Hine's Emerald Dragonfly, *Somatochlora hineana*
(Odonata: Corduliidae)

5-Year Review:
Summary and Evaluation

U.S. Fish and Wildlife Service, **Midwest Region**
Chicago Ecological Services Field Office
Barrington, Illinois

May 2013

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APPENDIX

5-YEAR REVIEW
Hine's Emerald Dragonfly (*Somatochlora hineana*)

1.0 GENERAL INFORMATION

1.1 Reviewers

Lead Regional Office:
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Cooperating Field Office(s):
Cathy Carnes, Green Bay, Wisconsin Field Office (920) 866-1732
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Paul McKenzie, Columbia, Missouri Field Office (573) 234-2132 extension 107

Cooperating Regional Office(s): none

1.2 Methodology used to complete the review:

Public notice was given in the *Federal Register* (72 FR 41348) requesting new scientific or commercial data and information that may have a bearing on the Hine's emerald dragonfly (*Somatochlora hineana*) classification of endangered status. Pertinent data was obtained from the Recovery Plan and from recent reports, species experts and scientific journals. This 5-year review was completed by Kristopher Lah, Endangered Species Coordinator, Chicago Ecological Services Field Office. The USFWS did not carry out a formal peer review of the 5-year review because scientific uncertainty or controversy is not high. The focus of this 5-year review is to evaluate whether new information indicates a change in the listing classification of the species is necessary and to summarize the current status of the Hine's emerald dragonfly.

1.3 Background:

1.3.1 FR Notice citation announcing initiation of this review:

72 FR 41348-41350 (July 27, 2007)

1.3.2 Listing history

Original listing
FR notice: 60 FR 5267-5273
Date listed: January 26, 1995
Entity listed: Hine's emerald dragonfly (*Somatochlora hineana*); species
Classification: Endangered

1.3.3 Associated rulemakings

Designation of Critical Habitat
FR notice: 72 FR 51101-51152
Date designated: September 5, 2007

Revised Designation of Critical Habitat
FR notice: 75 FR 21393-21453
Date designation revised: April 23, 2010

1.3.4 Review History

The notice announcing the initiation of this and other 5-year reviews and opening of the information request period for 90 days was published on July 27, 2007 (72 FR 41348-41350). We did receive information specific to the Hine's emerald dragonfly, but we did not receive any comment letters supporting continued protection under the Endangered Species Act of 1973 (Act), as amended, of all species noticed in this announcement.

1.3.5 Species' Recovery Priority Number at start of 5-year review

Five "C". The "5" indicates a high degree of threat and low recovery potential and it is in conflict with development and mining.

1.3.6 Recovery Plan

Name of plan: Hine's Emerald Dragonfly (*Somatochlora hineana* Williamson) Recovery Plan
Date issued: September 27, 2001

2.0 REVIEW ANALYSIS

2.1 Application of the 1996 Distinct Population Segment (DPS) policy

2.1.1 Is the species under review a vertebrate?

No.

2.2 Recovery Criteria

2.2.1 Does the species have a final, approved recovery plan containing objective, measurable criteria?

Yes.

2.2.2 Adequacy of recovery criteria.

2.2.2.1 Do the recovery criteria reflect the best available and most up-to date information on the biology of the species and its habitat?

Yes.

2.2.2.2 Are all of the 5 listing factors that are relevant to the species addressed in the recovery criteria (and is there no new information to consider regarding existing or new threats)?

Yes. While new threats to the species exist that were not known when the recovery criteria were written, these threats are addressed in the requirements of the recovery criteria (criterion 3 - habitat protection and management). In addition, the magnitude of some ongoing threats is not completely understood. Threats are covered in more detail below in section 2.3.2 Five-Factor Analysis.

2.2.3 List the recovery criteria as they appear in the recovery plan, and discuss how each criterion has or has not been met, citing information:

The Hine's emerald dragonfly may be considered for reclassification to threatened status when the following criteria are met:

<u>Criterion 1</u>. Each of the two Recovery Units contains a minimum of two populations, each composed of at least three subpopulations (i.e., 12 total subpopulations). Each subpopulation contains a minimum of 500 sexually mature adults for 10 consecutive years.

Criterion 1 has not been met. As identified in the recovery plan, the range of the species is divided into a Northern and Southern Recovery Unit. Since issuance of the recovery plan, previously unknown sites have been found in both recovery units and each of these "new" sites is described below under section 2.3.1.5. All known sites are listed in Table 1 (USFWS 2001). The Northern Recovery Unit consists of documented Hine's emerald dragonfly sites in Door and Kewaunee Counties in Wisconsin, and sites in Alcona, Alpena, Charlevoix, Mackinac, Menominee, and Presque Isle Counties in Michigan. The Southern Recovery Unit consists of sites in Iowa; Ozaukee and Richland Counties, Wisconsin; Cook, DuPage and Will Counties, Illinois; and Dent, Iron, Phelps, Reynolds, and Ripley Counties in Missouri.

Determination of what constitutes a population was defined in the recovery plan as "a group of individuals of the same species, coexisting at the same time and in the same geographic area, and capable of interbreeding (Purves *et al*. 1998 as cited in USFWS 2001, p. 7). Hine's emerald dragonfly populations are distinguished from each other by being separated by large distances (e.g., 31 miles (50 km) or more) and having a low probability of genetic exchange (USFWS 2001, p.7)." Genetic research conducted on Hine's emerald dragonfly supports the definition provided in the recovery plan (H. Britten, University of South Dakota, pers. comm. 2013). Based on this research, the sites within the Northern Recovery Unit make up two populations, referred to as the Northern Wisconsin and Michigan Populations. The Southern Recovery Unit consists of four populations: Ozaukee County Wisconsin, Southwest Wisconsin, Illinois, and Missouri Populations.

Table 1. Distribution and Status of Hine's Emerald Dragonfly Based on Recovery Criteria

Recovery Unit	Population	Subpopulation[1]	Adult Subpop. Size	Site[2] * = site found since issuance of recovery plan	Adult # per site	Number of Breeding Areas[3]	Legally Protected and Managed[4]	GW Area Delineated - Protected	Mntrng. Plan
Northern Recovery Unit	Northern Wisconsin Population	Mink River Estuary, Door County, WI	TBD	Mink River	TBD	Yes, 1 verified	Partially protected	Delineated partially protected	No
		The Ridges, Door County, WI	TBD	Three Springs Creek	TBD	Yes, 1 verified#	Partially protected	Delineated partially protected	No#
			TBD	North Bay Marsh	TBD	Yes, 1 verified#	Partially protected	Delineated partially protected	No#
			TBD	Mud Lake North Complex (Lime Kiln, Pioneer, and Grove Roads)	TBD	Yes, 6 verified#	Partially protected	Delineated partially protected	No#
			TBD	Mystery Creek (Mud Lake South)	TBD	Yes, unknown #	Partially protected	Delineated partially protected	No#
			TBD	Piel Creek	TBD	Yes, 1 verified#	Partially protected	Delineated partially protected	No#
			TBD	Baileys Harbor	TBD	Yes, unknown#	Partially protected	Delineated partially protected	No#
			TBD	Ridges Sanctuary	TBD	Yes, 3 verified#	Partially protected	Delineated partially protected	No#

Recovery Unit	Population	Subpopulation[1]	Adult Subpop. Size	Site[2] * = site found since issuance of recovery plan	Adult # per site	Number of Breeding Areas[3]	Legally Protected and Managed[4]	GW Area Delineated - Protected	Mntrng. Plan
			TBD	Toft Point	TBD	No	Unknown	No	No#
		Arbter Lake, Door County, WI	TBD	Arbter Lake	TBD	Yes, unknown#	Partially protected	Delineated partially protected	No
		Washington Island, Door County, WI	TBD	Big Marsh	TBD	Yes, 1 verified	Partially protected	Delineated partially protected	No
		Black Ash Swamp, Door and Kewaunee Counties, WI	TBD	Black Ash Swamp	TBD	Yes, unknown#	Not protected	No	No#
		Gardner Marsh, WI	TBD	Gardner Marsh	TBD	Yes, unknown#	Partially protected	Delineated partially protected	No#
		Ephraim Swamp, Door County	TBD	Ephraim Swamp	TBD	Yes, unknown	Partially protected	No	No
		Kellner Fen, Door County, WI	TBD	Kellner Fen	TBD	Yes, 1 verified	Partially protected	Delineated partially protected	No
	Michigan Population	Mackinac County 1, MI (I-75 West and MI CHU 1)#	TBD#	I-75 West#	TBD#	Not confirmed#	Partially protected#	No#	No#
			TBD#	Brevort Lake Road#	TBD#	Yes, 1 verified#	Fully protected#	No#	No#
			TBD#	Castle Rock Road*#	TBD#	Not confirmed #	Fully protected #	No#	No#

Recovery Unit	Population	Subpopulation[1]	Adult Subpop. Size	Site[2] * = site found since issuance of recovery plan	Adult # per site	Number of Breeding Areas[3]	Legally Protected and Managed[4]	GW Area Delineated - Protected	Mntrng. Plan
			TBD#	Summerby Swamp#	267#	Yes, 1 verified#	Fully protected#	No#	No#
			TBD#	Round Lake*#	TBD#	Yes, 1 verified#	Fully protected#	No#	No#
			TBD#	Hay Lake*#	TBD#	Yes, 1 verified#	Fully protected#	No#	No#
			TBD#	Huebner#	TBD#	Yes, 1 verified#	Fully protected#	No#	No#
		Mackinac County 2, Michigan (MI CHU 2)#	TBD#	I-75 East#	TBD#	Yes, 1 verified#	Partially protected#	No#	No#
			TBD#	Acklund Road#	TBD#	Yes, 1 verified#	Fully Protected#	No#	No#
			TBD#	Foley Creek#	TBD#	Yes, 1 verified#	Partially protected#	No#	No#
			TBD#	Martineau Creek#	TBD#	Yes, 1 verified#	#	No#	#
			TBD#	Inglesbee Swamp#	TBD#	Not confirmed#	Partially protected#	No#	No#
			TBD#	Horseshoe Bay#	TBD#	Not confirmed#	Fully Protected#	No#	No#
		Mackinac County 3 (MI CHU 3)#	TBD#	Bois Blanc Island#	TBD#	Yes, 1 verified#	#	No#	No#
		Presque Isle County (MI CHU 4)#	TBD#	Thompson's Harbor State Park*#	TBD#	Yes, 1 verified#	Fully Protected#	No#	No#

Recovery Unit	Population	Subpopulation[1]	Adult Subpop. Size	Site[2] * = site found since issuance of recovery plan	Adult # per site	Number of Breeding Areas[3]	Legally Protected and Managed[4]	GW Area Delineated - Protected	Mntrng. Plan
		Alpena County (MI CHU 5 and MI CHU 6)#	TBD#	North Point Rd. Fen#	TBD#	Yes, 1 verified#	Partially protected#	No#	No#
			TBD#	Misery Bay#	TBD#	Yes, 1 verified#	Not protected#	No#	No#
		Alcona County, MI#	TBD#	Negwegon State Park - North* #	TBD#	Not confirmed#	Fully Protected#	No#	No#
			#	Negwegon State Park – South*#	TBD#	Not confirmed#	Fully Protected#	No#	No#
		Menominee County, MI#	TBD#	Hayward Lake*#	TBD#	Not confirmed#	Fully Protected#	No#	No#
		Charlevoix County, MI#	TBD#	Garden Island (Beaver Island Archipelago)*#	TBD#	Not confirmed#	Fully Protected#	No#	No#
Southern Recovery Unit	Illinois Population	Illinois Subpopulation 1	154, 212	Lockport Prairie NP	79/13 4	Yes, 5 verified	Fully Protected	Delineated but not protected	No
				River South and Middle Parcel	66/69	Yes, 4 verified	Not protected	Delineated for River South, not protected	No
				Romeoville Prairie NP	TBD	Not confirmed	Fully Protected	No	No
				Long Run Seep NP and Long Run/ComEd Parcel	9	Yes, 2 verified	Partially protected	No	No

Recovery Unit	Population	Subpopulation[1]	Adult Subpop. Size	Site[2] * = site found since issuance of recovery plan	Adult # per site	Number of Breeding Areas[3]	Legally Protected and Managed[4]	GW Area Delineated - Protected	Mntrng. Plan
		Illinois Subpopulation 2	10	Keepataw FP	10	Yes, 5 verified	Fully Protected#	No	No
				Black Partridge FP	TBD	Not confirmed	Fully Protected#	No	No
				Waterfall Glen FP	TBD	Yes, 1 verified (no larvae found 2009-11)	Fully Protected#	No	No
		Illinois Subpopulation 3	TBD	Cherry Hill Woods FP*	TBD	Not confirmed	Fully Protected#	No	No
			TBD#	McMahon Fen NP#	TBD#	Yes, 2 verified#	Fully Protected#	No#	No#
			TBD	Palos Fen NP*	TBD	Not confirmed	Fully Protected#	No	No
	Ozaukee County, WI	Ozaukee County	TBD	Cedarburg Bog	TBD	Yes, 2 verified#	Partially protected	Delineated but not protected	No
	Southwest WI	Iowa County	TBD	Lower Wisconsin State Riverway – Kendall Lake and Avoca Wildlife Area*	TBD	Yes, 1 verified#	Fully Protected#	No	No

Recovery Unit	Population	Subpopulation[1]	Adult Subpop. Size	Site[2] * = site found since issuance of recovery plan	Adult # per site	Number of Breeding Areas[3]	Legally Protected and Managed[4]	GW Area Delineated - Protected	Mntrng. Plan
		Iowa and Richland Counties	TBD	Lower Wisconsin State Riverway - Knapp Creek*	TBD	Yes, 1 verified	Fully Protected#	No	No
	Missouri	Dent County	TBD	Bates Hollow*	TBD	Yes, 1 verified#	Partially protected	No	No
			TBD	Fortune Hollow*	TBD	Yes, 1 verified	Fully Protected#	No#	No#
		Iron Co.	TBD	Barton Fen	TBD	Yes, 1 verified#	Fully Protected#	Delineated but not protected#	No#
		Phelps Co.	TBD	Kaintuck Hollow*	TBD	Yes, 1 verified#	Fully Protected#	No#	No#
		Reynolds	TBD	Bee Fork East*	TBD	Not confirmed	Fully Protected#	No#	No#
			TBD	Bee Fork Center*	TBD	Yes, 1 verified#	Fully Protected#	No#	No#
			TBD	Bee Fork West*	TBD	Yes, 1 verified#	Fully Protected#	No#	No#
			TBD	Centerville Slough*	TBD	Yes, 1 verified#	Not protected	No#	No#
			TBD	Deckard Hollow*	TBD	Not confirmed	Not protected	No#	No#
			TBD	Grasshopper Hollow	TBD	Yes, 4 verified#	Fully Protected#	No#	No#
			TBD	Johnson Shut-in State Park –	TBD	Yes, 1 verified#	Fully Protected#	No#	No#

Recovery Unit	Population	Subpopulation[1]	Adult Subpop. Size	Site[2] * = site found since issuance of recovery plan	Adult # per site	Number of Breeding Areas[3]	Legally Protected and Managed[4]	GW Area Delineated - Protected	Mntrng. Plan
				proper*					
			TBD	Johnson Shut-in Walker Tract*	TBD	Yes, 1 verified#	Fully Protected	No#	No#
			TBD	Kay Branch*	TBD	Yes, 5 verified#	Not protected	No#	No#
			TBD	Ruble Meadow	TBD	Yes, 1 verified#	Not protected#	No#	No#
			TBD	Wisdom/Lanham Fen*	TBD	Yes, 1 verified#	Not protected#	No#	No#
		Ripley County	TBD	Cottonmouth Fen*	TBD	Not confirmed	Not protected#	No#	No#
			TBD	Emerald Fen*	TBD	Yes, 1 verified#	Not protected#	No#	No#
			TBD	Glass Lizard Fen*	TBD	Yes, 1 verified#	Fully Protected#	No#	No#
			TBD	Montgomery Fen*	TBD	Yes, 2 verified#	Fully Protected#	No#	No#
			TBD	Overcup Fen*	TBD	Not confirmed	Fully Protected#	No#	No#

1) Subpopulations are a theoretical depiction of the potential population structure within each population based on proximity of individual sites and number of breeding areas identified.
2) Sites where Hine's emerald dragonfly adults and larvae have been documented are included.
3) Site is considered a breeding site when at least one of the following criteria are met: a) presence of a Hine's emerald dragonfly exuvia; b) observation of a teneral Hine's emerald dragonfly; c) presence and verification (e.g., species expert, final instar male larva, or genetic analysis of larva is positive) of Hine's emerald dragonfly larvae; d) observation of a female Hine's emerald dragonfly ovipositing; or e) presence of multiple territorial male Hine's emerald dragonflies.
4) Legally protected and managed – long-term protection mechanisms such as watershed protection, deed restrictions, land acquisition, or nature preserve dedication.
Acronyms used: TBD= To be determined; NP = Nature Preserve; FP = Forest Preserve; Mntrng. = Monitoring

A subpopulation was defined in the recovery plan (USFWS 2001, p. 7) as "a local population occurring at a specific geographic site (e.g., Lockport, The Ridges, etc.). A subpopulation would be relatively self-sustaining (Pulliam 1988; Pulliam and Danielson 1991)." If a few individuals occur at a specific site primarily due to the immigration from a source population that would not constitute a subpopulation. In addition, over the course of several years, the combination of birth and immigration minus death and emigration in a subpopulation should balance out to have a non-negative growth rate. In cases where larval habitat constitutes what appears to be separate subpopulations, but adult habitat is contiguous, the geographic area used by the adults would define the edges of the subpopulation because it will be assumed that the adults are freely using the entire area and genetically mixing. Similarly, a road that cuts through an otherwise contiguous habitat would not create two subpopulations. These two areas would be considered one subpopulation.

Genetic analysis has provided support for a distinction or genetic separation between the Northern Recovery Unit and the Southern Recovery Unit as theorized in the recovery plan (H. Britten, pers. comm. 2013). The Northern Recovery Unit consists of two populations, the Northern Wisconsin Population and the Michigan Population. The Southern Recovery Unit is made up of four populations, Ozaukee County Wisconsin Population, the Illinois Population, the Southwest Wisconsin Population and the Missouri Population (see Table 1) (H. Britten, pers. comm. 2013; M. Mahoney, Illinois State Museum, pers. comm. 2012). Therefore the population number (2) for each recovery unit has been met.

Table 1 provides a theoretical depiction of the potential subpopulations within each population based on proximity of individual sites and number of breeding areas identified. Both the Northern Wisconsin Population and the Michigan Population consists of eight subpopulations. While the number of subpopulations currently present in each population (eight) exceeds the recovery criteria (three subpopulations per population), the subpopulation criteria pertaining to population numbers (a minimum of 500 sexually mature adults for 10 consecutive years) has only partially been met and only in the Northern Wisconsin Population. While quantitative population estimates have not been completed for sites within the Northern Wisconsin Population, the size of the population is thought to be in the order of several thousand adults (Kirk and Vogt 1995, pp.12-14; Soluk, University of South Dakota, pers. comm. 2012). Therefore, the Northern Wisconsin Population has partially met the recovery criteria of 1,500 adults within a population. Population data was collected for one site in the Michigan Population; Summerby Swamp and it is estimated to consist of 157-377 adult Hine's emerald dragonflies (Soluk et al 2012).

The Southern Recovery Unit is made up of four potential populations (H. Britten, pers. comm. 2012; M. Mahoney, Illinois State Museum, pers. comm. 2012) that may consist of 11 subpopulations (see Table 1). The Ozaukee County, Wisconsin Population consists of one site in Ozaukee County, Wisconsin. The Southwest Wisconsin Population consists of two subpopulations, one in Iowa County and another in Iowa and Richland Counties, Wisconsin. The Illinois population theoretically consists of three subpopulations,

referred to as Illinois Subpopulations 1, 2, and 3. The Missouri Population theoretically consists of five subpopulations, Dent, Iron, Phelps, Reynolds, and Ripley Subpopulations. Hine's emerald dragonfly sites within each occupied Missouri county are considered a subpopulation and are named accordingly.

None of the populations within the Southern Recovery Unit are believed to approach the recovery criterion of 1,500 mature adults. In fact, the only population with a quantified size estimate, the Illinois population, is estimated to be within the range of 86-313 adults (estimate includes standard error - Soluk and Mierzwa 2012, pp. 22-25). Illinois Subpopulation 1 is estimated to consist of 154 (s.e. 74) to 212 (s.e. 87) adult Hine's emerald dragonflies. Illinois Subpopulation 2 is estimated to consist of 10 (s.e. 4) adult Hine's emerald dragonflies. An estimate of the third subpopulation has not been developed because there is not enough quantitative information currently available to allow a meaningful analysis; however, it is believed to provide a minimal contribution to the Illinois population (Soluk and Mierzwa 2012, p. 2). Hine's emerald dragonfly abundance appears to be smaller at Missouri sites than Illinois, Michigan and Wisconsin sites (McKenzie and Vogt 2005, p.19). While the other populations in the Southern recovery Unit have not been quantified, they are not expected to meet the recovery criteria of 1,500 mature adults.

Criterion 2. Within each subpopulation, there are at least two breeding habitat areas (i.e., 24 total breeding areas), each fed by separate seeps and/or springs.

Criterion 2 has not been met. While 27 subpopulations potentially exist across the range of the Hine's emerald dragonfly, only 12 of them contain more than one breeding area and they are not distributed according to the criteria in the recovery plan (Table 1). Of the 16 potential subpopulations in the Northern Recovery Unit, four of them (The Ridges, Mackinac County 1, Mackinac County 2, and Alpena County) have two or more breeding areas. Of the 11 subpopulations in the Southern Recovery Unit, eight of them contain two or more breeding areas. The Cedarburg Bog site within the Ozaukee County, Wisconsin population consists of two breeding areas. Breeding has been confirmed in the Southwest Wisconsin population, at two locations. All three of the subpopulations in Illinois have two or more breeding areas. In Missouri, we hypothesize that there are five subpopulations and three of those have more than one breeding area.

Criterion 3. For each population, the habitat supporting at least two subpopulations should be legally or formally protected and managed for Hine's emerald dragonfly, using long-term protection mechanisms such as watershed protection, deed restrictions, land acquisition, or nature preserve dedication. In addition, mechanisms protecting the up gradient groundwatershed should also be in place.

Criterion 3 has not been completely met.

Habitat Protection and Management:
Of the 16 subpopulations within the Northern Wisconsin Population and Northern Michigan Population, the habitat of five of those subpopulations are entirely managed

and protected by Federal or State agencies, while others have a mixture of ownership and are not completely protected and managed (Table 1). Hine's emerald dragonfly breeding sites currently known or verified in the future within the Hiawatha National Forest will be protected under the Federal Threatened and Endangered Species and Regional Forest Sensitive Species Plan (USFS 2006).

The majority of the habitat within the three Illinois subpopulations is protected and managed by County and State agencies (Table 1) and State laws (K. Lah, USFWS, pers. comm. 2012). Private land exists within Illinois Subpopulation 1, but it is currently being managed to benefit Hine's emerald dragonfly.

The habitat within the Ozaukee County, Wisconsin Population is protected and managed by the Wisconsin Department of Natural Resources and the University of Wisconsin (Table 1; W. Smith, Wisconsin Department of Natural Resources, pers. comm. 2012).

The entire Hine's emerald dragonfly habitat area that has been identified within the Southwest Wisconsin Population is managed and protected by the Wisconsin Department of Natural Resources (Table 1; W. Smith, pers. comm. 2012).

In Missouri, the majority of the habitat in two of the five subpopulations are completely protected and managed by either the U.S Forest Service or Missouri Department of Conservation (Table 1; P. McKenzie, USFWS, pers. comm. 2012). The Forest Plan for the Mark Twain National Forest identifies a number of actions supporting management of Hine's emerald dragonfly habitat (USFS 2005). Management actions identified include control of non-native and/or undesirable (e.g., woody) plant species, restoration of local hydrology, and methods to minimize unauthorized vehicle and heavy equipment access near fens with known or suspected Hine's emerald dragonfly populations.

Groundwatershed Protection:

In the Northern Recovery Unit, groundwater recharge areas have been delineated for 13 sites in the Northern Wisconsin Population; 12 groundwater recharge areas were delineated by Cobb and Bradbury (2008). An additional groundwater recharge area has been mapped for Cedarburg Bog (Ozaukee County) by the Wisconsin Department of Natural Resources and Wisconsin Geological and Natural History Survey (Joanne Kline, WDNR, pers. comm., 2013). Groundwater research is under way for sites within the Michigan Population. In the Southern Recovery Unit groundwater recharge areas have been delineated at one site in Ozaukee County, Wisconsin (Cobb and Bradbury 2008), two sites in Illinois (Graef 2008; STS 2009), one site in Missouri (Beeman and Aley 2012) and another is under contract. The mechanisms that are in place to protect the groundwatershed for Hine's emerald dragonfly habitat include sections 7 and 9 of the Endangered Species Act of 1973 (ESA) and the Illinois Natural Areas Preservation Act. Section 7(a)(2) of the ESA requires Federal agencies to consult with the U.S. Fish and Wildlife Service prior to authorizing, funding or carrying out activities that may affect listed species or designated critical habitat. Section 9 of the ESA prohibits any person subject to the jurisdiction of the United States from taking listed wildlife species. The term "take" is defined to include harassing, harming, pursuing, hunting, shooting,

wounding, killing, trapping, capturing, or collecting. Regulations implementing the ESA (50 CFR 17.3) further define "harm" to include significant habitat modification or degradation that results in killing or injury of listed wildlife species by significantly impairing essential behavioral patterns including breeding, feeding, or sheltering. Illinois sites dedicated as Illinois Nature Preserves are afforded the maximum legal protection against future changes in land use, which can include changes to groundwater that discharges into dedicated nature preserves.

Criterion 4. A monitoring plan must be established for each population within 5 years to estimate population size on an annual basis for the purpose of determining whether recovery criteria have been achieved.

Criterion 4 has not been met. While population surveys have been conducted at most of the sites in Illinois, resources have not been available to consistently monitor sites. However, a better understanding of where breeding occurs within subpopulations is still being developed. Monitoring plans will need to be developed as more knowledge is gained about the habitat structure of sites and as resources become available.

2.3 Updated Information and Current Species Status

2.3.1 Biology and Habitat

2.3.1.1 New information on the species' biology and life history:

Life History and Survival Rates

Hine's emerald dragonfly eggs overwinter, and subsequent larval development has been shown to take 3-5 years (Soluk and Satyshur 2005b). From captive rearing experiments, Soluk *et al*. (2009, p. 16) estimate that larval development is 4.87 winters to emergence. Approximately 8% of the larval population, age 1+ or above, are pre-emergent (i.e., prior to emerging as adults) referred to as F-0 larvae (Foster and Soluk 2004, p. 18). The final instar headwidth is greater than 6.0mm and total length greater than >20.0mm (Foster and Soluk 2004, p. 17; Soluk *et al*. 2009, p. 19).

Based on studies of other dragonfly species (Duffy 1994 and Wissinger 1998), the survival rate of Hine's emerald dragonfly eggs to mature larvae is likely less than 1% to 5.5% but possibly lower (D. Soluk and R. DeMots, University of South Dakota, pers. comm. 2012). In general, dragonfly larval mortality is extremely high during the first few larval instars. This natural mortality is a result of predation, cannibalism, and sometimes starvation. However, very small larvae (headwidth < 2.00mm) grow faster than larger larvae (Satyshur 2008).

Based on surveys for exuviae, most of the Hine's emerald dragonfly emerged as adults in Wisconsin over a two to three week period between mid-June and early July (Foster and Soluk 2004, p.18). The sex ratio at emergence is approximately 1:1 and emergence is synchronous between the sexes (Foster and Soluk 2004, p. 17). The adult stage may last as long as four to six weeks (Foster and Soluk 2004, p. 18).

Associated Crayfish

Hine's emerald dragonfly larvae are commonly found in burrows of the devil crayfish (*Cambarus diogenes*) (Soluk *et al.* 1999, pp. 42-45). There is evidence that the crayfish will prey upon Hine's emerald dragonfly larva (Pintor and Soluk 2006, pp. 587-588).

In 2003, Soluk (2003, p. 9) the burrowing prairie crayfish (*Procambarus gracilis)*, was first observed in what has since been confirmed to be breeding habitat for the Hine's emerald dragonfly at Cedarburg Bog in Ozaukee County, Wisconsin. In 2011, Hine's emerald dragonfly larvae were documented at the Long Run parcel in Will County, Illinois (Brown and Soluk 2012, p. 3). The white river crayfish (*P. acutus*) is the most common crayfish species at this site. It is possible that Hine's emerald dragonfly larvae are capable of taking advantage of burrows of other species of crayfish other than the devil crayfish. However, Hine's emerald dragonfly larvae have not been collected from burrows that have been confirmed to be those of another species of crayfish other than the devil crayfish. Additional research on the life history of the Hine's emerald dragonfly in relation to the host burrow crayfish species is needed.

Adult Sexual Segregation

Monitoring of adult Hine's emerald dragonfly populations, in breeding and non-breeding habitats in Door County, Wisconsin found significant differences in habitat use between males and females. Males primarily used wetland habitats, while females primarily used dry meadows and edges of breeding habitats, apparently only coming into wetlands to oviposit or find mates. In addition, higher quality prey is more plentiful in wetland habitat (Foster and Soluk 2006, pp. 161-162).

Swarming Behavior

Zuehls (2003) recorded new information on dragonfly swarming behavior in Door County, Wisconsin, where swarms studied were dominated (75% of individuals) by Hine's emerald dragonflies. Swarms, thought to be associated with abundant localized prey, averaged 74 dragonflies (range 16 to 275), the majority of which were female. Swarms occurred at midday and in the evening, at times with reduced wind speed. Estimated prey mass was greater during swarm events than when swarms were absent. Behavior in swarms was dominated by foraging (99%), with some mating behaviors being more frequent outside of swarms. Zuehls (2003, p .67and 77) that swarming may provide some individual protection from avian and dragonfly predators; however, predation risk appears to be low and adult Hine's emerald dragonflies spend significant time foraging outside of swarms.

Adult movement

In 2004, observations of Hine's emerald dragonfly adults were made on both sides of the Des Plaines River in the Caton Farm Road Bridge Alignment area (Soluk 2005, p. 4). In 2009, observations were made of adults on Powerhouse Island located in the middle of the river valley (Soluk *et al*. 2009, p. 5). While the source of the dragonflies is not yet known, it is unlikely that breeding habitat occurs on the island based on habitat assessments that have been conducted (J. Miner, Illinois State Geological Survey and K. Lah, pers. comm. 2010). These findings suggest that Hine's emerald dragonflies may be

capable of crossing the river in portions of the valley; a behavior that was not expected because the species is known to avoid open bodies of water.

Groundwater research

Groundwater contribution areas (recharge areas) have been delineated for 13 Hine's emerald dragonfly larval sites in Wisconsin by Cobb and Bradbury (2008) and the Wisconsin Department of Natural Resources/Wisconsin Geological and Natural History Survey (Joanne Kline, WDNR, pers. comm., 2013), two sites in Illinois (Graef 2008, STS 2009) and one site in Missouri (Beeman and Aley 2012). Groundwater modeling studies are currently underway in Michigan and maps of the groundwater contribution areas will be available in 2013. See Table 1 for a list of each site. These maps are being used as tools to help conserve and protect Hine's emerald dragonfly habitat.

Research by Bradbury *et. al* (2012) on the ground and surface water inflows at the Mink River Estuary, one of the larger Hine's emerald dragonfly sites in Wisconsin, found, as expected, that the water is generally a calcium/magnesium bicarbonate type, and is relatively pristine with respect to common contaminants such as nitrate and chloride. They also found a mixing trend along the estuary from the softer, less mineralized water of Lake Michigan to the slightly harder, more mineralized water of the upper Mink River and springs. The groundwater and surface water were found to be isotopically similar, and groundwater discharging to the Mink River was determined to originate from local terrestrial precipitation. This research provides excellent baseline data against which to evaluate future water quality measurements in the Mink River Estuary.

2.3.1.2 Abundance, population trends (e.g., increasing, decreasing, stable), demographic features (e.g., age structure, sex ratio, family size, birth rate, age at mortality, mortality rate, etc.), or demographic trends:

The size of the Door County population is thought to be in the order of several thousand adults (Kirk and Vogt 1995, pp.12-14; Soluk, pers. comm. 2012); however, quantitative population estimates are currently only available for the Illinois population. Soluk and Mierzwa (2012) compiled Hine's emerald dragonfly adult and larval population survey data for Illinois. The estimated number of adults at individual sites is provided in Table 1. The Illinois population, is estimated to be within the range of 86 to 313 adults (estimate includes standard error - Soluk and Mierzwa 2012, pp. 22-25). While the estimate does not include some of the known breeding habitats in Illinois, the estimate for the Illinois population would most likely not change significantly by adding the smaller sites since the core of the Illinois population is included.

In this same report, the authors utilized 17 years of population data to develop an index that provides insight on the population trend in Illinois. The index values show a mean 17-year density, represented as an index value of 1.0. Index values greater than 1.0 (i.e., greater than the long-term mean) occurred in or prior to 2002, with most of the lower values occurring after 2002. The lowest value (0.07) coincided with a drought that Illinois experienced in 2005. The 2011 adult density (index of 0.60) is below the long-term mean, but slightly above the adult density documented in 2003 (index value of

0.51), a year with a relatively thorough larval dataset (Soluk and Mierzwa 2012, pp. 15 and 26). Whether assessing the size of the Illinois population based on the long-term mean or the 2003 data set, the size of the population is very low for any insect and appears to be on a downward trend.

Sex Ratio:
As noted in section 2.3.1.1, the sex ratio at emergence is approximately1:1 and emergence is synchronous between the sexes (Foster and Soluk 2004, p. 17). This finding is contrary to previous studies on other dragonfly species where significant male biases in the adult sex ratio were found and attributable to increased pre-reproductive female mortality (Anholt *et al*. 2001; Stoks 2001 as cited in Foster and Soluk 2006, p. 162). In fact, more adult (post-teneral) Hine's emerald dragonfly females occurred than males in all habitats surveyed. This finding suggests the presence of a female-biased or equal sex ratio among reproductive adult Hine's emerald dragonflies. There appears to be little difference in mortality between the sexes during the teneral or pre-reproductive period.

2.3.1.3 Genetics, genetic variation, or trends in genetic variation (e.g., loss of genetic variation, genetic drift, inbreeding, etc.):

Assessment of the genetic structure of Hine's emerald dragonflies based on microsatellite DNA analysis of samples from sites in Illinois, Wisconsin, and the Upper Peninsula of Michigan revealed a clear spatial pattern for this species with one population in Illinois; a second in Ozaukee County, Wisconsin; a third that is in Kewaunee and Door Counties, Wisconsin; and fourth in the Upper Peninsula of Michigan future (H. Britten, pers. comm. 2013). The assignment of individual sites to populations in Table 1 reflects the information from this research as well as the known flight distance of the species. Based on mark recapture studies Hine's emerald dragonflies can fly at least 3.4 miles (5.5 km) (Mierzwa et al. 1995a, Cashatt and Vogt 1996) but most likely not further than 30 miles (48.28 km) (D. Soluk, pers. comm. 2012).

All four populations analyzed have similar levels of genetic diversity and each has unique alleles. Most genetic variation is within populations (88%) with very little genetic variation among sites within populations (2%) and among populations (10%) (Monroe et al. 2012). However, this level of genetic diversity may not be maintained by regular gene flow in the future due to the loss of stepping stone habitats that must have existed previously based on the species dispersal capabilities.

Genetic work is ongoing and currently includes additional samples from the sites noted above and Washington Island (off the north end of the Door Peninsula, Wisconsin), the Upper Peninsula of Michigan, and a site in Southwest Wisconsin. An analysis of these samples is expected to be completed in the near future and results submitted for publication (H. Britten, pers. comm. 2013).

Based on tenets of genetics, the long term viability of any species is based on a combination of population size and genetic diversity that are essential to counteract

catastrophic events (Dudash and Fenster 2000). In order for a species to persist, its genetic diversity must be maintained range-wide and distinct haplotypes must be preserved. For some species, even a small loss of genetic diversity will preclude a species' ability to withstand significant changes to the environment.

Based on recent genetic analyses by Dr. Meredith Mahoney (pers. comm. 2012), of 141 samples of Hine's emerald dragonfly tissue analyzed for mitochondrial DNA (mtDNA) variation, there are 21 haplotypes rangewide, with up to six differences (1.1%) among them. Missouri exhibits the greatest genetic diversity across the range of the species with 13 of the 21 haplotypes found in Missouri including 10 that are unique to the state; whereas, Michigan has been found to only contain one haplotype and Wisconsin has four haplotypes.

Hine's emerald dragonfly sites in Illinois had previously been thought of as being the most genetically diverse (Purdue et al. 1996) prior to the discovery of sites in Missouri (M. Mahoney, pers. comm. 2012). There are six different haplotypes (genetic variants) that have been found in Illinois, four of which are unique to Illinois, with up to five differences (0.92% divergence) among them. The differences (number or %) are the maximum observed base pair substitutions between haplotype pairs looking either range wide or just within Illinois or other regions. Some haplotype pairs have only one or two differences between them. The four unique haplotypes were all found in sites (Lockport Prairie Nature Preserve, River South and Middle parcels, and Romeoville Prairie) within a close proximity (approx. 4.25 miles (6.84 km)) of each other. The haplotypes unique to Illinois are B, C, E, and F. Alternatively, haplotype D, which is found across the species range, has not yet been found in Illinois, though two other widespread haplotypes (A and G) do occur. Analyses of museum samples from extirpated Ohio populations found genetic variants that are not seen in other, extant, populations (Purdue et al., 1996, and Mahoney pers. comm. 2012). Range wide analysis showed little geographic structuring of genetic variation and most variation (77-86%) is within states (Mahoney pers. comm. 2012). Due to the high genetic diversity and unique haplotypes in Hine's emerald dragonfly populations in Illinois and Missouri, the long term viability of the species range-wide would be compromised if the genetic diversity of these populations is threatened.

Monroe et al. (2010, pp. 1014-1015) evaluated the effectiveness of nonlethal sampling techniques for larval and adult Hine's emerald dragonfly. The methods that they experimented with included shed exuviae, fecal pellets and tarsi from larvae, and wing clips from adults. Fecal pellets and shed exuviae did not provide high enough quality deoxyribonucleic acid (DNA) for microsatellite analyses. However, wing clips from adults and tarsi from larvae provided high-quality DNA that amplified 10 microsatellite markers for Hine's emerald dragonfly.

While they were unable to determine the effects of wing clipping on survival of adults captured in the field, Monroe et al. (2010, p. 1015) note that adults were able to fly away, without any visual effect on flight behavior. There also appeared to be no negative effects from tarsal removal from larvae when they experimented on surrogate species.

Survival among treatments was similar and ranged from 79 to 89%. Tarsal removal was also not found to be lethal for Hine's. They also found that some larvae regenerated one segment of their tarsi after the first molt. Likewise, Baker and Dixon (as cited in Monroe et al. 2010) have shown that tarsi will regenerate in other dragonfly species after one or two molt cycles allowing the larvae to completely recover before they emerge as adults.

2.3.1.4 Taxonomic classification or changes in nomenclature:

There are no changes in classification or nomenclature of Hine's emerald dragonfly since the final listing rule determination and issuance of the recovery plan.

Vogt and Cashatt (2001) published descriptions of larvae; however, identification of early instar larvae continues to be problematic. Vogt (2006, p. 23) notes that Jane Walker reared clamp-tipped emerald (*Somatochlora tenebrosa*) from eggs, and these exhibited middorsal hooks on abdominal segment S3, suggesting that while this character state was considered atypical for the clamp-tipped emerald (Cashatt and Vogt 2001) and characteristic of Hine's emerald dragonfly, use of this character for species level determinations probably should be accompanied by genetic verification.

2.3.1.5 Spatial distribution, trends in spatial distribution (e.g., increasingly fragmented, increased numbers of corridors, etc.), or historic range (e.g., corrections to the historical range, change in distribution of the species' within its historic range, etc.):

Since the issuance of the recovery plan (USFWS 2001), 29 additional sites have been found within the four states (Illinois, Michigan, Missouri and Wisconsin) that make up the current range of the Hine's emerald dragonfly. Table 1 lists all of the sites that are currently known across the species range. "New" sites are identified with an asterisk (*) next to the name of the site. A site is considered a Hine's emerald dragonfly breeding site when there is at least one of the following conditions: (1) the presence of a Hine's emerald dragonfly exuvia; (2) the observation of a teneral Hine's emerald dragonfly; (3) the presence of a final instar male larva or genetic analysis of larva is positive for Hine's emerald dragonfly; (4) observation of a female Hine's emerald dragonfly ovipositing; or (5) the presence of multiple territorial male Hine's emerald dragonflies. Below is a description of the new sites and where they are located.

<u>Illinois</u>

Long Run Seep Nature Preserve

While adult Hine's emerald dragonfly activity was known at this site when the recovery plan was issued, breeding was not verified until 2005 (K. Lah, pers. observ. 2005). Hine's emerald dragonfly productivity at this preserve appears to be quite variable (Mierzwa and Webb 2010, p. 9; Soluk and Mierzwa 2012, p. 23). A search for larvae has occurred in the four streamlet systems, and only one relatively short system (147 yards) has been found to support larvae (Soluk 2009, pp. 6-7).

Long Run/ComEd Parcel
Although territorial behavior by male Hine's emerald dragonflies have been observed over sedge meadow habitat in the northeastern and central parts of the Long Run/Com Ed parcel on a number of occasions (Mierzwa and Webb 2010, p. 4), successful breeding remained undocumented on the site until very recently. On August 31, 2011, larvae were confirmed in crayfish burrows in the central part of the site (Brown and Soluk 2012, p.3).

The white river crayfish, not normally associated with other Hine's emerald dragonfly breeding sites, are the most common crayfish present at the site. As only limited areas of potentially suitable breeding habitat have been identified, it is currently assumed that the Long Run/Com Ed Parcel makes only a small contribution to the Illinois Hine's emerald dragonfly population (Soluk and Mierzwa 2012, p. 11). In addition, this site was impacted by an oil spill that occurred in December 2010 and oil removal efforts are ongoing.

Lockport Prairie (French Drains and Crest Hill)
While adult and larval Hine's emerald dragonfly had been documented at Lockport Prairie Nature Preserve and cited in the recovery plan, some breeding habitat has been lost and gained within Lockport Prairie Nature Preserve since the plan was issued. In 1999, French drain water diversion structures were installed at Lockport Prairie Nature Preserve to partially restore the hydrology of the prairie. In 2009, larvae were documented in new rivulet systems created by the outflow of the French drains (Soluk and Satyshur 2009, p. 4).

Adult Hine's emerald dragonflies and low level breeding have been confirmed near the Cresthill Sewage treatment plant, 0.5 miles South of Lockport Prairie Nature Preserve (Soluk 2004, p. 3; Soluk *et al*. 2008, p. 4; Soluk and Satyshur 2009, p. 3). Due to the close proximity of the area to Lockport Prairie Nature Preserve, it is likely that most of the observed adults are either part of the Lockport Prairie population foraging in this area (Soluk *et al*. 2008, p. 5), or dispersing to this area. Soluk (2004, p. 4) also found a small area of breeding habitat at the Cresthill location along the DesPlaines River (Soluk 2004, p. 4); however this area is believed to have a low and inconsistent level of dragonfly productivity possibly due to frequent flooding from the river (Soluk and Satyshur 2009, p. 5).

Cherry Hill Woods
On June 14, 2011, Marla Garrison of McHenry County College, Crystal Lake, Illinois photographed an adult male Hine's emerald dragonfly at Cherry Hill Woods, Cook County, Illinois (E. Cashatt, Illinois State Museum, pers. comm. 2011). The site is approximately 1 to 1.3 miles South of the nearest documented site, McMahon Fen Nature Preserve. In 2012, on two separate occasions, adult Hine's emerald dragonflies were netted and photographed at the site (Soluk, , pers. comm. 2012; E. Cashatt, pers.comm. 2012). One of the dragonflies was a young teneral, which means that it emerged from nearby breeding habitat. However, breeding habitat has not been located at the site even after several visual assessments of the habitat with species experts (K. Lah obsrvd. 2012).

McMahon Fen Nature Preserve
Soluk and Satyshur (2009, p. 6) re-established that breeding takes place at McMahon Woods Nature Preserve in Cook County, Illinois, based on the presence of first-year larvae in crayfish burrows. Previous records of breeding at McMahon in the early 1990's (Cashatt and Sims 1993, p. 3) had only been based on observations of teneral adults and adult breeding behavior (ovipositing and territorial patrols). Population surveys are currently ongoing at McMahon Woods Nature Preserve but have been complicated by drought conditions in Illinois.

Palos Fen
On June 23, 2012, Mark Swanson, a professional photographer, took a photo of an adult Hine's emerald dragonfly at Palos Fen in Cook County, Illinois (K. Mierzwa, Winzler and Kelly Consulting Engineers, pers. comm. 2012). The photograph was verified to be a male Hine's emerald dragonfly by three species experts (K. Lah pers.comm. 2012). Breeding habitat has not been verified at this site.

Michigan
Castle Rock Road
Adult Hine's emerald dragonflies were documented by Mark O'Brien at Castle Rock Road in Mackinac County, Michigan on July 13, 2005 (Cashatt 2006, p. 3). This site is in the Hiawatha National Forest. Eight to ten adults were seen on feeding flights. One adult male was vouchered. Breeding has not been confirmed at this site.

Round Lake
Adult Hine's emerald dragonflies were documented at Round Lake, Mackinac County, Michigan on August 16, 2005, by Douglas Munson (Cashatt 2006, p. 3). One male was vouchered and three other males were observed flying territorial patrols over a marley seep. The site contains breeding habitat and is located within the Hiawatha National Forest.

Hay Lake
An adult male Hine's emerald dragonfly was collected as a voucher at Hay Lake, Mackinac County, Michigan on July 14, 2005 (Cashatt 2006, p. 3) by Timothy Vogt. The site contains breeding habitat and is located within the Hiawatha National Forest. In addition to the vouchered specimen, six to eight adults were seen feeding over an open gravel road through the swamp.

Huebner
An adult male Hine's emerald dragonfly was collected as a voucher at a site named Huebner in Mackinac County, Michigan on August 2, 2005, by Douglas Munson (Cashatt 2006, p. 3). In addition, five other males were also seen nearby on territorial patrols over marley cedar seeps. The site contains breeding habitat and is located within the Hiawatha National Forest.

Thompson's Harbor State Park
An adult male Hine's emerald dragonfly was collected as a voucher at Thompson's Harbor State Park, Presque Isle County, Michigan on July 15, 2005, by Steven Ross (Cashatt 2006, p. 3). The vouchered specimen was among five adults observed perched on trees in the area. The site contains breeding habitat and is owned and managed by the Michigan Department of Natural Resources.

Negwegon State Park - North
An adult male Hine's emerald dragonfly was collected as a voucher at Negwegon State Park, North in Alcona County, Michigan on July 19, 2007, by Stephen Ross (Cashatt 2008, p. 2). The dragonfly was feeding and patrolling along the back dune-forest edge of the Lake Huron shoreline.

Negwegon State Park - South
Again on July 19, 2007, in Negwegon State Park, South, a female adult Hine's emerald dragonfly was vouchered approximately 3 km (1.9 miles) South of the specimen taken earlier in the day. The park is owned and managed by the Michigan Department of Natural Resources. Breeding has not been confirmed at this site.

Hayward Lake
In Menominee County, Michigan South of Hayward Lake on August 4, 2008, Ryne Rutherford, a Michigan Odonata Survey volunteer, photographed two male Hine's emerald dragonflies (confirmed by Mark O'Brien, University of Michigan, Museum of Zoology 2008) (Cashatt 2009, p. 3). This site is West of the Door Peninsula of Wisconsin, about 30 air miles from Bailey's Harbor, Wisconsin. Discovery of this site extended the range of Hine's emerald in Michigan. Breeding has not been confirmed at this site that is owned and managed by the Michigan Department of Natural Resources.

Garden Island (Beaver Island Archipelago)
An adult male Hine's emerald dragonfly was found along the southern edge of a large coastal fen at Jensen Harbor on August 5, 2011, on Garden Island, Charlevoix County, Michigan (Cashatt 2012, p. 3). It was observed flying along a coastal fen and was collected by David Cuthrell and Yu Man Lee, Michigan Natural Features Inventory, as a voucher specimen for verification and documentation. Additional Hine's emerald dragonflies may have been observed during surveys at Jensen Harbor; however, the lack of a successful capture prevented confirmation of the species. Breeding has not yet been confirmed on the island but is likely due to the distance from other sites. Garden Island is an uninhabited 4,990 acre island located in the Beaver Island Archipelago in northern Lake Michigan. Most of the island is owned and managed by the Michigan Department of Natural Resources as part of the Beaver Island State Wildlife Research Area.

<u>Missouri</u>
Adult and larval collections and genetic studies were conducted to assess potential Hine's emerald dragonfly breeding as well as increase the number of documented Hine's emerald dragonfly sites in Missouri. A total of 82 larval genetic samples were collected from crayfish burrows at 22 localities. Genetic analyses have confirmed Hine's emerald

dragonfly larvae at four sites (M. Mahoney, pers. comm. 2012). Other larvae have been genetically identified as clamp-tipped emerald (*S. tenebrosa*). Hine's emerald dragonfly larvae co-occurred with clamp-tipped emeralds at three of the four sites documented with larvae. These preliminary results will be used to guide additional field collections, focusing on sites where only the clamp-tipped emerald larvae have been documented to date, or where Hine's emerald dragonfly adults have been seen or collected but breeding has not been confirmed.

Bates Hollow
An adult female Hine's emerald dragonfly was collected as a voucher at Bates Hollow in Dent County, Missouri on June 16, 2002, by Tim Vogt and Brett Landwer (Vogt 2003, p. 4). The site contains breeding habitat and an ovipositing female was observed at the site. The site is on private land as well as land managed by the Mark Twain National Forest.

Fortune Hollow
Larvae were collected and verified as Hine's emerald dragonflies from Fortune Hollow in Dent County, Missouri on October 13, 2004, by Timothy Vogt, Larry Ness, and Sara Bradly (Vogt 2005, p. 16). Larvae were collected as vouchers for the site. The site is managed by the Mark Twain National Forest.

Kaintuck Hollow
An adult male Hine's emerald dragonfly was collected as a voucher at Kaintuck Fen in Phelps County, Missouri on June 7, 2002, by Timothy Vogt and Paul McKenzie (Vogt 2003, p. 6). The site contains breeding habitat and is managed by the Mark Twain National Forest.

Bee Fork East
An adult male Hine's emerald dragonfly was collected as a voucher at Bee Fork East in Reynolds County, Missouri on June 24, 2005, by Jane Walker and Joe Smentowski (Cashatt 2006, p. 5). The vouchered specimen was one of three adult males observed at the fen. The fen contains breeding habitat and is under private ownership.

Bee Fork Center
An adult male Hine's emerald dragonfly was collected as a voucher specimen from Bee Fork Center in Reynold's County Missouri on June 18, 2004, by Joe Smentowski and Jane Walker (Walker and Smentowski 2004, p. 6). The site contains breeding habitat and is managed by the Mark Twain National Forest.

Bee Fork West
An adult male Hine's emerald dragonfly was collected as a voucher from Bee Fork West in Reynolds County, Missouri on July 4, 2004, by Paul McKenzie and Timothy Vogt (Vogt 2005, p. 18). The site contains breeding habitat and is managed by the Mark Twain National Forest.

Centerville Slough
An adult male Hine's emerald dragonfly was collected as a voucher from Centerville Slough in Reynolds County, Missouri on July 12, 2002, by Brett Landwer (Landwer 2003, p. 61). The site contains breeding habitat and is on private land.

Deckard Hollow
In October 2002, dragonfly larvae were collected from Deckard Hollow in Reynolds County, Missouri (Landwer and Vogt 2002). Due to the questionable identity of the early instar larvae, Jane Walker and Joe Smentowski revisited this site and vouchered an adult male Hine's emerald dragonfly (Cashatt 2007, p. 3). One other male was seen in flight at the fen. Breeding has not been confirmed at this privately-owned site.

Johnson Shut-in State Park – Proper
Five larvae were collected and confirmed by genetics to be Hine's emerald dragonfly from Johnson Shut-in State Park – Proper in Reynolds County, Missouri on June 30, 2011, by Richard Day and Bob Gillespie (Cashatt 2012, p. 15). In addition to the larval vouchers, five adult male Hine's emerald dragonflies were also observed. Breeding has been confirmed at this site that is owned and managed by the Missouri Department of Conservation.

Johnson Shut-in – Walker Tract
An adult male Hine's emerald dragonfly was collected as a voucher from the Johnson Shut-in Walker Tract in Reynolds County, Missouri on June 16, 2010, by Timothy Vogt (Cashatt 2011, p. 8). In addition to the vouchered specimen, several other male adults were observed. The site contains breeding habitat and is owned and managed by the Missouri Department of Conservation.

Kay Branch
An adult male Hine's emerald dragonfly was collected as a voucher from Kay Branch Fen Complex in Reynolds County, Missouri on June 30, 2006 (Cashatt 2007, pp. 3-9). This site, surveyed by Jane Walker and Joe Smentowski, is a "very significant" site for Hine's emerald dragonfly (Cashatt 2007, p. 3). Eight small fens were found along Kay Branch Creek for about 0.75 miles and adults were observed at seven of the eight fens. The privately-owned site contains five areas with breeding habitat.

Wisdom/Lanham Fen
An adult male Hine's emerald dragonfly was collected as a voucher at Wisdom Fen in Reynolds County, Missouri by Richard Day on July 10, 2008 (Cashatt 2009, p. 3). This privately-owned site contains breeding habitat.

Cottonmouth Fen
A female adult Hine's emerald dragonfly was collected as a voucher from Cottonmouth Fen in Ripley County, Missouri on June 14, 2004, by Timothy Vogt (Vogt 2005, p. 21). This privately-owned site contains breeding habitat.

Emerald Fen
A female adult Hine's emerald dragonfly was collected as a voucher from Emerald Fen in Ripley County, Missouri by Jane Walker & Joe Smentowski on June 27, 2002 (Walker and Smentowski 2002, pp. 8-9). The privately-owned site contains breeding habitat.

Glass Lizard Fen
Multiple sightings of adult Hine's emerald dragonflies were made, including a capture and release of a female, at Glass Lizard Fen in Ripley County, Missouri on June 25, 2002 (Walker and Smentowski 2002, pp. 6-7). Observers included Bret Landwer, Joe Smentowski and Jane Walker. The site contains breeding habitat and is owned and managed by the Missouri Department of Conservation.

Montgomery Fen
A female adult Hine's emerald dragonfly was collected as a voucher at Montgomery Fen in Ripley County, Missouri on June 29, 2007, by Richard Day and Robert Gillespie (Cashatt 2008, p. 3). The privately-owned site contains three fens, two of which contain breeding habitat for Hine's emerald dragonflies. The property lies a calculated 1.5 miles from Little Black Conservation Area.

Overcup Fen
A female adult Hine's emerald dragonfly was collected as a voucher from Overcup Fen in Ripley County, Missouri on June 19, 2005, by Jane Walker and Joe Smentowski (Cashatt 2006, p. 5). The site is currently believed to not contain breeding habitat. The site is owned and managed by the Missouri Department of Conservation.

Wisconsin
Since issuance of the recovery plan (USFWS 2001), two new Hine's emerald dragonfly breeding areas have been found along the Lower Wisconsin River in southwest Wisconsin on lands owned by the Wisconsin Department of Natural Resources. The major breeding area found is in two sloughs: Kendall Lake and Avoca Wildlife Area, within the same wetland complex in Iowa County, Wisconsin. Adults were reported here in 2007 by local photographer Todd Sima. In 2008, Sima submitted photos taken that year to Wisconsin Department of Natural Resources which confirmed the identity of Hine's emerald dragonfly in this area (W. Smith, pers. comm. 2012). Systematic surveys conducted in 2009 by Nicholas Sievert observed three adults at the Kendall Lake site and at least five adults and one teneral at the Avoca Wildlife Area site in 2009 (Cashatt 2013). Adults have been present at these sites every year since their discovery through 2012. Ovipositing has been observed and inferred from mud on the abdomen of females at the Kendall Lake site in 2011 and 2012. In 2011 over 20 specimens were netted, wing clips taken for genetics work, and released at the Kendal Lake site (W. Smith, pers. comm., 2012).

The second breeding area found is at Knapp Creek in Richland County. Nick Sievert observed at least four adults and one teneral here in 2009 (Cashatt 2013). This appears to be a poor breeding site as no other Hine's emerald dragonflies have been observed at this site since 2009 (W. Smith, pers. comm., 2012).

While Nicholas Sievert observed at least 3 Hine's emerald dragonfly adults at White Sloughs along the Lower Wisconsin River in 2009 including one territorial patrol and two males chasing each other (Cashatt 2013), suitable breeding habitat does not occur here and there have been no repeated observations, therefore this site is not considered a breeding site (W. Smith, pers. comm. 2012).

Hine's emerald dragonfly adults have also been observed in the Black Ash Swamp in Door and Kewaunee Counties (M. Grimm, The Nature Conservancy, pers. comm. 2012). It is likely that a breeding site occurs in or near this site, although none have been confirmed to date.

Adult Hine's emerald dragonflies have also been sighted along several roadways in Door County, Wisconsin e.g., Cana Island Road (east of the The Ridges Sanctuary), Meadow Road (northwest of Mud Lake South), Ahrens Road (west of Mud Lake South) and Lost Lake Lane (northern part of the Mink River Estuary) (Mike Grimm, The Nature Conservancy, pers. comm., 2012). These sightings are likely associated with already identified subpopulations.

2.3.2 Five-Factor Analysis

Table 2 lists all of the known locations where Hine's emerald dragonfly occurs across its range and the various threats to the species that occur at each of those sites. Known threats include direct loss of habitat, fragmentation, hydrological impacts, contaminants, vehicle mortality, invasive animals, invasive plants, livestock, and all-terrain vehicles. Some of these threats were described in the recovery plan while others were not known at the time of the final rule listing or issuance of the recovery plan. Below is a description of the additional threats since issuance of the recovery plan.

2.3.2.1 Present or threatened destruction, modification or curtailment of its habitat or range:

The greatest threat to the Hine's emerald dragonfly is the destruction and modification of its habitat. The recovery plan (USFWS 2001, pp. 19-23) covers many of these threats in detail. Below is a description of threats to the species that the U.S. Fish and Wildlife Service and our partners have learned about since the recovery plan was issued in 2001.

<u>Invasive Plants</u>
The Hine's emerald dragonfly recovery plan identified the need for studies to evaluate the short and long-term responses of larvae and adults to habitat management practices including non-native species control (Action 2.5.1). This is an on-going need as invasive species continue to threaten the Hine's emerald dragonfly and its habitat.

Table 2. Threats at Hine's emerald dragonfly sites.

Site	Direct loss of habitat	Fragmentation	Hydrological	Contaminants	Vehicle mortality	Invasive animals	Invasive plants	Livestock	ATV's
Mink River Estuary			X	X			X		
Three Springs Creek			X	X		X	X		
North Bay Marsh			X	X	X		X		X
Mud Lake North Complex (Lime Kiln, Pioneer, and Grove roads)			X	X	X	X	X		
Mystery Creek (Mud Lake South)			X	X	X		X		
Piel Creek			X	X	X		X		X
Baileys Harbor			X	X	X		X		
Ridges Sanctuary			X	X	X		X		
Toft Point			X	X			X		
Arbter Lake			X	X			X		
Big Marsh			X	X	X		X		
Black Ash Swamp			X	X			X		
Gardner Marsh			X	X	X		X		
Ephraim Swamp			X	X			X		
Kellner Fen			X	X			X		
Cedarburg Bog			X	X	X		X		
Lower Wisconsin State Riverway – Kendall Lake/Avoca Wildlife Area			X				X		
Lower Wisconsin State Riverway - Knapp Creek Wetland			X				X		
I-75 West		X	X	X	X		X		
Brevort Lake Road		X			X		X		X
Castle Rock Road		X	X		X		X		
Summerby Swamp			X	X	X		X		

Site	Direct loss of habitat	Fragmentation	Hydrological	Contaminants	Vehicle mortality	Invasive animals	Invasive plants	Livestock	ATV's
Round Lake							X		X
Hay Lake			X				X		
Huebner		X					X		
I-75 East			X	X	X		X		
Acklund Road		X					X		
Foley Creek		X	X		X		X		
Martineau Creek		X	X				XX		
Inglesbee Swamp		X	X		X		X		
Horseshoe Bay		X					X		
Bois Blanc Island			X	X	X				
Thompson's Harbor State Park			X						
North Point Rd. Fen			X						
Misery Bay									
Negwegon State Park - North		X					X		
Negwegon State Park – South		X					X		
Hayward Lake									
Garden Island									
Lockport Prairie		X	X	X	X		X		X
River South and Middle Parcel	X	X	X	X	X		X		X
Romeoville Prairie		x	X	X	X		X		X
Long Run Seep and Long Run/ComEd		X	X	X	X		X		
Keepataw			X	X	X		X		X
Black Partridge		X	X	X	X		X		X
Waterfall Glen		X	X	X	X		X		
Cherry Hill Woods		X			X		X		
McMahon Fen		X	X	X	X		X		X
Palos Fen		X		X	X		X		
Bates Hollow			X			X			
Fortune Hollow			X			X			X

Site	Direct loss of habitat	Fragmentation	Hydrological	Contaminants	Vehicle mortality	Invasive animals	Invasive plants	Livestock	ATV's
Barton Fen			X	X	X	X	X		
Kaintuck Hollow			X			X		X	X
Bee Fork East			X			X		X	
Bee Fork Center			X	X		X		X	
Bee Fork West			X	X		X			
Centerville Slough			X	X	X	X			
Deckard Hollow		X	X			X			
Grasshopper Hollow			X	X		X			
Johnson Shut-in State Park – proper			X			X	X		
Johnson Shut-in Walker Tract			X			X	X		
Kay Branch			X			X	X	X	X
Ruble Meadow			X			X	X	X	
WisdomFen			X		X	X	X	X	
Cottonmouth Fen		X	X			X	X		
Emerald Fen			X			X	X		
Glass Lizard Fen		X	X			X	X		
Montgomery Fen			X			X		X	
Overcup Fen		X	X			X	X		

Direct loss of habitat – ground disturbance, filling wetlands, quarrying
Fragmentation – barriers to movement or loss of corridors for movement
Hydrological – impacts to the quantity and quality to surface and subsurface hydrology
Contaminants – habitat altering chemicals and other substances that may cause direct or indirect take
Vehicle mortality – mortality due to direct and indirect impacts with cars, trucks and trains
Invasive animals – feral hogs, armadillos, beavers and other animals that can cause destruction of habitat
Invasive plants – vegetation that impacts habitat features (e.g. common reed) and/or encroaches on habitat (woody vegetation)
Livestock and haying – crushing crayfish burrows and loss of vegetation in adult and larval habitat from livestock, equestrian use and haying
ATV's – impacts to wetland vegetation and rivulets from all-terrain vehicles

Invasive vegetation can potentially impact Hine's emerald dragonfly behavior and habitat. The encroachment of cattails (*Typha* spp.) and woody vegetation has the potential to affect adult flight behavior and movement. Mierzwa *et al*. (2007, p. 10) suggests that adult breeding habitat is being encroached upon by the accumulation of layers of cattail thatch at marshes in Illinois sites that have not been maintained by continued prescribed fire. During habitat assessment and adult surveys conducted in the Upper Peninsula of Michigan, observers found that utility right-of-ways that are kept clear of woody vegetation appear to serve as flight corridors (D. Soluk, pers. comm. 2012). In addition, observations of Hine's emerald dragonfly adults in Missouri revealed that the species will not fly more than100 meters (328 feet) into closed canopy forest (T. Vogt, Missouri Department of Natural Resources, pers. comm. 2007). It is likely that decades of fire suppression has allowed woody vegetation to encroach upon Ozark fen communities and closed in areas that served as corridors to movement.

Other invasive plant species can impact habitat features that help fulfill life history requirements. For example, a necessary component of larval habitat is groundwater. Encroachment of woody invasive species in upland areas has the potential to allow greater runoff of precipitation and loss of subsurface water through evapotranspiration (Parish and Sellar 2006, pp. 14-15).

Herbaceous invasive species can also impact necessary breeding habitat features. For example, common reed (*Phragmites australis*) is believed to displace crayfish (D. Soluk, pers. comm., 2009), and hence their burrows that serve as refugia for Hine's emerald dragonfly larvae, possibly due to the thick rhizomatous mat that develops in monocultures of the species. Preliminary study results from research being conducted at the Meissner Preserve in Door County, Wisconsin indicates that crayfish burrow numbers decrease with increasing density of reed canary grass (D.Soluk, pers. comm., 2013).

Fragmentation

Since the recovery plan was written new information was gained on barriers to adult Hine's emerald dragonfly movement. These barriers to movement can effect dispersal and flight behavior that may lead to isolated populations and increase the vulnerability of Hine's emerald dragonfly to effects from demographic and genetic stochasticity. The long term viability of any species is based on a combination of population size and genetic diversity that are essential to counteract stochastic or catastrophic events. Fragmentation or barriers to movement can lead to reduced population sizes and/or a loss in genetic diversity. Barriers to movement that may lead to fragmentation include closed canopy forest and bridges.

Observations of adult Hine's emerald dragonfly flight behavior around the Interstate 355 bridge that extends over the DesPlaines River Valley in Illinois have been made before and after bridge construction (Soluk et al. 2011, p. 14). Research has shown a decrease in observed adult activity beneath the bridge since the completion of the bridge deck, with adults avoiding the area underneath the bridge. In general, dragonflies were often observed flying towards the bridge, quickly increasing flight height to deck level, and then crossing at or near traffic height. In 2011, of the eleven possible Hine's emerald

dragonflies observed, three flew directly over the bridge, and none flew under it; the remaining individuals did not attempt to cross the bridge. At this time, it is unclear as to what causes the various flight behaviors observed or what other bridges may serve as barriers to movement. Methods to mitigate this impact are being assessed. Preliminary studies were initiated in 2012 to observe specific aspects of Hine's emerald dragonfly flight behavior around barriers and to assess the potential to discourage road crossing with various mitigative measures (e.g., planted vegetation, netting, etc.) (D.Soluk, pers. comm., 2012).

Invasive Animals

Feral hogs, armadillos, and beavers could potentially destroy Hine's emerald dragonfly habitat in Missouri (Vogt 2005, p. 38; Walker and Smentowski 2006, p. 28), as well as in northern parts of the species range. Feral hogs are known to rut while foraging for tubers, insects and other organisms and this rutting behavior can cause significant impacts to fens and other wetland communities. Currently feral hogs do not pose a threat to Hine's emerald dragonfly habitat outside of Missouri but feral hogs are known to occur in southern Illinois and western Wisconsin.

Likewise, the nine-banded armadillo (*Dasypus novemcinctus*) foraging behavior has the potential to destroy habitat. Armadillos dig-up insect larvae for food and will forage in underground burrows during cold periods. The armadillo's range expansion is expected to continue (Taulman and Robins 1996). Armadillos have been consistently moving northward and eastward from the Rio Grande since the latter part of the 19th century. There are different hypotheses as to why the armadillo has expanded its range including changes in land use practices, removal of natural predators, and climate change. Threats from the armadillo to Hine's emerald dragonfly and its habitat will need to be monitored.

Beaver dams can cause flooding of wetland communities supporting the Hine's emerald dragonfly. Beavers had posed a potential threat at Lockport Prairie in Illinois but this threat has been reduced with the installation of a beaver drain tube in the beaver dam (USFWS 2001, p.40). The U.S. Forest Service has effectively used Clemson Beaver Pond Levelers at Barton Fen (Iron County, Missouri) to manage flooding from beaver dams (Vogt 2006, p.7). In addition, measures to minimize threats from feral hogs and beavers will continue to be implemented by the Missouri Department of Conservation through implementation of their state-wide recovery plan for the Hine's emerald dragonfly (Missouri Department of Conservation 2007, pp. 1–3). However, it is not known if such control measures will be sufficient to eliminate the adverse impacts that continue to threaten sites in Missouri.

Livestock

High density of livestock or prolonged periods of grazing have the potential to alter the floristic quality of fens. Overgrazing can reduce or remove sensitive native plant species and can promote the establishment of increaser species (i.e., plant species that increase in relative amount under heavy grazing pressure) species such as poison hemlock (Conium maculatum) and invasive species such as multiflora rose (Rosa muliflora) and meadow fescue (Festuca pratensis) (Moore 2005, p. 3). Large livestock also has the potential to

trample habitat features like crayfish burrows that serve as refugia for larvae. Grazing is viewed as a threat at several sites in Missouri (Moore 2005, p.7; Walker and Smentowski 2005, pp.5-20).

All-Terrain Vehicles

All-terrain vehicles (ATV) have caused impacts to wetland vegetation and rivulets in Hine's emerald dragonfly breeding habitat. A year after Hine's emerald dragonfly larvae were found at Blue Flag Fen in Missouri, extensive damage from an ATV trail and associated rutting had altered the hydrology of the fen, resulting in surface water at the site to become reduced and confined (Walker and Smentowski 2005, p. 20). Damage from ATV activity was reported at rivulet 2N in Lockport Prairie Nature Preserve in Illinois (Soluk 2008, p. 4). The rivulet was damaged when deep [up to 40 centimeters (15.75 inches)] ruts caused by an ATV led to altered flow paths for this stream channel, with the channel moving as far as 16.5 ft. (5m) off of its previous configuration. Extensive down-cutting through organic soils was observed, as well as heavy silt deposition with dead adult crayfish embedded in the silt. Moore (2005, pp. 5-8) and Vogt (2005, p. 38) recommended using fencing, planted vegetation, or 'shot rock' as a barrier to ATV encroachment.

2.3.2.2 Overutilization for commercial, recreational, scientific, or educational purposes:

Overutilization is not believed to be a factor in the continued existence of the Hine's emerald dragonfly. Federal protection under section 9 of the ESA prohibits unauthorized collection of individuals of the species. In addition, ESA section 10 recovery permits issued to researchers when conducting activities that may adversely affect the Hine's emerald dragonfly include conditions to avoid and minimize harm to the dragonfly.

2.3.2.3 Disease or predation:

Disease and predation are not believed to be a factor affecting the continued existence of the Hine's emerald dragonfly.

2.3.2.4 Inadequacy of existing regulatory mechanisms:

The Hine's emerald dragonfly is listed as federally endangered species and is therefore afforded protection in all states under the ESA. In addition, the Hine's emerald dragonfly is State listed as endangered in the four states (Illinois, Michigan, Missouri and Wisconsin) that are within its current range, thereby affording the species additional State level protections.

2.3.2.5 Other natural or manmade factors affecting its continued existence:

Contaminants

The recovery plan discusses the potential threat of habitat altering chemicals. Research has been initiated and is ongoing on the potential impacts of herbicides used as a

management tool to control invasive vegetation. Preliminary results have shown effects in growth, feeding and behavior of larvae from exposure to various concentrations of herbicides (Soluk *et al.* 2011, p. 14).

The University of South Dakota has conducted laboratory toxicity studies to assess the effect of Fusilade, a grass specific herbicide, on the Hine's emerald dragonfly (Soluk *et al.* 2011). All Fusilade treatments (3 mg/L, 0.3 mg/L and 0.03 mg/L) included the surfactant Activator 90 (a surfactant only control was also part of the research). No Hine's emerald dragonfly larval mortality occurred in any of the herbicide or control treatments and no direct lethal effects of the herbicides or surfactant were noted. No larval growth differences were detected in any of the Fusilade treatments. No detectable difference on feeding was found between the two controls and the low and medium concentrations. The high Fusilade treatment group (3.0 mg/L) did exhibit a significant effect on feeding. Some larval behavioral responses to stimuli (swirling) studied over a 4 week period were significantly different than controls for low and medium concentrations of Fusilade, but not for the high concentration of Fusilade. However, the research showed no significant differences in larval mass. There was a significant effect on feeding rate to high Fusilade exposed larvae, however no reduction in growth was seen. The research finds that Hine's emerald dragonfly larvae appear somewhat resilient to environmentally high concentration of Fusilade and there is some potential for sub-lethal impacts that require more analyses (Soluk *et al.* 2011). A separate prior experiment found no lethal effects on the chironomid prey in similar testing conditions (J. Kirby, University of South Dakota, pers. comm. 2010).

The Service is using a structured decision making process to develop a model to assist in deciding which herbicides to use when controlling invasive species in Hine's emerald dragonfly habitat (K. Lah, pers. comm., 2012). The model incorporates four main objectives which are to: 1) minimize direct and indirect effects to the Hine's emerald dragonfly from the herbicide used; 2) effectively control the target invasive species; 3) maintain the native vegetation; and 4) minimize costs. It is anticipated that the model will be ready for use in 2013 to help guide management decisions. Additional research is being pursued on the effects of herbicides and adjuvants to further assess effects to the dragonfly and to improve the model (J. Kirby, pers. comm., 2012). It is not known if other yet to be tested herbicides will have similar effects on Hine's emerald dragonfly.

Recently a new contaminant, oil from pipeline breaks, threatened two Illinois sites. In September 2010, an oil pipeline break occurred outside of Romeoville Prairie Nature Preserve (K. Lah, obsrvd. 2010). In December 2010, another pipeline broke releasing oil into Hine's emerald dragonfly habitat at the Long Run/ComEd site. Efforts to clean-up this spill and assess impacts to the species and its habitat are ongoing.

Climate Change

Climate change will be a particular challenge for biodiversity because the interaction of additional stressors associated with climate change and current stressors (e.g., invasive species, hydrologic changes, etc.) may push species beyond their ability to survive (Lovejoy 2005, pp. 325-326). The synergistic implications of climate change and habitat

fragmentation is the most threatening facet of climate change for biodiversity (Hannah *et al.* 2005, p. 4). In addition, local extinction and range shifts are also being documented for some species including dragonflies. Recent changes in climate have expanded, contracted, or shifted the climate niches of many species; the result is often a change in the species' geographic range (Parmesan and Yohe 2003). In a study of all 37 species of resident odonates (dragonflies and damselflies) in the United Kingdom, all but two species increased in range size, and all but three species shifted northwards at their range margin in the last 40 years (Hickling *et al*. 2005, p. 504).

While there is uncertainty about the exact nature and severity of climate change related impacts anticipated within the Hine's emerald dragonfly's range, a number of scientific studies project that there will be increased duration and intensity of heat waves in summer, higher levels of humidity and evaporation; changing patterns of precipitation with fewer rain events of greater intensity; increased frequency and more severe dry spells; and more flooding from heavy rains (Easterling and Karl 2000, pp. 168–169, 172, 176; Hall and Stuntz 2007, pp. 5-7; Intergovernmental Panel on Climate Change 2007, pp. 30- 46).

Climatic changes may impact the Hine's emerald dragonfly and its habitat in a variety of direct and indirect ways including: changes in hydrology; loss of suitable habitat; loss of inter-specific relationships with crayfish; and increased threats from invasive species. As a result, these changes have the potential to have demographic impacts on the species. For example, data on population sizes in Illinois reveal that declines in the population correlate with short-term droughts (Soluk and Mierzwa 2012, pp. 22-25). In years when droughts occur, there is very low recruitment which leads to a small cohort. While the population eventually recovers slightly, it appears to not return to its pre-drought size.

Summary of Threats

Destruction and modification of habitat continues to be the greatest threat to the Hine's emerald dragonfly. Many of the threats to habitat vary across the range of the species (Table 2) but also vary in magnitude and ability to be mitigated. Direct loss of habitat is the most severe of all of the threats but occurs infrequently due to laws protecting wetlands and measures taken to preserve habitat. Other threats to hydrology or from fragmentation and contamination can also have a permanent impact on habitat and even entire populations of the species but our ability to manage or prevent these threats is limited. Invasive plant species is the most widespread of the threats; however, the magnitude of this threat and our ability to manage it depends on the invasive species and the degree that it has encroached upon Hine's emerald dragonfly habitat. Management of impacts from invasive plants and animals will be an ongoing effort.

2.4 Synthesis

The recovery criteria for the Hine's emerald dragonfly were designed to address the viability of the species through the conservation principles of resiliency (e.g., 500 adults per subpopulation, number of breeding areas per subpopulation, protection of habitat, etc.) and redundancy (e.g., North and South Recovery Units with two populations

consisting of three subpopulations). The recovery criteria for population distribution and size have not been met, nor have those that address habitat features and protection (see discussion in section 2.2.3).

Currently, every population of the Hine's emerald dragonfly is under stress from threats that are directly and indirectly impacting the species and its habitat (Table 2).

The populations in the Southern Recovery Unit may be experiencing a greater magnitude of threats with the Illinois population being the most vulnerable to extirpation of all of the populations. The Illinois population, is estimated to be within the range of 86-313 adults and is on a downward trend (estimate includes standard error - Soluk and Mierzwa 2012, pp. 22-25), far from the recovery criteria of 1,500 adults and well below what most research (Shtickzelle et al. 2005; Trailla et al. 2007; Frankham et al. 2010) suggests is required to maintain a viable insect population. While the populations in the South Recovery Unit are believed to be smaller, there is greater genetic diversity within the Southern populations which makes them extremely important to the survival and recovery of the species. Alternatively, the populations in the Northern Recovery Unit are larger, yet have less genetic diversity.

The vulnerability of Hine's emerald dragonfly populations in the South and the species as a whole, to effects from demographic and genetic stochasticity, may be increasing due to the severity of the threats to the small populations. Demographic stochasticity can cause small populations to vary widely in size. Genetic stochasticity are random changes in a population's genetic makeup that can have deleterious effects on the ability of individuals to survive and reproduce. A drastic reduction in population size can exacerbate the effects of genetic stochasticity, or can lead to the further decline of a population to extirpation. As a population loses individuals, it may lose genetic variation, which may reduce the species' fitness or ability to cope with environmental change. So while the Southern populations may currently contain genetic diversity that may be necessary for the species to survive and adapt in a changing environment, the potential for the Southern populations to become extirpated is compounded by several direct and indirect threats and by small population sizes, which compromises the viability of the species rangewide.

Based on the current population status and distribution, and the continuing threats to the species and its habitat, the Hine's emerald dragonfly continues to be in danger of extinction throughout all or a significant portion of its range, and therefore, continues to meet the definition of an endangered species.

3.0 RESULTS

3.1 Recommended Classification:

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist
_X_ No change is needed

3.2 New Recovery Priority Number: No change

Brief Rationale: The recovery priority number remains at 5C because there is a high degree of threat to the Hine's emerald dragonfly and low recovery potential.

4.0 RECOMMENDATIONS FOR FUTURE ACTIONS

To prevent Hine's emerald dragonfly populations from being extirpated, continued efforts need to be made to better understand and address threats to the species and its habitat. The impacts of some threats, like invasive species, are well understood and their control will require ongoing management and maintenance. However, additional research is needed to more clearly understand the direct and indirect effects of herbicides (used to control invasive species) on the various life stages of the dragonfly and to improve the decision model on herbicide use that is nearing completion.

Other threats like habitat fragmentation and the impact of hydrologic changes on the Hine's emerald dragonfly and its habitat are not as well understood especially as these threats may affect the viability of the species. Research needs to be designed and conducted to address these threats and methods to avoid or mitigate potential impacts caused by the threats implemented as necessary to enable the species to survive and recover.

Modeling the population dynamics of the Hine's emerald is a high priority recovery action. One of the current criteria to delist the species is that each population consist of at least 1,500 adults (i.e., three subpopulations of 500 adults). However, a population of 1,500 adults is not considered to be very large for an insect. Frankham *et al*. (2010, p. 519) recommend census sizes >6,000 are a good target for long-term persistence in invertebrates; however, due the complicated life history of the Hine's emerald dragonfly (overwintering eggs, larval stage of for four-five years, overlapping generations, etc.) the species may have persisted at smaller population sizes than other insects. A better understanding of a minimum viable population size for Hine's emerald dragonfly is needed. Population viability modeling should be used to compare and identify alternative population and metapopulation structures that provide equivalent persistence probabilities. These results and the knowledge we have gained regarding the species genetic diversity may be used to revise recovery criteria or to determine whether an alternative population distribution provides long-term stability. New information on the

size of populations and their genetic structure and diversity should be included in the model as it becomes available.

Another high priority recovery action is to determine the size of Hine's emerald dragonfly populations and to monitor the populations on a regular basis. To date most of the population monitoring for the species has been done in Illinois. This is partly due to the small size and accessibility of the sites in Illinois which are more conducive to the population survey protocols that have been developed for monitoring adult and larval Hine's emerald dragonflies. Some population surveys, though not as extensive, have also been done in Wisconsin. Survey protocols may need to be established for each state or for different habitat structures. In addition, a schedule for monitoring sites should be developed that would allow for monitoring that could be done periodically, yet adequately capture changes and trends in a subpopulation.

While a great deal of research has recently been conducted on the genetic structure and diversity of Hine's emerald dragonfly populations, this work needs to be expanded to cover the entire range of the species. To date, analysis on the population structure has not included sites in Missouri and more samples are needed in other parts of the species range (e.g. Southwest Wisconsin). Recent research on genetic diversity has expanded our understanding of the importance of the smaller populations in the Southern Recovery Unit. A more complete understanding of the population structure within and among populations of the Hine's emerald dragonfly will provide the necessary information to determine the most appropriate recovery criteria, as well as serve as a guide in implementing recovery actions.

Protocols for successful rearing of Hine's emerald dragonfly larvae from eggs to adult emergence have been developed over the last 5 to7 years (Satyshur 2009, Soluk *et al*. 2008-2012). Methods have been developed to safely harvest eggs from females in the field, hatch them and rear them with up to 50% rates of survival. In the field, survival rates of eggs to mature larvae are likely less than 1%, so the of benefit of captive rearing is that it may be able to generate larvae and adults from those that would have most likely died. These captive-reared individuals can then be used to conduct crucial studies or buffer natural populations from local extinction events. Captive-reared larvae are being used for evaluations of herbicide toxicity, quality assessment for created/restored habitat, genetic structuring of populations and various other life history and ecological studies. Given that the size of the entire Illinois population of the Hine's emerald dragonfly appears to currently average approximately 200 adult and is on a downward trend (Soluk and Mierzwa 2012), activities such as population augmentation and head-starting seem increasingly essential if the population is to remain viable and the species will survive.

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APPENDIX 1

Hine's Emerald Dragonfly Sites by Landowners

Site	Landowner
Mink River	TNC, Wisconsin DNR and private
Three Springs Creek	DCLT and private
North Bay Marsh	Mixed, TNC, Wisconsin DNR and private
Mud Lake North Complex (Lime Kiln, Pioneer, and Grove Roads)	Mixed, TNC, Wisconsin DNR and private
Mystery Creek (Mud Lake South)	Mixed, TNC, Wisconsin DNR and private
Piel Creek	Mixed, TNC, private
Baileys Harbor	Mixed, TNC, private
Ridges Sanctuary	Mixed, Ridges Sanctuary, TNC, University of Wisconsin and private
Toft Point	Unknown
Arbter Lake	Mixed, TNC and private
Big Marsh	Mixed, Wisconsin State Natural Area and private
Black Ash Swamp	Private
Gardner Marsh	Mixed, Wisconsin DNR and private
Ephraim Swamp	
Kellner Fen	Mixed, DCLT, private
I-75 West	
Brevort Lake Road	Yes, Hiawatha NF
Castle Rock Road*	Yes, Hiawatha NF
Summerby Swamp	Yes, Hiawatha NF
Round Lake*	Yes, Hiawatha NF
Hay Lake*	Yes, Hiawatha NF
Huebner	Yes, Hiawatha NF
I-75 East	Mixed
Acklund Road	Yes, Hiawatha NF
Foley Creek	Mixed
Martineau Creek	
Inglesbee Swamp	Mixed
Horseshoe Bay	Yes, Hiawatha NF
Bois Blanc Island	
Thompson's Harbor State Park*	Yes – Michigan DNR
North Point Rd. Fen	Mixed, MichiganDNR, private
Misery Bay	No, Private
Negwegon State Park - North*	Yes, Michigan DNR
Negwegon State Park – South*	Yes, Michigan DNR
Hayward Lake*	Yes, Michigan DNR

Site	Landowner
Garden Island (Beaver Island Archipelago)*	Yes, Michigan DNR
Lockport Prairie NP	Yes, County FP and Illinois NP.
River South and Middle Parcel	Private, managed
Romeoville Prairie NP	Yes, County FP and Illinois NP
Long Run Seep Nature Preserve (LRSNP) and Long Run/ComEd Parcel	Mixed, Private and Illinois DNR Illinois NP
Keepataw FP	Yes, County FP
Black Partridge FP	Yes, County FP
Waterfall Glen FP	Yes, County FP
Cherry Hill Woods FP*	Yes, County FP
McMahon Fen NP	Yes, County FP and Illinois NP
Palos Fen NP*	Yes, County FP and Illinois NP
Cedarburg Bog	Mixed, State and private
Lower Wisconsin State Riverway – Kendall Lake and Avoca Wildlife Area	Yes, Wisconsin DNR
Lower Wisconsin State Riverway - Knapp Creek Wetland	Yes, Wisconsin DNR
Bates Hollow*	Mixed, Private and Mark Twain NF
Fortune Hollow*	Yes, Mark Twain NF
Barton Fen	Yes, Mark Twain NF
Kaintuck Hollow*	Yes, Mark Twain NF
Bee Fork East*	No, private
Bee Fork Center*	Yes, Mark Twain NF
Bee Fork West*	Yes, Mark Twain NF
Centerville Slough*	No, private
Deckard Hollow*	No, private
Grasshopper Hollow	Yes, TNC
Johnson Shut-in State Park – proper*	Yes, Missouri DOC
Johnson Shut-in Walker Tract*	Yes, Missouri DOC
Kay Branch*	No, private
Ruble Meadow	No, private
Wisdom/Lanham Fen*	No, private
Cottonmouth Fen*	No. private
Emerald Fen*	No, private
Glass Lizard Fen*	Yes, Missouri DOC
Montgomery Fen*	No, private
Overcup Fen*	Yes, Missouri DOC

Acronyms used: TNC = The Nature Conservancy; DNR = Department of Natural resources; DCLT = Door County Land Trust; NF = National Forest; NP = Nature Preserve; FP = Forest Preserve; DOC = Department of Conservation

U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW of the Hine's Emerald Dragonfly

Current Classification: Endangered

Recommendation resulting from the 5-Year Review

____ **Downlist to Threatened**
____ **Delist**
X **No change is needed**

Appropriate Recovery Priority Number: 5C

Review Conducted By: Kristopher J. Lah, Endangered Species Coordinator

FIELD OFFICE APPROVAL:
Lead Field Supervisor, U.S. Fish and Wildlife Service

Approve Louise Clemency Date 3/8/2013
Louise Clemency

REGIONAL OFFICE APPROVAL:
Assistant Regional Director, Ecological Services, U.S. Fish and Wildlife Service, Midwest Region

Approve Lynn M Lewis Date 5/9/13