services Evaluation Memorandum (USFWS/NMFS, 2003), these studies were not considered appropriate for risk estimation in place of the life cycle studies because quantitative relationships between these effects and the ability of fish to survive, grow, and reproduce has not been established. The magnitude of the reported sublethal effect associated with reduced survival or reproduction has not been established; therefore it is not possible to quantitatively link sublethal effects to the selected assessment endpoints for this ESA. In addition, in the fish life cycle studies, no effects were observed to survival, reproduction, and/or growth at levels associated with the sublethal effects. Also, there were limitations to the studies that reported sublethal effects that preclude their quantitative use in risk assessment (see Appendix A and Section 4.2.1). Nonetheless, if future studies establish a quantitative link between the reported sublethal effects and fish survival, growth, or reproduction, the conclusions may need to be revisited.

6.2.6. Exposure to Pesticide Mixtures

In accordance with the Overview Document and the Services Evaluation Memorandum (U.S. EPA, 2004; USFWS/NMFS, 2004), this assessment considers the single active ingredient of atrazine, as well as available information on registered products containing multiple active ingredients in addition to atrazine. However, the assessed species and its environments may be exposed to multiple pesticides simultaneously. Interactions of other toxic agents with atrazine could result in additive effects, synergistic effects, or antagonistic effects. The available data suggest that pesticide mixtures involving atrazine may produce either synergistic or additive effects. Mixtures that have been studied include atrazine with insecticides such as organophosphates and carbamates or with herbicides including alachlor and metolachlor. A number of study authors claim additive or synergistic effects in several taxa including fish, amphibians, invertebrates, and plants.

As previously discussed, evaluation of pesticide mixtures is beyond the scope of this assessment because of the myriad of factors that cannot be quantified based on the available data. Those factors include identification of other possible co-contaminants where the Topeka shiner resides and their concentrations, differences in the pattern and duration of exposure among contaminants, and the differential effects of other physical/chemical characteristics of the receiving waters (e.g. organic matter present in sediment and suspended water). Evaluation of factors that could influence additivity/synergism/antagonism is beyond the nature and quality of the available data to allow for an evaluation. However, it is acknowledged that not considering mixtures could over- or under-estimate risks depending on the type of interaction and factors discussed above.

6.3 Assumptions Associated with the Acute LOCs

The risk characterization section of this endangered species assessment includes an evaluation of the potential for individual effects. The individual effects probability associated with the acute RQ is based on the mean estimate of the slope and an assumption of a probit dose response relationship for the effects study corresponding to the taxonomic group for which the LOCs are exceeded.

Sufficient dose-response information was not available to estimate the probability of an individual effect on the midge (one of the dietary food items of the Topeka shiner). Acute ecotoxicity data from the midge were used to derive RQs for freshwater invertebrates. Based on a lack of dose-response information for the midge, the probability of an individual effect was calculated using the only probit dose response curve slope value reported in available freshwater invertebrate ecotoxicity data for technical grade atrazine. Therefore, a probit slope value of 4.4 for the amphipod was used to estimate the probability of an individual effect on the freshwater invertebrates. It is unclear whether the probability of an individual effect for freshwater invertebrates other than amphipods would be higher or lower, given a lack of dose-response information for other freshwater invertebrate species. However, the assumed probit dose response slope for freshwater invertebrates of 4.4 would have to decrease to approximately 1 to 2 to cause an effect probability ranging between 1 in 10 and 1 in 100, respectively, for freshwater invertebrates.

6.4. Uncertainty in the Potential Effect to Riparian Vegetation vs. Water Quality Impacts

Effects to riparian vegetation were evaluated using submitted guideline seedling emergence and vegetative vigor studies and non-guideline woody plant effects data. LOCs were exceeded for seedling emergence and vegetative vigor endpoints with the seedling emergence endpoint being considerably more sensitive. Based on LOC exceedances and the lack of readily available information to allow for characterization of riparian areas of the Topeka shiner, it was concluded that atrazine use is likely to adversely affect the Topeka shiner via potential impacts on grassy/herbaceous riparian vegetation resulting in increased sedimentation. However, soil retention/sediment loading is dependent on a number of factors including land management and tillage practices. Use of herbicides (including atrazine) may be incorporated into a soil conservation plan. Therefore, although this assessment concludes that atrazine is likely to adversely affect the assessed listed species and its designated critical habitat by potentially impacting sensitive herbaceous riparian areas, it is possible that adverse impacts on sediment loading may not occur in areas where soil retention strategies are used.

7. Summary of Direct and Indirect Effects to the Topeka shiner and Adverse Modification to Designated Critical Habitat

In fulfilling its obligations under Section 7(a)(2) of the Endangered Species Act, the information presented in this ESA represents the best data currently available to assess the potential risks of atrazine to the Topeka shiner and its designated critical habitat. A summary of the risk conclusions and effects determination for the Topeka shiner and designated critical habitat, given the uncertainties discussed in Section 6, by assessment endpoint, is presented in Tables 7.1 and 7.2.

Overall, this assessment suggests that atrazine has the potential to adversely affect the Topeka shiner or adversely modify its critical habitat by direct chronic effects and from potential impacts to aquatic plants and riparian habitat.

Table 7.1. Effects Determination Summary for the Topeka shiner (by Assessment Endpoint)

Assessment Endpoint	Effects Determination	Basis for Conclusion
1. Survival, growth, and reproduction of individuals via direct acute or chronic effects	**Acute effects** No Effect – all uses	RQs across all uses did not exceed any LOC based on the most sensitive available freshwater fish LC50. See Section 5.2.1.1
	Chronic effects [a] **LAA** Corn (all regions); fallow (west region) **No effect** All other uses	RQs were up to 1.3 to 1.6 for corn and fallow uses, respectively, based on 60-day EECs estimated using PRZM/EXAMS. The LOAEC in the most sensitive life-cycle study was 120 ug/L based on a 7% reduction in length and 16% reduction in weight in brook trout. 60-Day EECs were lower than the fish life-cycle LOAEC; therefore, at the 60-day EECs, the magnitude of potential effect to the Topeka shiner would be expected to be lower than effects observed at the LOAEC if the Topeka shiner is equally sensitive to atrazine as brook trout. See Section 5.2.1.2.
2. Indirect effects to individuals via potential effects to aquatic plants (food, and primary productivity)	**LAA** Corn, sorghum, fallow, and forestry uses **NLAA** All other uses	Community level effects thresholds are exceeded based on PRZM/EXAMS 14- to 90-day EECs. See Section 5.2.2.2. NLAA conclusion was based on significance of effect as defined in Section 5.
3. Indirect effects to individuals via direct effects to aquatic and terrestrial invertebrates as food items	NLAA for all uses	NLAA conclusion was based on significance of effect as defined in Section 5. The potential magnitude of effect to aquatic and terrestrial invertebrate food items is expected to be low such that measurable effects to the Topeka shiner are not expected. See Section 5.2.2.1.
4. Indirect effects to individuals via direct effects to other fish needed for spawning habitat (*e.g.*, sunfish) and diet.	NLAA for all uses	NLAA conclusion was based on significance of effect as defined in Section 5. No acute LOCs were exceeded for fish. The chronic LOC was exceeded for the most sensitive species tested (brook trout); however, the potential magnitude of effect to fish is expected to be low such that measurable effects to the Topeka shiner are not expected. See Section 5.2.2.3.
4. Indirect effects to individuals via reduction of terrestrial vegetation (i.e., riparian habitat) required to	Direct effects to sensitive riparian vegetation: LAA	Riparian areas within the Great Plains are expected to be predominantly grasslands. Data presented in Section 4 of this assessment indicates that grassy and herbaceous vegetation may be sensitive to atrazine. Therefore,

Assessment Endpoint	Effects Determination	Basis for Conclusion
maintain acceptable water quality and habitat		riparian areas that are predominantly grassy/herbaceous vegetation and that receive runoff or spraydrift from atrazine use sites may be affected. Until further analysis on specific land management practices and sensitivity of riparian vegetation adjacent to Topeka shiner habitat is performed, potential effects to riparian vegetation as indicated by terrestrial plant LOC exceedance, is presumed to potentially adversely affect the Topeka shiner and its designated critical habitat. See Section 5.2.2.4.

[a] Topeka shiner habitats include side pools of low-order streams with low/negligible flow rates. PRZM/EXAMS was considered appropriate to represent both short-term and long-term potential exposures in these types of habitats. However, there is uncertainty in this assumption as discussed in Section 3 of this assessment.

Table 7.2 Effects Determination Summary for the Critical Habitat Impact Analysis

PCE[a]	Conclusions	Basis for Conclusions (see Section 5.3. for additional information)
Streams and side-channel pools with water quality necessary for unimpaired behavior, growth, and viability of all life stages. The water quality components can vary seasonally and include--temperature (1 to 30[deg]Centigrade), total suspended solids (0 to 2000 ppm), conductivity (100 to 800 mhos), dissolved oxygen (4 ppm or greater), pH (7.0 to 9.0), and other chemical characteristics	LAA	As described in Table 1.1, RQs were exceeded for aquatic and terrestrial plants (Sections 5.2.2.2 and 5.2.2.4), which suggest that effects to aquatic and sensitive riparian plants could occur and potentially result in alteration of suspended solid levels, oxygen levels, and other chemical characteristics.
Living areas for juvenile Topeka shiners with water velocities less than 0.5 meters/second (approx. 20 inches/second) with depths less than 0.25 meters (approx. 10 inches) and moderate amounts of instream aquatic cover, such as woody debris, overhanging terrestrial vegetation, and aquatic plants	LAA	As described in Table 1.1, RQs were exceeded for aquatic and terrestrial plants (Sections 5.2.2.2 and 5.2.2.4), which suggests that "amounts of instream aquatic cover, such as woody debris, overhanging terrestrial vegetation, and aquatic plants" could be affected. Woody plant species are not expected to be adversely affected by atrazine at EECs presented in this assessment; however, other overhanging vegetation and aquatic plants could potentially be impacted in areas that are in close proximity to atrazine use.
Sand, gravel, cobble, and silt substrates with amounts of fine sediment and substrate embeddedness that allows for nest building and maintenance of nests and eggs by native *Lepomis* sunfishes (green sunfish, orangespotted sunfish, longear sunfish) and Topeka shiner as necessary for reproduction, unimpaired behavior, growth, and viability of all life stages	LAA	Atrazine may affect riparian vegetation of the Topeka shiner's habitats that are in close proximity to atrazine use sites. However, sedimentation / siltation in a stream may depend on numerous factors, and determining whether atrazine use is expected to result in an overall increase in sediment/silt levels in a habitat is difficult. Nonetheless, sensitive riparian areas exposed to atrazine could be adversely impacted (MRID 42041403), which could indirectly affect the Topeka shiner. Until further analysis is performed on specific land management practices in areas surrounding Topeka shiner habitats, terrestrial plant LOC exceedance is presumed to indicate potential adverse indirect effects the Topeka shiner and its designated critical habitat.
An adequate terrestrial, semiaquatic, and aquatic invertebrate food base that allows for unimpaired growth, reproduction, and survival of all life stages	NLAA	As indicated in Table 1.1, atrazine is not likely to adversely affect the Topeka shiner via reduction in aquatic and terrestrial invertebrates as food supply.

a Other PCEs (described in Section 2.4) were not evaluated because there was no perceived direct link between those PCEs and processes that could be affected by atrazine use.

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