Hine's Emerald Dragonfly

(*Somatochlora hineana* Williamson)

Recovery Plan

U.S. Department of the Interior
United States Fish and Wildlife Service
Great Lakes--Big Rivers Region (Region 3)
Fort Snelling, Minnesota

HINE'S EMERALD DRAGONFLY
(*Somatochlora hineana* Williamson)

RECOVERY PLAN

Prepared by

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and

The Hine's Emerald Dragonfly Recovery Team

for

Region 3
U.S. Fish & Wildlife Service
Fort Snelling, MN

Approved

Regional Director, Region 3
U.S. Fish and Wildlife Service

Date: 9/27/01

DISCLAIMER

This recovery plan has been prepared by the Hine's emerald dragonfly Recovery Team under the leadership of Dr. Dan M. Johnson with assistance in writing the document by Deanna Zercher of the Illinois Natural History Survey in Champaign, Illinois. The purpose of the plan is to delineate reasonable actions needed to restore and/or protect the endangered Hine's emerald dragonfly (*Somatochlora hineana*). Recovery objectives will be attained and funds made available subject to budgetary and other constraints affecting the parties involved, as well as the need to address other priorities.

The plan does not necessarily represent the views or official position of any individuals or agencies involved in plan formulation, other than the U.S. Fish and Wildlife Service (USFWS). The approved recovery plan will be modified as dictated by new findings, changes in species status, and the completion of recovery tasks.

Literature citations should read as follows:

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EXECUTIVE SUMMARY
Hine's Emerald Dragonfly Recovery Plan

Current Status: The Hine's emerald dragonfly, *Somatochlora hineana,* was listed as endangered in January 1995. Extant Hine's emerald dragonfly populations are currently known to persist in Illinois, Wisconsin, Michigan, and Missouri. The Illinois population is the most genetically diverse, and the Wisconsin populations are the largest and presumably most secure. Information on the status of the Michigan and Missouri populations is limited because of their recent discoveries. Historically known from Ohio and Indiana, it is thought to be extirpated from these states.

Habitat Requirements and Limiting Factors: The Hine's emerald dragonfly occupies marshes and sedge meadows fed by calcareous groundwater seepage and underlain by dolomite bedrock. In general, these areas are characterized by the presence of slowly flowing water and nearby or adjacent forest edges. Known occupied habitats are currently restricted to the lower Des Plaines River valley, in Illinois; northeastern Door County and Cedarburg Bog, Wisconsin; areas of the Hiawatha National Forest, in the Upper Peninsula of Michigan, three areas in the Lower Penninsula of Michigan, and at three fens in Missouri. Loss of this already rare and restricted habitat to agriculture, commercial and industrial development is the primary cause of the species' decline. Loss of remaining habitat from the same pressures, combined with successional change in the existing habitats and disruption of ecological and hydrological processes, are threats to surviving populations.

Recovery Objectives: The objective of this recovery plan is to restore the Hine's emerald dragonfly to viable populations so that it may be removed from the Federal list of *Endangered and Threatened Wildlife and Plants.*

Recovery Criteria: Each of the two Recovery Units contains a minimum of three populations composed of at least three subpopulations. Each subpopulation contains a minimum of 500 reproductive adults for 10 consecutive years. Within each subpopulation, there are at least two breeding habitat areas, each fed by separate seeps and/or springs. For each population, the habitat supporting at least three 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.

Actions Needed:
1. Protect and manage extant populations
2. Conduct studies
3. Conduct searches for additional Hine's emerald populations
4. Conduct an information and education program
5. Conduct a reintroduction and augmentation program
6. Review and track recovery progress

Total Cost of Recovery: The total estimated cost for the recovery actions outlined in this plan is $13,163,000. These recovery actions will benefit not only the Hine's emerald dragonfly, but entire natural communities and other environmental amenities such as drinking water. Many of the actions described in this recovery plan are already funded by existing programs in agency and private organization budgets. The cost estimate represents expenditures over a 20 year time period.

Date of Recovery: Full recovery of this species could occur within 10 years of initially meeting the recovery criteria for delisting. It is anticipated that recovery could occur as soon as 2019.

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The U.S. Fish and Wildlife Service recognizes that the development of this Recovery Plan would not have been possible without the assistance of the many individuals who attended recovery meetings, contributed sections, provided information, and reviewed earlier versions of this document. In particular, the USFWS wishes to thank the following individuals for their assistance with this Plan:

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PART I. INTRODUCTION

The Hine's emerald dragonfly, *Somatochlora hineana* Williamson, also known as Ohio emerald, Hine's bog skimmer, and hook-tipped emerald, is among the most endangered dragonflies in the United States (Bick 1983, Cashatt 1991). Hine's emerald dragonfly is currently known to occur in Illinois, Wisconsin, Michigan and Missouri. Historically, this species was known to occur in three areas of Ohio, and one site in Indiana. One specimen was collected in Alabama. Since 1961, Hine's emerald dragonfly has not been collected from Ohio or Indiana, and it is believed to be extirpated from these States.

Based on its limited distribution and need for protection, the Hine's emerald was proposed for Federal listing as endangered on October 4, 1993 (USFWS 1993a) and was listed as endangered under provisions of the Endangered Species Act of 1973 (ESA), as amended, on January 26, 1995 (USFWS 1995). Departments of Natural Resources in Illinois, Wisconsin, and Ohio list this species as state endangered (Herkert 1992, ODNR 1997, WDNR 1997). This species is proposed for listing as state endangered in Michigan. The International Union for the Conservation of Nature (IUCN) also lists Hine's emerald dragonfly as endangered (Moore 1997), and The Nature Conservancy lists this species as globally imperiled (USFWS 1995).

The Hine's emerald dragonfly is apparently restricted to wetland habitats characterized by thin soils over dolomite bedrock with marshes, seeps, and sedge meadows. Fragmentation and destruction of suitable habitat are believed to be the main reasons for this species' endangered status and continue to be the primary threats to its recovery. The known breeding sites in Illinois occur along the Des Plaines River floodplain, which has been fragmented by industrial and urban development (Cashatt 1991). In Wisconsin, land development for agriculture, light industry, and tourism are principal threats (Vogt and Cashatt 1990). Off-road vehicle use and possibly logging, creation of water impoundments, real estate development, road development and maintenance, pipeline construction, and changes in hydrology, are potential threats in Michigan (Steffens 1997). In addition, the species is vulnerable to loss of habitat caused by off-site hydrology alterations and groundwatershed development affecting the groundwater-fed seeps and springs.

TAXONOMY AND DESCRIPTION

Order Characteristics: Order Odonata (dragonflies and damselflies) is cosmopolitan and includes at least 5,309 species (Bridges 1994). Dragonflies and damselflies are characterized by two pairs of large membranous wings; large compound eyes; short, bristle-like antennae; chewing mouth parts; slender, elongate abdomens; and male secondary reproductive organs. Larvae (nymphs, naiads) are predominantly aquatic and characterized by tracheal gills and a large hinged labium (lower lip). *Somatochlora hineana* is in the Family Corduliidae ("emeralds") which includes 384 species. Of 39 described species of *Somatochlora*, 26 occur in North America (Bridges 1994).

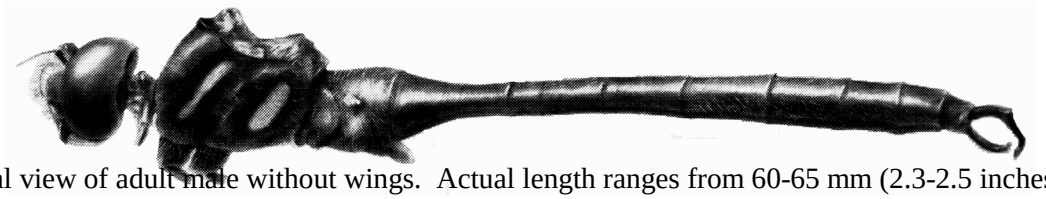
Adult Characteristics: Hine's emerald, like many other members of its family, has brilliant green eyes. It is distinguished from all other species of *Somatochlora* by its dark metallic green

thorax with two distinct creamy-yellow lateral lines, and distinctively-shaped male terminal appendages and female ovipositor (Figure 1) (Williamson 1931). Adults have a body length of 60-65 millimeters (mm) (2.3-2.5 inches) and a wingspan of 90-95 mm (3.5-3.7 inches). The wings are clear and may have an amber hue towards the base of the hind wings. Other species of *Somatochlora* that occur in the same range and may be confused with Hine's emerald dragonfly, *S. hineana*, include *S. linearis*, *S. tenebrosa*, *S. ensigera*, *S. elongata*, and *S. williamsoni* (Walker and Corbet 1975, Needham and Westfall 1954). However, distinctive shapes of terminal appendages and ovipositors separate adults of this species from all others (Figures 1B and 1C).

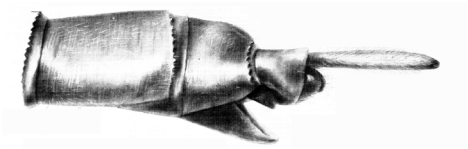
Two characteristics change with the age of the Hine's emerald dragonfly. After emerging as an adult, the eyes are initially brown and turn emerald green within 1 to 3 days. Toward the end of the adult life span, the wings may turn from clear to a slightly opaque, smokey color.

Larval Characteristics: No one character has been found that will easily and reliably differentiate larvae of Hine's emerald dragonfly (Figure 2) from the species listed above. Among the species with middorsal hooks, *S. elongata*, *S. linearis*, *S. minor*, and *S. tenebrosa* are often the most difficult to distinguish from *S. hineana*. Most *S. hineana* specimens may be distinguished from most other *Somatochlora* by the presence of a small middorsal hook on segment three. However, *S. minor* also has a middorsal hook on segment three, while *S. elongata*, *S. linearis*, and *S. tenebrosa* occasionally have a small or vestigial middorsal hook on this tergite. Other characters include head width, metatibial length, palpal crenulation setae, and total length. A detailed discussion is presented in Cashatt and Vogt (2001). Soluk *et al*. (1998) described the distinguishing features of *S. hineana* larvae from other larval dragonfly species in Door County, Wisconsin, as "the size of the dorsal hooks on the abdomen, general hairiness, shape of head, and lack of stripes on the legs." The earliest instars of *S. hineana* larvae have fewer dorsal hooks than later instars.

Figure 1. Adult Hine's emerald dragonfly (*Somatochlora hineana*). Images from Williamson (1931), courtesy of the University of Michigan Museum of Zoology.



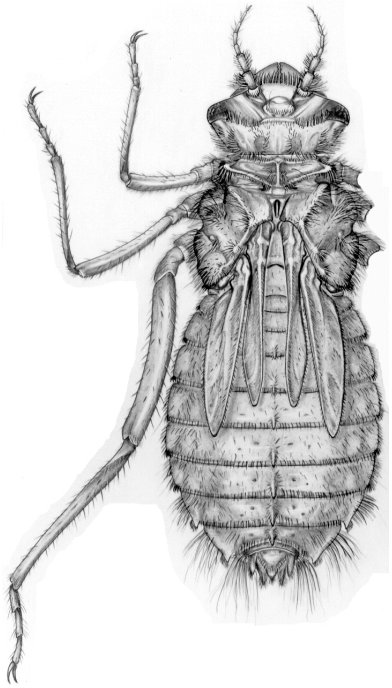
A. Lateral view of adult male without wings. Actual length ranges from 60-65 mm (2.3-2.5 inches).



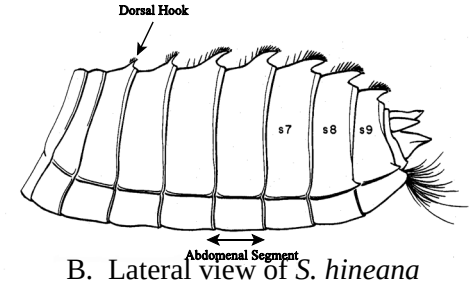
B. Lateral view of female abdominal tip.

C. Lateral view of male abdominal tip.

Figure 2. Larval Hine's emerald dragonfly. Illustrations by Julie Snider, courtesy of the Illinois State Museum.



A. Dorsal view of larval *S. hineana*. Actual size of final instar larva ranges from 23.5-25.0 mm (0.92-0.98 inches).



B. Lateral view of *S. hineana* larval abdomen.

PRESENT AND HISTORICAL DISTRIBUTION

Currently, populations of Hine's emerald dragonfly occur in Wisconsin, Illinois, Michigan, and Missouri (Figure 3). Appendix 2 provides a list of the sites surveyed for Hine's emerald dragonfly, the years visited, years when Hine's emerald dragonfly was observed, life stage, behavior, and sampling effort expended at each site.

Distribution by State and County:
Illinois: Nine sites in Will, Cook, and Du Page Counties
Wisconsin: Twenty sites in Door, Kewaunee and Ozaukee Counties
Michigan: Ten sites in Mackinac, Presque Isle, and Alpena Counties.
Missouri: Three sites in Reynolds and Iron Counties.
Ohio: Believed extirpated. Historically collected from Lucas, Logan, and Williams Counties.
Indiana: Believed extirpated. One specimen historically collected from Lake County in 1945.
Alabama: Believed extirpated. One specimen historically collected from Jackson County in 1978.

Present Distribution:
Illinois: Hine's emerald dragonfly inhabits nine sites in Will, Cook, and DuPage Counties, Illinois (Figure 3). Breeding behavior has been observed at five sites in Will County: Keepataw Forest Preserve, Lockport Prairie Nature Preserve, Long Run Seep Nature Preserve, Middle Parcel and River South Parcel in Yard 61 at Material Service Corporation, and at two sites in Cook County: Black Partridge Woods Nature Preserve and McMahon Woods. Two sites where Hine's emerald dragonfly adults have been observed foraging or in transient flight are Romeoville Prairie Nature Preserve in Will County and Waterfall Glen Forest Preserve in Du Page County. Figure 4 illustrates the relative location of the Illinois sites. All nine sites are within 20 kilometers (km) (about 12 miles) of each other, within 4 km (2.5 miles) of the Des Plaines River, and occur in the Des Plaines River watershed.

Wisconsin: Hine's emerald dragonfly inhabits 20 sites in Door, Kewaunee and Ozaukee Counties, Wisconsin (Figure 3). The dragonfly breeds at nine sites in Door County: Arbter Lake, Big Marsh (Washington Isalnd), Ephraim Swamp, Mud Lake "North" at Lime Kiln Road, Mud Lake "South," North Bay, The Ridges Sanctuary, Three Springs Creek, and the Upper Mink River. The dragonfly also breeds at one site in Ozaukee County: Cedarburg Bog (Vogt and Cashatt 1990, Kirk and Vogt 1995, Soluk *et al*. 1998a, Kathy Kirk, pers. comm. 2001, Dan Soluk, Illinois Natural History Survey, pers. comm. 2001, Gretchen Meyer, Cedarburg Bog Field Station, pers. comm. 2001). Breeding is also likely at the Kellner Fen in Door County (Mike Grimm, The Nature Conservancy, pers. comm. 2001) and the Black Ash Swamp in Kewaunee County (Kathy Kirk, pers. comm. 2001). Hine's emerald dragonfly adults have been recorded from eight additional Door County locations where they have been seen foraging, perching or in transient flight: Bailey's Harbor Township marsh, Bailey's Harbor Swamp, Mud Lake "North"at Pioneer Road, Mud Lake "North" near Grove Road, Piel Creek, Toft Point and near Spring Road (Soluk et al. 1998, Mike Grimm, pers. comm. 2001, Janice Stiefel, pers. comm. 2001). Roadkill specimens of the dragonfly have also been collected along County Q Road, State Highways 42 and 57 in Door County and County Road X in Kewaunee County (Soluk *et al*. 1998a, Paul Burton, pers. comm. 2000, Kathy Kirk, pers. comm. 2001).

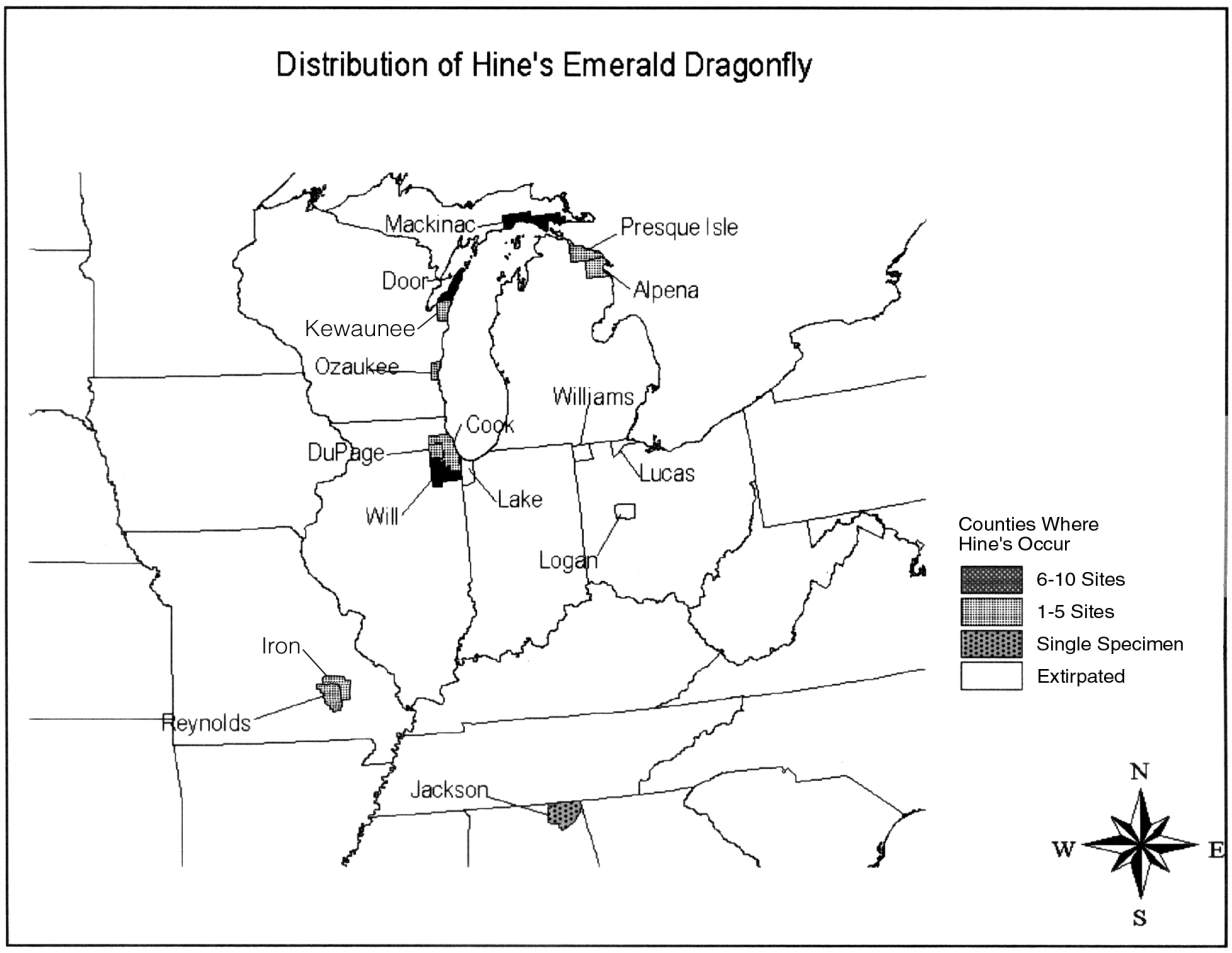


Figure 3. Present number of Hine's emerald dragonfly sites per county in the Great Lakes Region. All historic occurrences and single specimens collected are included in this map.

The Door County sites from Big Marsh (Washington Island) to Kellner Fen (near Sturgeon Bay) occur within a 69 km (43 mile) stretch in Door County. The furthest distance between two sites is approximately 20 km (12.5 miles), and the majority of the sites are within a 10 km (6.2 mile) radius. All of these areas are less than 6 km (4 miles) from the Lake Michigan shoreline. The Black Ash Swamp in Kewaunee County lies 18 km (11 miles) south of Kellner Fen, and the site furthest south in Wisconsin, Cedarburg Bog, is located 142 km (88 miles) south of Kellner Fen.

Michigan: Hine's emerald dragonfly inhabits a total of 10 sites in Michigan in Mackinac, Presque Isle, and Alpena counties (Figure 3). Seven of these sites occur in the Upper Peninsula in the Hiawatha National Forest, Mackinac County. These sites are Acklund Road, Brevort Lake Road, Horseshoe Bay, I-75 East, I-75 West, Martineau Creek SW, and Summerby Swamp (Steffens 1997, 1998). A roadkilled specimen was collected along Inglesbe Road north of Mackinac Trail and could represent either a new location or a wandering specimen (Steffens 1997). All areas within the National Forest are located within 12 km (7.4 mile) radius. During 1999 surveys, three new Hine's emerald sites were discovered: Snake Island Fens on Bois Blanc Island in Mackinac County, Loop 2 Fen at Thompson's Harbor State Park in Presque Isle County, and Misery Bay in Alpena County (Steffens 1999). These sites are approximately 37, 111, and 151 km (23, 69, and 94 miles), respectively, from the closest site in the Upper Peninsula (Steffens 1999).

Missouri: Hine’s emerald dragonfly inhabits three sites in Missouri, the Grasshopper Hollow Natural Area and Ruble Meadow in Reynolds County and Barton Fen in Iron County (L. Trial, Missouri Department of Conservation, pers. comm. September 2001).

Collection History and Historical Distribution:
Hine’s emerald dragonfly was first described in 1931 from specimens collected near Indian Lake in Logan County, Ohio, in 1929 and 1930 (Williamson 1931). Hine’s emerald dragonfly has also been collected in Ohio from Lucas County within the Maumee River watershed, and Williams County within the St. Joseph River watershed (Figure 3) (Price 1958, Glotzhober 1995). Numerous individuals were collected from the site in Lucas County between 1952 and 1961. Only a small number of individuals were collected at the other sites. Hine’s emerald dragonfly may have been extirpated from Ohio. The habitats at the Ohio sites have since been severely altered and Hine’s emerald dragonfly has not been found again at these sites (Glotzhober 1995, Moody 1995). Suitable habitat may still be found in northwest Ohio, northeastern Indiana, or southern Michigan (Moody 1994).

Only one Hine’s emerald dragonfly specimen has been recorded from Indiana, collected by William Kowlek from Gary, Lake County, in 1945 (Figure 3) (Montgomery 1953). Currently, this area is highly polluted from industry and steel mills, and if a viable population existed at this site, it is highly probable that it has been extirpated (Bick 1983). In 1995, visits to potential habitats in Lake County were unsuccessful in locating any Hine’s emerald dragonflies. A single adult male was collected in 1978 from Jackson County in northeastern Alabama (Vogt and Cashatt 1994).

Ronald J. Panzer collected the first Illinois specimen of Hine’s emerald dragonfly in 1983 during an insect survey at Lockport Prairie Nature Preserve. The specimen was identified as

this species by Tim E. Vogt in 1987. Hine's emerald dragonfly was first collected from Wisconsin in 1987 by William A. Smith near the Mink River in Door County (Vogt and Cashatt 1990). In 1997, Wayne Steffens collected the first Michigan specimen of this species during a Hine's emerald dragonfly status survey of the Upper Peninsula (Steffens 1997). This discovery extended the known range of Hine's emerald dragonfly approximately 200 km (124 miles) to the northeast from previously known locations in the Door Peninsula, Wisconsin. In 1999, Linden Trial collected an adult male Hine's emerald dragonfly from the Grasshopper Hollow Natural Area, in Reynolds County, Missouri. This specimen was sent to Tim Vogt for identification that same year. Grasshopper Hollow is approximately 603 km (375 miles) southwest of the Illinois site and almost as far northwest of the Alabama collection.

The full extent of the historical range of this species is unknown. Hine's emerald dragonfly had not been known to occur in Michigan prior to 1997, yet searches of potentially suitable habitat located a population in the Upper Peninsula of Michigan. It is important to identify a potential range for this species to guide searches for remaining undiscovered extant populations of Hine's emerald dragonflies. Information on the potential historical range of this species and guidelines for surveys are presented in Appendix 3.

STATUS OF EXTANT POPULATIONS

In order to describe the status of extant populations of Hine's emerald dragonfly, the following terminology will be used to distinguish between populations and subpopulations, and the sites at which these occur. A population is defined 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). For example, the Hine's emerald dragonfly individuals in the lower Des Plaines River valley, Illinois, would constitute a population, the individuals in Door County, Wisconsin, would constitute a second population, and the individuals in Mackinac County, Michigan, would constitute a third population. Populations are distinguished from each other by being separated by large distances (e.g., 50 km (31 miles) or more) and having a low probability of genetic exchange.

A subpopulation in most cases would be defined 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 (e.g., Middle Parcel, River South, and Lockport), 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 (Figure 4). Similarly, a road that cuts through an otherwise contiguous habitat would not create two subpopulations. These two areas would be considered one subpopulation.

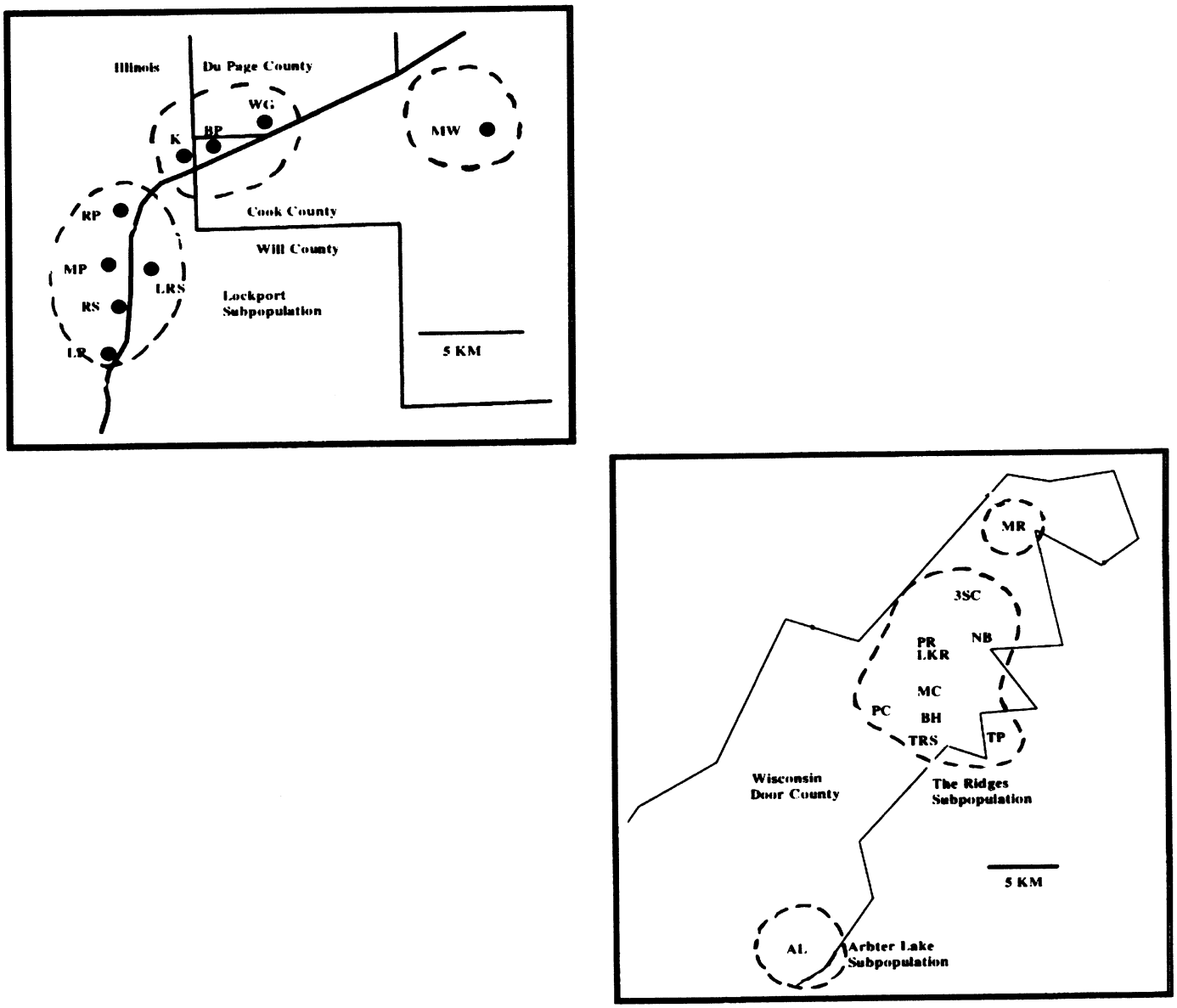


Figure 4. Hine's emerald dragonfly sites in Illinois and a subset of sites in Door County Wisconsin. Maps are different scales and illustrate relative locations of sites. Dashed circles illustrate potential subpopulation boundaries. Initial grouping are based on dispersal distance observations from mark-recapture studies. Nature and forest preserves are abbreviated NP and FP. Illinois abbreviations: BP - Black Partridge FP, K - Keepataw FP, LP - Lockport Prairie NP, LRS - Long Run Seep NP, MW - McMahon Woods, MP - Middle Parcel, RP - Romeoville Prairie Nature Preserve, RS - River South Parcel, and WG - Waterfall Glen FP. Wisconsin abbreviations: AL - Arbter Lake, BH - Bailey's Harbor, MR - Mink River, LKR - Mud Lake "North" (Lime Kiln Rd)., PR - Mud Lake "North" (Pioneer Rd.), MC - Mud Lake South (Mystery Creek), NB - North Bay marsh, PC - Piel Creek, 3SC - Three Springs Creek, TP - Toft Point, and TRS - The Ridges Sanctuary.

It is assumed that a sustainable subpopulation requires more than one breeding area and more than one seep head or spring located within the breeding area inhabited by the subpopulation. Breeding areas are important to the survival of this species and to the individual subpopulations the breeding areas support. Having at least two breeding areas would reduce the chances of losing an entire subpopulation if one of the breeding areas became unsuitable and unable to support reproduction. Male territorial patrols, oviposition, larvae, exuviae, or teneral adults, indicate that Hine's emerald dragonflies breed at a site.

Lack of sufficient information on demographics, dispersal, and status of populations has made it difficult to determine the population dynamics of Hine's emerald dragonfly. The patchy nature of habitat in Illinois and Wisconsin suggests a metapopulation structure, where there are groups of local breeding populations, each affected by some level of dispersal among these groups so that a metapopulation may be viewed as being composed of several smaller populations (Hanski and Simberloff 1997). Accordingly, metapopulation theory (Hanski and Gilpin 1997) has been used as a reference for establishing viability recovery criteria. The term "metapopulation" is not used in this plan to define units of Hine's emerald dragonfly populations because it is unclear how much migration and/or dispersal actually occurs among populations and subpopulations. It is assumed that dispersal between populations on the order of 10 km (6.2 miles) apart would be feasible for this species, but it is assumed that populations separated by distances of greater than 50 km (31 miles) would not have frequent exchange of individuals. It is not known, however, whether dispersal between subpopulations actually occurs or whether this species resembles a metapopulation solely due to habitat fragmentation. Subpopulations of species characterized by metapopulation dynamics are also assumed in many cases to have separate, independent fates. There is not yet enough information about the trends in each Hine's emerald dragonfly subpopulation to determine if this is the case.

Mierzwa *et al*. (1997) suggested that the mainland-island metapopulation model appears to fit the lower Des Plaines River valley population in Illinois the best. However, insufficient information on the Hine's emerald dragonfly's population dynamics, dispersal capabilities, and habitat stability do not allow researchers to confidently identify the importance or lack of importance of any of the sites. For example, in Illinois, the sites with the larger population sizes that could be identified as a mainland subpopulation occur within a relatively small groundwatershed, perhaps leaving this subpopulation at risk of extirpation from extreme drought or hydrologic changes due to development. If the larger subpopulation becomes extirpated or reduced in size, the sites with smaller Hine's emerald dragonfly population sizes may be critical to the survival of the lower Des Plaines River valley population as a whole if they serve as recruitment sources for the larger subpopulation. Until sufficient information is known about Hine's emerald dragonfly's population structure, sites with smaller population sizes should be considered important for the maintenance of the species.

Illinois:
The River South Parcel and Lockport Prairie Nature Preserve, located less than 1 km (0.62 miles) apart, support the greatest numbers of Hine's emerald dragonflies in Illinois (Mierzwa *et al*. 1995b, 1998). Population numbers at the remaining sites are relatively low.

Lockport Prairie Nature Preserve and River South Parcel support the largest and second largest number of larvae and exuviae (Table 1). One larva was found at Keepataw Forest Preserve, and exuviae were found at Middle Parcel (Cashatt *et al*. 1992, Soluk *et al*. 1996, 1998a, and Mierzwa *et al*. 1995b, 1998).

Wisconsin:
Three adult populations of the Hine's emerald dragonfly have been surveyed in Wisconsin to date, all in Door County. Of the three populations surveyed, the Ridges Sanctuary supported the largest population size (Vogt and Cashatt 1990, 1992; WDNR 1993). Mud Lake "North" and Three Springs Creek ranked second and third, respectively, in adult population size estimates (Table 2).

Mud Lake "North" had the highest density of Hine's emerald dragonfly larvae of the three sites sampled: Mud Lake "North," North Bay, and The Ridges Sanctuary (Table 1). The difficulty in locating larvae within the large area of potential larval habitat at The Ridges Sanctuary could explain why very few individuals have been collected from this site.

Since these studies, additional Hine's emerald dragonfly sites have been found that may support significant dragonfly populations including Cedarburg Bog (Ozaukee County), Black Ash Swamp (Kewaunee County) and Ephraim Swamp (Door County).

Michigan:
No attempt to determine population size has been made in Michigan. Steffens (1997, 1998) observed dragonfly breeding behavior, territorial patrol and oviposition, at four sites (Ackland Road, I-75 East, I-75 West, and Martineau Creek SW), and possible oviposition at two sites (Horseshoe Bay and Brevort Lake Road). The number of Hine's emerald dragonflies observed at each site ranged from one to four individuals. Steffens (1999) observed Hine's emerald dragonflies patrolling and feeding at Snake Island Fens, Loop 2 Fen, and Misery Bay. At least 15 adults were observed at the Snake Island Fens, the most ever observed at one time in Michigan (Steffens 1999). Surveys are being conducted to monitor the presence of Hine's emerald dragonfly at existing sites and *de novo* surveys are planned at sites with potential habitat. To date, no larval surveys have been conducted in Michigan.

Missouri:
No attempt to determine population size has been made in Missouri to date because new sites are being discovered. In 1999, Linden Trial collected an adult male Hine's emerald dragonfly from the Grasshopper Hollow Natural Area, in Reynolds County, Missouri. This specimen was sent to Tim Vogt for identification that same year. Two new sites were verified in Missouri in 2001, Ruble Meadow in Reynolds County and Barton Fen in Iron County. Reynolds County is approximately 603 km (375 miles) southwest of the Illinois sites and almost as far northwest of the Alabama collection.

Table 1. Hine's emerald dragonfly larval abundance and sampling effort in Illinois and Wisconsin (Soluk *et al*. 1996, 1998, unpub. data, Mierzwa *et al*. 1998).

	No. Larva/No. Samples		
Location	1996	1997	1998
River South, IL	NSC	39/54	TBA
Lockport Prairie NP, IL	37/210	35/454	10/298
Long Run Seep NP, IL	NSC	0/28	0/11
Middle Parcel, IL	NSC	0/11	TBA
Waterfall Glen FP, IL	NSC	0/13	NSC
Keepataw FP, IL	0/33	1/27	0/25
The Ridges Sanctuary, WI	0/20	0/36	1/22
Mud Lake "North," WI	7/19	52/138	264/159
North Bay, WI	2/23	1/12	NSC

TBA=To be announced; NSC=No survey conducted

Table 2. Hine's emerald dragonfly adult population survey results. Adult population survey at three Hine's emerald dragonfly sites in Wisconsin and two sites in Illinois using a mark-resighting method (Kirk and Vogt 1995, Mierzwa *et al.* 1995a, Cashatt and Vogt 1996). Fisher-Ford trellis model was used to calculate population estimates. The total annual adult population size at each site may be estimated by multiplying the Average Daily Population Estimate by a factor of 30 (Gall 1984, Watt *et al.* 1977).

Location and State	Average Daily Pop. Estimate	Daily Population Estimate Range	No. of Individuals Marked	No. of Resightings
The Ridges Sanctuary, WI	2938	159-5607	635	28
Mud Lake "North," WI	1699	169-2276	240	12
Three Springs Creek, WI	141	25-374	62	6
Lockport Prairie, IL	57	15-329	71	17
River South Parcel, IL	100	15-209	110	11

Genetic Diversity:
The Illinois population of Hine's emerald dragonflies contains the highest genetic diversity, as measured by numbers of different sets of maternal genes, or haplotypes (Purdue *et al*.1996). Six different haplotypes occur in the Illinois population. Three of the Illinois haplotypes are found only at Lockport Prairie Nature Preserve, and two are found only at the River South Parcel. The Wisconsin and Michigan populations are composed entirely of a seventh haplotype, which is not found in Illinois (Purdue *et al*.1996, Illinois Natural History Survey (INHS), unpub. data) . This suggests that females do not disperse between Illinois and Wisconsin or Michigan. Because this genetic analysis is based on genetic material inherited from the mother, it offers no information about whether males are dispersing between Illinois and Wisconsin or Michigan.

Tests conducted on specimens collected in Ohio and Alabama revealed that the Alabama haplotype was indistinguishable from the Wisconsin and Michigan haplotype, indicating a link between the Alabama specimen and the Wisconsin and/or Michigan populations (Purdue *et al*.1996). Analyses of Ohio's specimens indicate a relatively high level of genetic diversity with haplotypes being shared with the Illinois, Wisconsin, and Michigan populations. Specimens collected in 1999 from a site in Missouri and a site in southern Wisconsin each represented an additional unique haplotype (J. Purdue, Illinois State Museum, pers. comm.).

Genetic analysis of haplotype distribution in related *Somatochlora* species, *S. tenebrosa*, *S. linearis* and *S. ensigera*, have revealed a pattern similar to *S. hineana*, with greater diversity occurring in the unglaciated southern portion of the species' range, and lower diversity, probably indicating some interaction of post glacial dispersal into these areas and genetic drift, in the northern glaciated portion (Purdue *et al*.1999).

LIFE HISTORY AND ECOLOGY

Life Cycle:
The life cycle of Hine's emerald dragonfly is similar to most dragonflies in that it is comprised of the following stages: aquatic egg, aquatic larva, and a terrestrial/aerial adult (Corbet 1962). A Hine's emerald dragonfly female will most likely lay more than 500 eggs during her life (D. Soluk, Illinois Natural History Survey, pers. comm. 1999). After an egg is hatched, the larvae may spend 2 to 4 years in small streamlets, foraging and molting as they grow (Soluk *et al*. 1996, 1998a). Upon completion of larval development, the larvae begin to emerge as adults, possibly as early as late May in Illinois and late June in Wisconsin and continue to emerge throughout the summer (Vogt and Cashatt 1994, Soluk et. al. 1996, Mierzwa *et al*. 1997). The first emergence date can be estimated using temperature and precipitation data (Mierzwa *et al*. 1995a). The Hine's emerald dragonfly's known flight season lasts up to early October in Illinois (Vogt and Cashatt 1994, Soluk *et al*. 1996) and to late August in Wisconsin (Vogt and Cashatt 1994). Fully adult Hine's emerald dragonflies can live at least 14 days (Soluk *et al*. 1996), and may live 4 to 6 weeks (Mierzwa *et al*. 1995b). As with most dragonflies, adult Hine's emerald dragonflies feed, establish territories, mate, and oviposit (lay eggs) (Corbet 1962). Most dragonfly adults are general predators throughout their entire life cycle, feeding primarily on insects they can capture while flying.

Larval Life History:
From lab observations of *Somatochlora williamsoni* and a small number of Hine's emerald dragonflies (D. Soluk, Illinois Natural History Survey, pers. comm.), Hine's emerald dragonfly is assumed to be a sit-and-wait predator as described in Johnson (1991), remaining motionless until a prey item comes within striking range. Analyses of larval behavior using time lapse video and infrared light indicate that Hine's emerald dragonfly larvae are much more active at night than during the day (Pintor and Soluk, INHS, unpub. data). Hine's emerald dragonfly larvae have also been observed crawling around in streamlets at night (Mierzwa *et al*. 1998). Mobility at night may reduce predation risks. It is also possible that Hine's emerald dragonfly is an active predator, and the observed larvae were in search of prey items.

Preliminary analyses of fecal pellets from Hine's emerald dragonfly larvae indicate this species feeds on oligochaetes and larval mayflies and caddisflies, which are common in its habitat (Soluk *et al*. 1998a). Direct observation of larvae in containers indicate that Hine's emerald dragonfly will attack and consume mayflies, isopods, and smaller larvae of a related species, *Somatochlora williamsoni* (Soluk, INHS, unpub. data). Dragonfly larvae commonly feed on smaller insect larvae, including mosquito and dragonfly larvae, worms, small fish, and snails (Pritchard 1964, Merrill and Johnson 1984, Ross and Mierzwa 1995). As larvae grow, it is likely their prey items or prey size change. It is probable that Hine's emerald dragonfly is an opportunistic predator and does not rely on certain prey items for its diet.

Hine's emerald dragonfly larvae can occur in small clusters within their habitat (Soluk *et al*. 1996, 1998a, Mierzwa *et al*. 1998). Sample sizes of 1 square-foot have yielded different-size classes of Hine's emerald dragonfly individuals and up to 28 newly-hatched larvae (Mierzwa *et al*. 1998, Soluk, INHS, unpub. data). Single individuals have also been collected from numerous 1 square-foot samples. The pattern of distribution is unknown; however, these data imply that Hine's emerald dragonfly can coexist in clusters or remain independent. The quality of substrate may influence larval distribution within a site (Soluk *et al*. 1996).

Hine's emerald dragonfly larvae may become less active and/or crawl into tight spaces during cooler water temperatures in the late fall to early spring (Soluk *et al*. 1998a). Collectors have generally been unsuccessful in finding any Hine's emerald dragonfly larvae in streamlets during this time, even in streamlets that previously contained larvae. Hine's emerald dragonfly larvae have been located during this season by pumping water out of crayfish burrows. A single burrow contained as many as 21 larvae (D. Soluk and L. Pintor, Illinois Natural History Survey, pers. comm. 1999). This overwintering behavior and possible shift in habitat is an important aspect of the larval life history that should be studied further.

Another interesting aspect of larval ecology is the ability to withstand drought conditions. Hine's emerald dragonfly larvae have been found under discarded rail road ties embedded in a dry streamlet channel in Illinois (Soluk *et al*. 1998a). In Wisconsin, Hine's emerald dragonfly larvae were collected from moist streamlets and hummocks that had little to no surface water (Soluk *et al*. 1998a). The larval habitat in both Illinois and Wisconsin has dried up in the summer months during different years, and rainfall amounts in both Will County, Illinois and

Door County, Wisconsin, show similar drought frequencies (Soluk *et al*. 1998a). Hine's emerald dragonfly larvae may be adapted to survive drought conditions (Soluk *et al*. 1998a).

Adult Life History:
Hine's emerald dragonfly goes through three adult phases: pre-reproductive, reproductive, and post-reproductive (Cashatt *et al*. 1991). Pre-reproductive adults may fly 1 to 3 kms (0.6-1.9 miles) from their emergence sites and take short feeding flights of 1 to 3 minutes. Reproductive adults establish breeding sites and territories, using these areas to mate and oviposit. Males start patrolling territories approximately 7 to 10 days after emergence. Foraging flights for reproductive adults may be 1 to 2 kms (0.6-1.2 miles) from breeding sites and can last 15 to 30 minutes. Post-reproductive adults behave similarly to pre-reproductive adults.

Adult Hine's emerald dragonflies capture aerial prey in flight and have been observed foraging on small dipterans (gnats and other two-winged flies) (Vogt and Cashatt 1994). Typically, flight courses are irregular and occur over herbaceous habitat, often near clusters of shrubs or the forest edge (Cashatt and Vogt 1990; Vogt and Cashatt 1990, 1994, Nuzzo 1995). They frequently fly over open fields at a height of 1 to 3 meters (3-10 feet). Adults feed any time during the day but are most active during the morning (Mierzwa *et al*. 1995b, Cashatt and Vogt 1996, Soluk *et al*. 1998a). Crepuscular and diurnal feeding swarms of Hine's emerald dragonflies have been observed in both Illinois and Wisconsin (Vogt and Cashatt 1994). Hine's emerald dragonflies forage over meadows, successional fields, narrow roads, and along Lake Michigan (Vogt and Cashatt 1994).

In contrast to feeding flights, male territorial patrols are concentrated near aquatic habitats. Territories typically encompass a range of 2-4 meters (m) (6-13 feet) in length with flight heights ranging between 0.5-2.0 m (2-6 feet) (Cashatt and Vogt 1990, Vogt and Cashatt 1994). Vogt and Cashatt (1994) described territorial patrols in the following text: "males darted rapidly throughout their territories. They frequently hovered and often pivoted while hovering. Males usually conducted territorial patrols within small clearings of cattails, just above lower emergent vegetation (*Sagittaria* sp.), or just above the cattails. Also, males often assumed territorial patrols over a streamlet and hovered within 0.3 m (1 foot) of the surface. Occasionally, they perched near the top of cattail floral spikes. Territories were defended from intrusion by conspecific and nonconspecific Anisoptera [dragonflies]." Hine's emerald dragonflies patrol above both more permanent waters (streamlets) and temporary waters (inundated forest edges) (Soluk *et al*. 1998a).

Dispersal between sites and within sites in Illinois was documented during a 1995 mark-resighting study (Mierzwa *et al*. 1995a, Cashatt and Vogt 1996). From 180 marked Hine's emerald dragonflies, 4 out of a total of 48 resighted individuals were observed on a different site from which they were captured. Dispersal occurred from River South to Lockport Prairie Nature Preserve twice, Lockport Prairie Nature Preserve to River South, and Middle Parcel to Lockport Prairie Nature Preserve. The distances these four individuals traveled ranged from 3.3 km (2 miles) to at least 5.4 km (3.4 miles). Within River South Parcel, one male was documented traveling about 800 m (875 yards) in approximately 2.5 hours. The Des Plaines River and its riparian zone may be an important dispersal corridor (Cashatt and Vogt 1996).

Although dispersal between sites was not documented in Wisconsin, the extensive wetland system between the known sites in Door County may facilitate the dispersal of Hine's emerald dragonfly (Kirk & Vogt 1995).

Copulating pairs have been observed from early June (Vogt and Cashatt 1994) to late August (Vogt and Cashatt 1997) in Illinois and from early July to late July in Wisconsin (Vogt and Cashatt 1992). Males have been observed intercepting females within their territory, flying off in tandem with a female, and copulating while perched in shrubs (Vogt and Cashatt 1994). Females have also been observed flying over to males, which resulted in copulation (Soluk *et al*. 1996). These females were flying in a regular pattern approximately 0.5 m (1.6 feet) above the cattails. Occasionally, the females would chase nearby dragonflies, and on three occasions, these confrontations led to copulation. This female behavior is considered atypical for the genus *Somatochlora* and for other dragonfly species (E. Cashatt, Illinois State Museum, pers. comm. 1999).

Hine's emerald dragonfly females oviposit by repeatedly dipping their abdomens up to 200 times in shallow water. Observations of oviposition in Illinois range from late June to late August (Vogt and Cashatt 1997), and from early to late July in Wisconsin. Females have been observed with muck or mud on their abdomens, suggesting these females had oviposited in soft muck and/or shallow water. Females with muck on abdominal segments 7-10 have been observed as early as 6 June. Females oviposit in cattail seepage marshes, seepage sedge meadows, sedge hummocks near a marshy stream edge, near the edge of a swale, in muck in sluggish water at the margin of a spring run, in small puddles, in streamlets, and in small marl/muck bottomed pools (Vogt and Cashatt 1994, Soluk *et al*. 1996, 1998a, Steffens, pers. comm. 1998). Numerous females have been observed ovipositing between hummocks in shallow water with sheet flow in seepage sedge meadows (Vogt and Cashatt 1997, 1999). In cattail seepage marshes, females have been observed flying slowly into dense cattail stands. Occasionally, they fly just above cattails and then drop down into small clearings within the seepage marsh. Females will also fly slowly over small, shallow channels approximately 0.2 m (8 inches) above the water's surface within seepage marshes. These flights may be pre-ovipositional (Vogt and Cashatt 1994). All observations of oviposition by Soluk *et al*. (1998a) occurred in more permanent waters (streamlet and cattail/meadow borders).

HABITAT/ECOSYSTEM REQUIREMENTS

Hine's emerald dragonfly lives in wetlands dominated by grass (graminoid) or grass-like plants and fed primarily by water from a mineral source, or fens (Swink and Wilhelm 1994). Two important characteristics common to wetlands inhabited by Hine's emerald dragonfly appear to be groundwater fed, shallow water slowly flowing through vegetation, and underlying dolomitic bedrock or calcareous limestone. The flowing water can range from barely detectable sheet flow to deeper, well-defined streamlet channels. Parts of the streamlet channels are usually covered by vegetation such as cattails or sedges. These slow-moving aquatic systems provide appropriate habitat for larval development. Soil types of these aquatic systems can range from organic muck to mineral soils like marl. Two other important components of these wetland

complexes are open, vegetated areas and nearby or adjacent forest edge. Areas of open vegetation serve as places to forage. Forests, trees, or shrubs provide protected, shaded areas for Hine's emerald dragonfly to perch and roost.

Nearby or adjacent forested areas in Illinois are mainly floodplain deciduous forests. In Wisconsin and Michigan conifer swamps and forests are common. In Michigan, marl is a common substrate type, and in Illinois and Wisconsin, muck is the predominant substrate.

Habitat descriptions, community types, the physical aspects of Hine's emerald dragonfly sites, and a map of surface dolomite deposits are provided in Appendix 3. A list of dragonfly and damselfly species that often occur in Hine's emerald dragonfly habitat is also provided in Appendix 3.

Habitat descriptions from historic sites in Ohio include "a small, densely vegetated stream," "a bog meadow," "a shallow water (5-8 centimeters (cm) (2-3 inches) deep) bog densely vegetated with tall grasses and sedges," "a shallow pond," and "pond and streamlet" (Price 1958). Williamson (1931) further described one site as having a small stream with shallow water winding through brush, open areas, and through lizard tail. Trees were also present at this site.

Larval habitat may be an important factor affecting the distribution and population size of this species. Hine's emerald dragonfly larvae are usually found in small flowing streamlets within cattail marshes, sedge meadows, and hummocks (Cashatt *et al*. 1992, Vogt and Cashatt 1994, Soluk *et al*. 1996,1998a, Mierzwa *et al*. 1998). The marsh streamlet microhabitat in Illinois has "dead, coarse, cattail thatch which accumulates at constrictions in the channel" (Soluk *et al*. 1996). The majority of Hine's emerald dragonfly larvae in Illinois are collected in marsh streamlets with firm, intact cattail and sedge thatch. Prescribed burns may influence the amount and consistency of thatch in the streamlets. In Wisconsin, Soluk *et al*. (1998a) collected most larvae from small streamlet channels or from the water that flows between hummocks. The highest density of larvae came from distinct flowing channels that had silt, leaf litter, and decaying grasses for substrate. Larvae were also collected "among hummocks, which featured a braided network of pools between tussock sedges connected with narrow channels between the hummocks."

The hydrology of these wetlands may be one of the most critical components of the larval habitat. As previously stated, sheet flow through vegetation and/or slow-flowing streamlet channels within vegetation appear to be common characteristics of the Hine's emerald dragonfly larval habitat. Most of the larval habitat is believed to be fed by groundwater from seeps and springs. Some of the Hine's emerald dragonfly sites have experienced periods of drought and inundation. Natural hydrologic cycles including periods of drought may be an important aspect of the larval ecology.

Water quality may be another important component of larval habitat. Seeps occur at many of the Hine's emerald dragonfly sites. Water chemistry at known sites in Illinois and Wisconsin are consistent with the presence of dolomitic bedrock at or near the surface. The pH at these sites ranges from neutral to slightly alkaline (Vogt and Cashatt 1994, Midwest Environmental

Services 1995). A water quality study conducted in 1995 suggested the waters at the two Illinois sites with the largest Hine's emerald dragonfly population sizes were being enriched with nitrogen and phosphorous from fertilizers most likely used in agriculture (Midwest Environmental Services 1995). No pesticide or PCB residues were detected in this study. Appendix 4 presents a table of water chemistry for known and potential larval habitat at Hine's emerald dragonfly sites in Illinois and Wisconsin as reported in Soluk *et al*. (1998a). These data illustrate the wide range of chemical values of the known and potential aquatic Hine's emerald dragonfly larval habitat. A more in-depth study comparing water chemistry in areas with and without Hine's emerald dragonfly larvae may help in defining the water chemistry needs for this species. Appendix 4 provides a list of reports that provide water quality data at known Hine's emerald dragonfly locations. A summary and analysis of water quality results from past studies was conducted by Mierzwa *et al*. (1995b). None of the studies have found unique water chemistry parameters for the Hine's emerald dragonfly sites. Due to the fact that the larvae are found in water with good water quality, it is believed that this species may be sensitive to water quality degradation. Habitats occupied by Hine's emerald dragonfly frequently support other rare species of plants and animals as well (Appendix 5). Conservation of the Hine's emerald dragonfly is also expected to benefit these species as well.

Habitat Description by State:

Illinois: All sites in Illinois are wetland complexes consisting of several natural communities such as marsh, sedge meadow, dolomite prairie, spring, seep, and pond (Mierzwa *et al*. 1995a, Cashatt and Vogt 1996, Soluk *et al*. 1996, 1998a, Steffens 1997, 1998). Marshes are dominated by cattails (*Typha* spp.) and sedge meadows by tussock sedge (*Carex stricta*). Both of these communities can be broadly defined as fen (any minerotrophic peatland or mire) or fen-like. Shallow soils, including muck (Wascher *et al*. 1962, Link *et al*. 1978, Mapes 1979), overlie dolomitic bedrock (Niagaran limestone; Bretz 1939). Bedrock is occasionally exposed at the surface. Because these wetlands are spring-fed, water temperature fluctuations are minor. Forest communities are dominated by deciduous trees that are mainly floodplain forests. A beaver impoundment occurs at one of the Illinois locations.

Nuzzo (1995) and Mierzwa *et al*. (1998) sampled the structure and floral composition of the Hine's emerald dragonfly larval and adult foraging habitats at Lockport Prairie Nature Preserve, River South Parcel and Middle Parcel in Illinois. It was suggested that the presence of water, emergent vegetation, and percent of exposed surface water could be the critical components of the larval habitat, and that the type of emergent vegetation may not be as important. Oviposition occurred in marsh and sedge meadow communities with flowing water that averaged 0.7-13.5 cm (0.3-5.3 inches) in depth with a preferred water depth of 1.6-6.6 cm (0.6-2.6 inches) (Nuzzo 1995). As of 1995, oviposition had been observed at the following habitat types: "1. Channels within cattail marsh, with and without flow, 2. Channels within sedge meadow, 3. Shallow, wet depressions in sedge meadow with slow sheet flow, where water is at the surface for much of the year, 4. Seep heads on lower bluff faces" (Ross and Mierzwa 1995). Nuzzo (1995) found that Hine's emerald dragonfly preferred to forage in areas with a patchy habitat that occurred near areas with short and tall vegetation. High use foraging areas were located near larval habitats. Hine's emerald dragonflies also appeared to prefer patchy areas for breeding activities.

Wisconsin: The Wisconsin sites are described from wetland complexes with marsh, sedge meadow, small creek, pond, and spring communities (Vogt and Cashatt 1990, Kirk and Vogt 1995, Soluk *et al*. 1996, 1998a). Small, calcareous, marshy streams appear to be common at all Wisconsin sites. Marshes are dominated by cattails (*Typha* spp.), and sedge meadows are dominated by sedges (*Carex* spp.). Ridge-swale, river estuary, cedar swamps, low-gradient first and second order streams are habitat types that Hine's emerald dragonfly inhabits in Wisconsin. There appears to be a strong correlation between the distribution of Hine's emerald dragonfly and outcrops of Niagaran dolomite (Vogt and Cashatt 1990). Bedrock is exposed at the surface of some of the sites. Stream substrates are primarily muck and peat with some sand. Surrounding habitats include cedar swamps dominated by white cedar (*Thuja occidentalis*), wet-mesic upland forests, and old field communities. Tamarack (*Larix laricina*), black ash (*Fraxinus nigra*), and eastern white pine (*Pinus strobus*) are tree species that are present in this area. Beaver impoundments are known to occur at some locations.

Michigan: Similar to the Hine's emerald sites in Illinois and Wisconsin, Michigan sites with Hine's emerald dragonfly were underlain by shallow dolomite and were identified as calcareous or northern fens. These sites were described as "thinly treed, alkaline peatlands (Penskar and Albert 1988)." Sedges and cattails are present at the Michigan sites. Communities present at these sites included rich conifer swamps, northern fens, marl fens, and coastal fens with seeps, marl pools, hummocks, shallow pools, small creeks, and "small marly seeps and creeks." Northern fens are dominated by sedges and rushes and are commonly surrounded by white cedars. Very high microsite diversity was documented for several of the sites. One site had both minerotrophic and ombrotrophic wetland plant species. Surrounding habitat of some of the sites included white cedar swamps with scattered small fens. Most sites had Markey and Carbondale soil types that are partly defined as "very poorly drained organic soils (mucks and mucks over sand) on glacial lake beds and outwash plains (Natural Resources Conservation Service 1995)." Seeps were documented at five of the seven sites, and most of the sites were believed to be spring-fed. Characteristics of all Michigan Hine's emerald sites have been described in Steffens (1997, 1998, 1999).

Missouri: Grasshopper Hollow Natural Area contains a variety of habitats including fens, upland and bottomland forests, and pasture and old fields. Nigh (1992) identified four fens, a forested fen, ten deep muck fens, and one prairie fen. He considers the prairie fen to be the best of its known type in Missouri based on size and natural quality. The first Hine's emerald dragonflies collected in Missouri were taken as they flew over this prairie fen. Grasshopper Hollow is in an area that is moderately dissected with broad to narrow ridgetops, gentle to steep sideslopes, and narrow stream valleys. The watershed that includes the natural area is approximately 2000 acres of surface area. Eminence Dolomite underlies the valley bottom, Gasconade Dolomite underlies the uplands, and Roubidoux Sandstone/Dolomite occurs on the ridges and upper slopes (Nigh 1992).

In addition to the prairie fen at Grasshopper Hollow, the Hine's emerald dragonfly has also been collected at two deep muck fens in Missouri, Ruble Meadow and Barton Fen. Ruble Meadow is a privately owned site that is 3.4 acres in size and is considered an excellent example of a deep muck fen with deep peaty sedge-shrubs in diverse plant communities. Barton Fen, managed by

the U.S. Forest Service, is a high quality deep muck fen that is two acres in size (Janet Sternburg, Missouri Department of Conservation, pers. comm. 2001).

THREATS TO THE EXISTENCE OF THE SPECIES

The significant threats to the existence of this species have been identified as habitat destruction/alteration and contamination. The other threats described in this section are considered potential concerns but are not considered significant threats to the existence of this species.

Significant threats to the existence of Hine's emerald dragonfly:

Habitat Destruction/Alteration: Destruction or alteration of Hine's emerald dragonfly habitat is one of the main threats to its survival. Developing commercial and residential areas, quarrying, creating landfills, constructing pipelines, and filling of wetlands could decrease the area of suitable habitat available to the Hine's emerald dragonfly and fragment populations. Direct loss of breeding and/or foraging habitat could potentially reduce both adult and larval population sizes. A reduction in foraging habitat has the potential to reduce the fitness of the adults, which may result in females laying fewer eggs. Hine's emerald dragonfly habitat is closely associated with surface dolomite deposits, an extractable resource that is often quarried. River South Parcel and Middle Parcel in Illinois and Mud Lake "South" in Wisconsin occur near quarries. Mineral mining rights are owned under a portion of Grasshopper Hollow. Mining for lead is expected to continue in this area, but may not occur under the natural area.

Changes in surface and sub-surface hydrology could be detrimental to the Hine's emerald dragonfly. Alteration of water regimes could potentially affect surface water flow patterns, cause loss of seep heads, and reduce existing or potential larval habitat. Permanent loss of appropriate hydrology also has the potential to reduce the amount of suitable breeding and larval habitat. Road construction, channelization, and alteration of water impoundments, temperature, discharge quantity, water quality, and lake levels have the potential to affect important hydrologic characteristics of Hine's emerald dragonfly larval habitat that could be necessary for the survival of this species. A study to predict hydrologic changes to a spring near Black Partridge Creek from a proposed interstate highway suggested that an 8 to 35 percent reduction in spring discharge may occur after the construction of the highway (Hensel *et al*. 1993). Hensel *et al*. (1993) suggested that the highway could cause a loss of recharge water for the spring and lower the water table, reducing the discharge of the spring. Pumping of groundwater for industrial and agricultural use also has the potential to lower the water table and change the hydrology, which may affect larval habitat. Dye-tracing indicates the fens at Grasshopper Hollow are fed by springs originating south of the natural area in the Logan Creek valley (Aley and Adel 1991). These results were not anticipated when setting the natural area boundaries and a portion of the recharge area is not on public lands.

Loss of important habitat types within suitable wetland systems may also threaten this species. Wetland systems with wet prairie, sedge meadow, cattail marsh and/or hummock habitat,

interspersed with native shrubs, appear to be an important part of the overall habitat requirements of the Hine's emerald. The balance of these habitat types within the wetland systems may be important to the survival of this species. Woody vegetation may replace open wetland habitats through succession. Woody vegetation creates shade that can change plant community composition. Invading non-native species such as purple loosestrife could alter the wetland communities and decrease the amount of wet prairie, sedge meadow, and/or cattail marsh. Habitat changes can also be human-induced, caused by overuse from scientific studies and recreation and outreach activities. Management techniques for natural areas, such as prescribed burns and brush control, should be evaluated to determine how the Hine's emerald dragonfly is affected by habitat alterations.

Contamination: Contamination from landfills and past/present applications of habitat-altering chemicals may be harmful to this species. Due to its long aquatic larval stage, contamination of groundwater and surface water are primary threats to this species. Because groundwater moves relatively slowly through sediments, contaminated water may remain toxic for long periods of time and may be difficult or impossible to treat.

The larvae of this species live in streamlets fed by groundwater, and contamination of this source of water could have serious detrimental impacts on the survival of this species. High water quality may be a critical component of this species' habitat; the level of poor water quality that Hine's emerald larvae can tolerate is unknown. Hine's emerald dragonfly's reactions to toxic chemicals are unknown, and any contaminant introduced into its system may cause detrimental effects including mortality. It is possible that contaminated water could decrease or eliminate the number of larvae able to survive in the contaminated system.

Leaching may be one source of contamination of Hine's emerald habitat. Landfills may leach contaminants into the surrounding aquatic system, decreasing the water quality. Acidic water leaching from a sawdust pile at the Missouri site impacts the water chemistry of fens and stream reaches nearest this pile. Extensive data were collected in 1991 and a few readings made in 1996. The Nature Conservancy has water chemistry data on file in their Van Buren office (Blane Heumann, The Nature Conservancy, pers. comm. 1999). Data were collected to measure the impact from water leaching from a sawdust pile into nearby fens, deep muck fens, and small streams. An increase in acidity was noticeable in water near the sawdust pile. The impact appeared to be confined to areas near the sawdust pile. The sawdust pile started to burn in 1999 and has been much reduced in size. If it continues to burn, the water chemistry impacts should lessen. Winter winds can blow dust from lead mine tailings onto the northen end of Grasshopper Hollow Natural Area. Because this is an active lead mine and mill, tailings can be expected to be added to existing settling basins. Lead and arsenic are residues that may remain within watersheds from past orchard industry practices, which may be of concern in Door County, Wisconsin. During 1995, the Wisconsin Department of Agriculture, Trade and Consumer Protection (DATCP) conducted a pesticide risk assessment of five Door County Hine's emerald dragonfly sites. Potential pesticide risks to Hine's emerald habitat included cherry and apple orchard operations (Three Springs Creek, Mud Lake "North"), plant nursery development (Mud Lake "North") and use of pesticides by the Town of Liberty Grove in roadside spraying (Mink River) (USDA 1995). Other potentially toxic chemicals include

insecticides, herbicides, and fertilizers from agriculture and recreation purposes (golf course development and maintenance). Gypsy moth and mosquito control may be detrimental to Hine's emerald dragonfly. It is unknown how insecticides would affect Hine's emerald adults and larvae if applied near their habitat. Indirect effects from chemicals such as fertilizers can include habitat alteration (eutrophication of aquatic systems).

Inadequate Regulatory Protection: Because habitat alteration and degradation are factors affecting the existence of this species, regulatory protection is important. The regulatory protections that pertain to the Hine's emerald dragonfly are described in the Conservation Measures section. The recovery of the species will depend on ensuring adequate suitable habitat and protection of that habitat.

Potential Concerns:

Environmental Extremes: Natural catastrophes and environmental extremes such as floods, drought, and/or severe freezing have the potential to reduce population sizes or cause extirpation of populations. Due to the relatively close proximity of the sites inhabited by Hine's emerald dragonfly, a natural catastrophe has the potential to impact all of the subpopulations within an area. The vulnerability of Hine's emerald dragonfly populations to extirpation from environmental extremes may be increased by the habitat alteration and fragmentation caused by human development, such as the alteration of hydrology. Impoundments built by beavers can also modify the hydrology of a system.

Transportation: Adult mortality from direct impacts with vehicles or trains may reduce Hine's emerald dragonfly population sizes (Steffens 1997, 1998, Soluk *et al*. 1998a). Because Hine's emerald dragonflies are known to be killed by vehicles and they have been observed flying over railroad tracks, it is believed that high speed trains may also have the potential to serve as a source of mortality for this species (Soluk *et al*. 1998b). However, the extent to which Hine's emerald dragonfly populations are affected by roadway or railway mortality needs to be determined. The ability to link the mortality of adult individuals to a reduction in population size and/or a loss in genetic diversity is difficult due to the complex population dynamics and life cycle of this species.

In Illinois, roadways with the most potential to serve as sources of vehicle-related mortality for Hine's emerald dragonfly adults are Highway 53, Route 7, and New Avenue. An interstate is proposed to be built through and near Hine's emerald dragonfly habitat in Illinois, which could possibly reduce the population size and/or decrease dispersal between subpopulations. Railways are a concern in Illinois because active railroads pass through and near the habitat of three of the sites with the largest population sizes. At two of these sites, railway speed is reduced to 4 to 6 miles per hour during the Hine's emerald dragonfly flight season. These trains probably do not kill adult dragonflies from direct impacts (Mierzwa *et al*. 1998). High speed trains run near the third site, and a high speed railway system is being proposed in this area. A preliminary assessment of the effects from a high speed train on the Hine's emerald dragonfly indicated that the high speed of these trains has the potential to be a source of mortality for this species (Soluk *et al*. 1998b).

In Door County, Wisconsin, roadways shown to serve as sources of vehicle-related mortality for the Hine's emerald dragonfly are State Highways 42 and 57, County Route Q, and Ridges Road. In Kewaunee and Ozaukee Counties, County Route X and Blue Gooose Road, respectfully, appear to be sources of vehicle related mortality. It is possible that some of the roads in Door County may be expanded in the future to accommodate tourist traffic. Traffic increases during tourist season, which correlates with the flight season of the adults. Railways are not currently a problem in Door County, Wisconsin.

Several of the Michigan sites are located near roadways, and it is believed vehicles may serve as a source of mortality in these areas (Steffens 1997, 1998). Interstate 75, a busy four-lane divided highway, and Mackinac Trail run near several of the sites. Currently, there are no railroads near the Hine's emerald dragonfly sites in Michigan.

Transportation corridors such as roads and railroads may also impact the Hine's emerald dragonfly habitat. The creation of impoundments from road and railroad development could change appropriate hydrology which could decrease or alter suitable larval habitat. Maintenance of roads and railroads could also be detrimental to this species. Salt spray from roads and creosote from railroad ties may leach into its aquatic habitat. This may create a toxic environment for the Hine's emerald larvae and decrease population size. Discharge from the Chicago Sanitary and Ship Canal is also a potential threat to larval habitat in Illinois.

Demographic and Genetic Stochasticity: The vulnerability of Hine's emerald dragonfly to effects from demographic and genetic stochasticity (Schaffer 1981) may be increased by habitat fragmentation and small population sizes. Demographic stochasticity is the random outcome of deaths, births, sex ratio, and other demographic variables within a population. Demographic stochasticity can cause small populations, like the Illinois and Michigan populations, to vary widely in size. A drastic reduction in population size can lead to the further decline of a population to extirpation, or can exacerbate the effects of genetic stochasticity. As a population loses individuals, it may lose genetic variation, which may reduce the species' fitness or ability to cope with environmental change. The Wisconsin population has little genetic variation, and the Illinois population has the most genetic diversity. This indicates the importance of the Illinois population to the survival of the Hine's emerald dragonfly.

Disease or Predation: The vulnerability of Hine's emerald dragonfly to effects of predation may be increased by habitat fragmentation and small population sizes. Dragonfly larvae can be consumed by wading birds, puddle ducks, shorebirds, fish (mud minnows and sunfish), turtles, amphibians, crayfish, and other aquatic invertebrates, including other dragonflies, or vertebrates larger than the larvae. Adults may fall prey to spiders, frogs, birds, and other invertebrates including large dragonflies.

It is probable there are pathogens, diseases, fungi and/or parasites that could kill or decrease the fitness of the Hine's emerald dragonfly; however, no pathogens are known to affect this species. Parasitic mites are known to attach to odonates (Smith 1988, Forbes and Baker 1990, 1991, Forbes 1991); however, their impact on dragonflies is poorly understood. Little information is known about insect pathogens affecting dragonflies in general. If a disease outbreak occurred, it

would be difficult, if not impossible, to determine and correct the cause. Insect populations have been known to be reduced to low levels due to insect pathogens (S. Kohler, pers. comm. 1999). A fatal outbreak could be especially detrimental to the Hine's emerald dragonfly given its relatively small population size.

Overutilization for Commercial, Recreational, Scientific, or Educational Purposes: Collection of Hine's emerald dragonfly individuals for commercial, recreation, science, or educational purposes is not considered a significant threat to this species. It is estimated that the number of individuals collected for scientific purposes would be relatively low. Of that number, the majority would most likely be males. Before the inadvertent collection of Hine's emerald dragonfly during a general insect survey in Illinois, this species was believed to be extinct. Knowledge of Hine's emerald dragonfly individuals inadvertently taken would be beneficial in locating new areas inhabited by this species. To avoid violation of the ESA through inadvertent collection of Hine's emerald dragonfly, dragonfly surveyors should obtain a section 10 research permit from USFWS if they propose to collect from potential Hine's emerald habitat areas.

CONSERVATION MEASURES

Endangered Species Act Protections:

The Federal Endangered Species Act of 1973, as amended (ESA) contains protection and recovery provisions for federally listed threatened and endangered species. Recognition through listing encourages and results in conservation actions by Federal, State, and private agencies, groups, and individuals. The ESA provides for cooperation with the States, including possible land acquisition, and requires that recovery and conservation actions be carried out for all listed species.

"Take" Prohibitions:

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. It is also unlawful to attempt such acts, solicit another to commit such acts, or cause such acts to be committed. 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. "Harass" means an intentional or negligent act or omission which creates the likelihood if injury to listed wildlife species by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering.

Federal Permits:

Section 10 of the ESA provides for the issuance of two types of permits that may be granted to authorize activities prohibited under section 9:

Section 10(a)(1)(A): permits for scientific purposes or to enhance the propagation or survival of a listed species;

Because very little was known about the biology and ecology of the Hine's emerald at the time of listing, section 10(a)(1)(A) permits were granted for several research projects conducted to gather more information that contributed to the understanding and recovery of this species. The USFWS funded population and habitat monitoring studies for Illinois populations (Cashatt and Vogt 1996), genetic studies (Purdue *et al*. 1996), population surveys (Moody 1994, Steffens 1997, 1998), population monitoring and dispersal studies in Wisconsin with the cooperation of The Nature Conservancy (TNC) and Wisconsin DNR (Kirk & Vogt 1995), and population, behavior, and life history studies on larvae and adults in Illinois and Wisconsin (Soluk *et al*. 1998a). Section 10 permits have also been granted for research projects funded by Illinois Department of Natural Resources, Illinois Department of Transportation, Commonwealth Edison, and Material Service Corporation. These projects have included studies on Hine's emerald dragonfly annual population and habitat use (Mierzwa 1995, Mierzwa *et al*. 1995b, Soluk *et al*. 1996, Mierzwa *et al*. 1997, TAMS 1997, Vogt & Cashatt 1997), site hydrology, water quality monitoring, genetics (Purdue *et al*. 1996), adult flight behavior near roadways, larval population, and life history in Wisconsin and Illinois (Soluk and Swisher 1995, Soluk *et al*. 1996, 1998a).

Research has provided valuable information toward the recovery of the Hine's emerald dragonfly. Population surveys have provided population size estimates for sites in Illinois and Wisconsin. These surveys have been useful in locating sites where Hine's emerald dragonflies are breeding. These studies have also provided evidence of dispersal between several of the Illinois sites, which has been useful in evaluating the Illinois' population structure. Genetic research has been useful in identifying 1) the genetic diversity of the past and present populations, 2) Illinois as the most genetically diverse extant population, 3) the lack of genetic diversity in the Wisconsin population, 4) the genetic links between the populations and sites, and 5) closely related species. Adult and larval ecology and life history studies have provided valuable information on adult habitat preference, larval habitat characteristics, length of larval period, phenology, and potential interspecific species interactions. Information on Hine's emerald dragonfly ecology has and will improve the recovery and management recommendations for this species. Water quality monitoring has provided important information on Hine's emerald larval habitat requirements and is important to the management of this species.

A Safe Harbor Policy has been established by the USFWS and the National Marine Fisheries Service (USFWS 1999). This policy encourages non-Federal landowners to voluntarily conserve threatened and endangered species. Under a Safe Harbor agreement, a private landowner would agree to create, restore or maintain habitats, and/or manage their lands so that listed species will benefit. In return, the USFWS provides assurances that future landowner activities above baseline conditions will be exempt of additional future regulatory restrictions. The USFWS issues section 10 (a)(1)(A) permits to cover non-Federal landowner agreements under the Safe Harbor Policy.

Section 10(a)(1)(B): permits for "take" that is "incidental to, and not the purpose of, carrying out an otherwise lawful activity."

Section 10(a)(1)(B) of the ESA allows permits to be issued for take that is "incidental to, and not the purpose of, carrying out an otherwise lawful activity" if the intent is not for research or recovery activities, and the activity occurs on non-Federal land where no Federal action is involved. An applicant for an incidental take permit must prepare a habitat conservation plan that specifies the impacts of the take, steps the applicant will take to minimize and mitigate the impacts, funding that will be available to implement these steps, alternative actions to the "take" that the applicant considered, and the reasons why such alternatives are not being utilized. No section 10(a)(1)(B) permits have been issued for the dragonfly.

Section 7 Consultations: Section 7(a)(2) of the ESA requires Federal agencies to consult with the USFWS prior to authorizing, funding, or carrying out activities that may affect listed species. Section 7(a)(1) also requires that these agencies use their authorities to further the conservation of federally listed species. This consultation process promotes interagency cooperation in finding ways to avoid or minimize adverse effects to listed species. Several section 7 consultations have been conducted for actions in the rapidly developing lower Des Plaines River valley in Illinois. Such actions have included expansion of a commuter airport, expansion of a quarrying operation, extension of a highway, building of a bridge, and upgrading of a railroad. Because the Hine's emerald dragonfly depends on a wetland habitat, most of these consultations have involved the U.S. Army Corps of Engineers, pertaining to their Clean Water Act section 404 permits for wetland filling. Most of these consultations resulted in no project modifications or blockages, while related studies contributed information important to the recovery of the species. For a railroad upgrade project, Commonwealth Edison took an innovative approach by using steel railroad ties as an alternative to creosote-treated ties that could potentially contaminate the wetlands used by the dragonfly. An offshoot of the railroad upgrade consultation was the formation of a Right-of-Way Management Team, composed of Federal, state, and county natural resource agencies, Commonwealth Edison, Material Service Corporation, and the EJ & E Railroad Company. This Right-of-Way Management Team meets at least quarterly to review progress and results of studies and to make recommendations for implementing compatible right-of-way activities and Hine's emerald dragonfly habitat management.

Other Federal Protection:
Wetland habitat loss through the discharge of fill material is regulated under section 404 of the Clean Water Act by the U.S. Army Corps of Engineers and may provide protection for Hine's emerald dragonfly habitat. The U.S. Environmental Protection Agency provides guidance and some funding for groundwater protection. In September 1994, 14 Federal agencies, including the USFWS, National Park Service, U.S. Army Corps of Engineers, Federal Highway Administration, and Department of Defense signed a Memorandum of Understanding (MOU) affirming their commitments to carry out programs for the conservation of federally listed species and the ecosystems on which they depend including cooperation in the implementation of recovery plans.

State Protection:
Illinois: The Hine's emerald dragonfly is listed as endangered by the Illinois Endangered Species Protection Board and is protected from take by the Illinois Endangered Species

Protection Act. The Illinois Endangered Species Protection Act also requires consultation with the Illinois Department of Natural Resources (Illinois DNR) for actions authorized, funded, or carried out by any agency of state and local governments to ensure that state-listed species are not negatively affected by the action. Due to the complexity of most development projects within the lower Des Plaines River valley, there is often state, local, and Federal involvement. In such cases, state and Federal consultations are conducted in coordination with each other.

Under the Illinois Natural Areas Preservation Act, dedicated nature preserves are afforded the maximum legal protection against future changes in land use. Three of the Hine's emerald dragonfly sites occur within Illinois nature preserves. The Illinois Nature Preserves Commission coordinates with the USFWS in consultations on actions involving these nature preserves and requires permits for research and other activities conducted within the preserves.

The Will County and Du Page County Forest Preserve Districts and the Illinois DNR have carried out habitat management measures, such as prescribed burns, brush clearing, and non-native vegetation control, on their lands to benefit the Hine's emerald dragonfly, as well as other federally and state listed species and rare and unique wetland plant communities. Material Service Corporation has also conducted a controlled burn at a Hine's emerald dragonfly site on their property. As part of a mitigation requirement for a Clean Water Act permit for filling wetlands, another quarrying operation funded extensive brush clearing at an Illinois site supporting the Hine's emerald dragonfly, which may provide additional potential breeding habitat. As part of another wetland mitigation requirement for a highway extension, the Illinois State Toll Highway Authority implemented a project to restore historic hydrologic conditions at an Illinois Hine's emerald dragonfly site that had been altered in the past by a railroad and by ditching.

Wisconsin: The Hine's emerald dragonfly was listed as endangered by the Wisconsin Department of Natural Resources in 1997. The Wisconsin statutes require that a state agency must consult with the Wisconsin DNR if an activity that it funds, conducts, or approves may affect a listed species. The statutes allow for the issuance of permits for incidental take of listed species if an appropriate conservation plan that minimizes and mitigates for the take is submitted by the applicant.

Currently, The Nature Conservancy has project areas in Door County, Wisconsin, that encompass several Hine's emerald dragonfly sites. The Nature Conservancy is interested in providing long-term protection of the project areas by purchasing important habitat, working with other organizations (e.g., The Ridges Sanctuary, Inc. and the Door County Land Trust) to purchase and obtain conservation easements for important habitat, contacting landowners to provide information on ways to conserve the Hine's emerald dragonfly, and conducting public outreach to the outlying community.

Michigan: The Hine's emerald dragonfly is proposed for listing as state endangered under the Endangered Species Protection section of the Natural Resources and Environmental Protection Act (Part 365 of Public Act 451 of 1994). Part 303 of Public Act 451 also provides for the preservation, management, protection, and use of certain wetland habitats. The law lists habitat

for threatened and endangered wildlife species as a criterion to be considered in the administration of the Public Act. The Michigan Department of Environmental Quality is responsible for regulating the discharge of pollutants into surface waters, including wetlands. Since most known Hine's emerald dragonfly sites occur within the Hiawatha National Forest, which is managed by the U.S. Forest Service, the U.S. Forest Service would conduct biological evaluations for projects that may affect the Hine's emerald dragonfly sites and would consult with the USFWS regarding potential impacts. Most of the Hine's emerald dragonfly sites occur in wilderness or research natural areas, which are considered protected areas.

Missouri: The Hine's emerald dragonfly will be listed as endangered in Missouri. This species will be included in the 2001 Wildlife Code.

Ohio: The Hine's emerald dragonfly has also been listed as state endangered by the Ohio Division of Wildlife. The Ohio statute restricts the taking or possession of native wildlife, or any eggs or offspring thereof, that is threatened with statewide extinction.

Outreach:
Education and outreach can be important tools for recovery, especially for little-known invertebrate species such as the Hine's emerald dragonfly. Internet web sites with information on the Hine's emerald dragonfly, including images of adults, larvae, and habitat, can be found at the following addresses USFWS Endangered Species program, http://endangered.fws.gov; Illinois Natural History Survey's Center for Aquatic Ecology, http://www.inhs.uiuc.edu/cae/; Daniel Soluk's personal page, http://www.inhs.uiuc.edu/cae/staff/~dsoluklab/hines.htm; and Illinois State Museum, museum.state.il.us/research/entomology/hines/mainpage. Guest lectures on the Hine's emerald dragonfly and other listed species have been provided to high schools, universities, a college, an environmental education center, and Cub Scouts. A Recovery Team member has given a presentation to a mosquito abatement district on the status and protection needs of the Hine's emerald dragonfly. Recovery Team members and research personnel from the Illinois State Museum and the Illinois Natural History Survey presented four research presentations on the Hine's emerald dragonfly at the annual meeting of the North American Benthological Society in San Marcos, Texas, in May 1997. Recovery Team members also presented papers about the Hine's emerald dragonfly at the 1999 International Congress of Odonatology at Colgate University, Hamilton, New York, in July 1999. Other outreach by Recovery Team members include alerting people nationwide to the plight of this species and the need for more research.

RECOVERY STRATEGY

Due to the limited numbers and small sizes of extant Hine's emerald dragonfly populations, the overriding priority for recovery of this species is to protect and maintain the known populations and their associated terrestrial and aquatic habitat. A second component will be to survey for additional populations and to monitor known populations to detect population trends. To achieve recovery, it may be necessary to establish populations at appropriate places within the historic range of the species. Because so little is known about the biology and population

dynamics of Hine's emerald dragonfly, research is an important supporting component of the recovery strategy to guide these efforts.

The recovery criteria are based upon conservation biology and metapopulation theory. It is assumed that a metapopulation structure (with most populations made up of several subpopulations) provides a stable system for long term viability. Though much is unknown about the population dynamics of Hine's emerald dragonfly (*e.g.*, fecundity and dispersal), the basic metapopulation structure increases the potential for the species to survive chance events that might lead to extinction of a single population, and increases the potential of a rescue effect, or recolonization of extirpated populations by individuals from remaining populations (Brown and Kodric-Brown 1977). The criteria to reclassify from endangered to threatened status include an alternative population size requirement that relies on the existence of additional numbers of small populations rather than on the metapopulation structure. The subpopulation size criterion is based on data from an adult Hine's emerald dragonfly mark-recapture study (Mierzwa *et al*. 1995) and Hine's emerald dragonfly larval studies (Soluk *et al*. 1996, 1998a), and on the conservation biology literature. New information on adult dispersal patterns and modeling of alternative population distributions may identify additional arrangements that provide long-term viability for recovery (see task 2.1.3).

A population size of 500 adults would not be considered very large for an invertebrate (insect) population. For comparison, Mace and Lande (1991) assessed differences between threatened and endangered vertebrate species. They proposed three different categories of threat: *critical* for any species with 250 individuals and two or fewer populations, *endangered* for any species with 2500 individuals and five or fewer populations, and *vulnerable* for any species with fewer than 10,000 individuals and five or fewer populations. Criteria for insect populations could be even an order of magnitude larger in size given the potential for large fluctuations in population size. The criteria for delisting the Hine's emerald dragonfly are six populations and 9000 individuals.

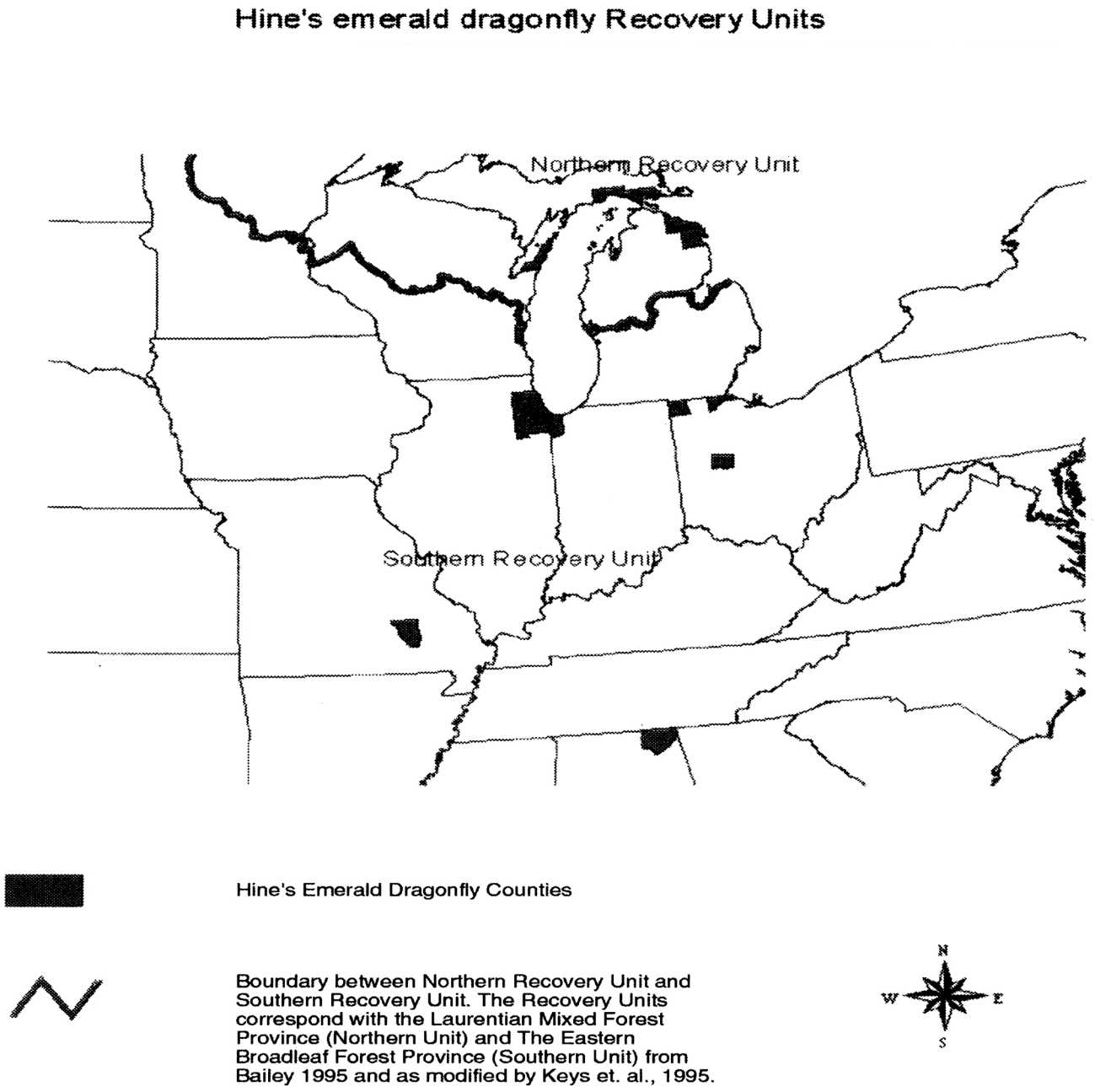
A minimum viable population (MVP) as defined by Schaffer (1981) is "the smallest isolated population having a 99 percent chance of remaining extant for 1000 years despite the foreseeable effects of demographic, environmental, and genetic stochasticity and natural catastrophes." MVPs may be defined according to different survival probabilities and time periods, but a given probability of a population's survival over a given time period will depend on a minimum population size. An effective population size of 500 was frequently cited in the early 1980's as a guideline for MVPs (Franklin 1980, Frankel and Soulé 1981), but this value was based solely on genetics (Menges 1992). Genetics is only one of the four factors considered in a population viability analysis, and populations can spiral downward at an even faster rate than expected if these factors (e.g., genetics and demographics) interact (Gilpin and Soulé 1986). In addition, it is rarely easy to estimate effective population size. Because most populations do not behave as ideal populations, effective population size is generally smaller than actual population size. This difference is caused by unequal sex ratios, unequal reproductive success among individuals, and variation in population sizes over time.

A population viability analysis of the Hine's emerald dragonfly has yet to be conducted. The recovery criterion for minimum population size is based upon current census values for existing

population sizes of Hine's emerald dragonfly, and the following assumptions: 1) larval populations of dragonflies are generally at least two orders of magnitude larger than adult populations (Benke and Benke 1975, Ubukata 1981, Johnson 1986), 2) mean reproductive output per female could easily be over 500 eggs per life span, and 3) a 3 year life cycle (overlapping generations). The 10 year criterion requires monitoring over several generations to ensure that population trends are discerned. Given the potentially large natural fluctuations in insect populations among years and the overlapping of three separate generations, this would provide a minimum amount of data with which to discern a trend.

The two recovery units (Figure 5) are broadly based upon Bailey's ecoregions (*e.g.*, Eastern Broadleaf Forest Province and Laurentian Mixed Forest Province) and as modified by Keys *et al.* (1995), so that local recovery planning can be coordinated among populations within more similar habitats with like management concerns.

Figure 5. Hine's emerald dragonfly Recovery Units. The Recovery Units (RU) are based on ecoregions from Bailey (1995) and as modified by Keys *et al.* (1995). The two divisions used from Bailey's (1995) ecoregions were the Warm and Hot Continental Divisions. See Appendix 3 for details.



PART II: RECOVERY

RECOVERY OBJECTIVE

The objective of this recovery plan is to assure the long-term viability of the Hine's emerald dragonfly by arresting or reversing its decline and addressing threats to its survival. When this objective is achieved, the Hine's emerald dragonfly may be removed from the Federal list of *Endangered and Threatened Wildlife and Plants* (50 CFR 17.11 and 17.12).

The recovery criteria are based on the available information for the Hine's emerald dragonfly and related odonate species and on basic principles of conservation biology. As additional information on the life history, ecology, population dynamics, and current status of this species becomes available, it may be necessary to revise these criteria.

Figure 5 illustrates the location of the recovery units.

CRITERIA FOR RECLASSIFICATION TO THREATENED

The Hine's emerald dragonfly will be considered for reclassification from endangered to threatened status when all of the following criteria are achieved:

1. Each of the two Recovery Units contains a minimum of two populations, each composed of at least three subpopulations. Each subpopulation contains a minimum of 500 sexually mature adults for 10 consecutive years.

The number 500 is intended to represent the annual effective population size (the number of adult dragonflies that emerge over the flight season and mature to be capable of reproducing) of the population or subpopulation, rather than the number of adult dragonflies present at any one moment. Census techniques used to determine whether the population size criterion has been met may only be able to provide an estimate of relative population sizes. Relative population size estimates will be affected by several factors regarding Hine's emerald dragonfly population dynamics that are still unknown, including sex ratios, differential survival of males and females post-emergence, and survival probabilities in transitions from one life stage to the next (*e.g.*, late instar larvae to tenerals, tenerals to reproductive adults). It is understood that resources for monitoring populations are limited, that some sites may be too fragile to support annual monitoring, and that research to improve population size estimates is a priority.

2. Within each subpopulation, there are at least two breeding habitat areas, each fed by separate seeps and/or springs.

Because a breeding area within a single drainage system would be vulnerable to loss from events such as contamination and hydrological changes, it is important to have another site with potential breeding habitat available that may not be affected by the same event or events. A back-up breeding habitat area would reduce the risk of losing an entire subpopulation, such as might occur if all the larvae were concentrated in one breeding area during a drought.

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.

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.

CRITERIA FOR DELISTING

The Hine's emerald dragonfly will be considered for delisting when all of the following criteria are achieved:

1. Each of the two Recovery Units contains a minimum of three populations composed of at least three subpopulations. Each subpopulation contains a minimum of 500 reproductive adults for 10 consecutive years.

2. Within each subpopulation, there are at least two breeding habitat areas, each fed by separate seeps and/or springs.

3. For each population, the habitat supporting at least three 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 will also be in place within 5 years.

STEPDOWN RECOVERY OUTLINE

1. PROTECT AND MANAGE EXTANT POPULATIONS
    - 1.1 Protect extant populations
        - 1.1.1 Review Federal, state, and private activities
        - 1.1.2 Develop recovery implementation strategies to promote recovery
        - 1.1.3 Determine watershed ownership
        - 1.1.4 Long-term watershed habitat protection
            - 1.1.4.1 Land protection
            - 1.1.4.2 Groundwater protection

    - 1.2 Monitor extant populations
        - 1.2.1 Annual monitoring
            - 1.2.1.1 Presence/absence surveys
            - 1.2.1.2 Census surveys
        - 1.2.2 Annual intensive monitoring
            - 1.2.2.1 Intensive larval monitoring
            - 1.2.2.2 Intensive adult monitoring

    - 1.3 Manage habitat
        - 1.3.1 Illinois
            - 1.3.1.1 Black Partridge Forest Preserve
            - 1.3.1.2 Keepataw Forest Preserve
            - 1.3.1.3 Lockport Prairie Nature Preserve
            - 1.3.1.4 Long Run Seep Nature Preserve
            - 1.3.1.5 McMahon Woods
            - 1.3.1.6 Middle Parcel
            - 1.3.1.7 River South Parcel
            - 1.3.1.8 Romeoville Prairie Nature Preserve
            - 1.3.1.9 Waterfall Glen Forest Preserve
        - 1.3.2 Wisconsin
            - 1.3.2.1 The Ridges Sanctuary
            - 1.3.2.2 Mink River
            - 1.3.2.3 Mud Lake “North”
            - 1.3.2.4 Mud Lake “South”
            - 1.3.2.5 Arbter Lake, North Bay, and Three Springs Creek
            - 1.3.2.6 Piel Creek
            - 1.3.2.7 Cedarburg Bog
        - 1.3.3 Michigan
            - 1.3.3.1 Acklund Road, Brevort Lake Road, Horseshoe Bay, I-75 East, I-75 West, Martineau Creek SW, and Summerby Swamp
            - 1.3.3.2 Snake Island Fens
            - 1.3.3.3 Loop 2 Fen
            - 1.3.3.4 Misery Bay
        - 1.3.4 Missouri
            - 1.3.4.1 Grasshopper Hollow

1.3.5 New sites as they are verified
1.3.5.1 Additional Sites

2. CONDUCT STUDIES
2.1 Population ecology
2.1.1 Larval ecology
2.1.2 Adult ecology
2.1.3 Model population dynamics

2.2 Monitoring synthesis
2.2.1 Correlate larval and adult population sizes
2.2.2 Analyze techniques for estimating population size

2.3 Hydrologic studies
2.3.1 Illinois
2.3.1.1 Lockport Prairie Nature Preserve, Romeoville Prairie Nature Preserve, Middle Parcel, River South Parcel, and Keepataw Forest Preserve
2.3.1.2 Waterfall Glen Forest Preserve
2.3.1.3 Black Partridge Forest Preserve and McMahon Woods
2.3.1.4 Long Run Seep Nature Preserve
2.3.2 Wisconsin
2.3.2.1 The Ridges Sanctuary and Mud Lake "North"
2.3.2.2 Mud Lake "South"
2.3.2.3 Arbter Lake
2.3.2.4 North Bay
2.3.2.5 Three Springs Creek
2.3.3 Michigan
2.3.4 Missouri
2.3.5 New sites as they are verified
2.4 Genetics
2.5 Habitat management studies
2.5.1 Evaluate responses to habitat management practices
2.6 Roadkill studies to include strategies for minimizing roadkills
2.7 Water quality monitoring
2.8 Effects of environmental contaminants
2.8.1 Contaminants
2.8.2 Mosquito abatement programs

3. CONDUCT SEARCHES FOR ADDITIONAL POPULATIONS
3.1 Search for larval habitat within existing sites
3.2 Search for additional populations in Michigan
3.3 Search for populations in Alabama
3.4 Search for additional populations in Missouri
3.5 Search for additional populations in Wisconsin
3.6 Search for populations in Ohio

3.7 Search for populations in Indiana
3.8 Search for populations in New York
3.9 Search for populations in Maine
3.10 Search for populations in Arkansas, Iowa, Illinois, Kentucky, Minnesota, Tennessee, West Virginia, and Canada
3.11 Assess potential for Hine's emerald dragonfly in other states

4. REINTRODUCTION, INTRODUCTION, AND AUGMENTATION PROGRAM
4.1 Develop captive rearing protocols
4.2 Implement captive rearing program
4.3 Assess sites for reintroduction, introduction, or augmentation
4.3.1 Illinois
4.3.2 Wisconsin
4.3.3 Michigan
4.3.4 Ohio and Indiana
4.4 Implement reintroduction, introduction, or augmentation
4.5 Monitor reintroduced, introduced and/or augmented populations annually

5. CONDUCT AN INFORMATION AND EDUCATION PROGRAM
5.1 Encourage private landowners to conserve the Hine's emerald dragonfly
5.2 Inform local and county governments of recovery goals
5.3 Develop outreach material on life history and conservation

6. REVIEW AND TRACK RECOVERY PROGRESS
6.1 Maintain a clearinghouse for Hine's emerald dragonfly information
6.2 Conduct Recovery Team meeting(s) at least biannually to evaluate progress
6.3 Revise plan as appropriate at 5 year intervals

STEPDOWN NARRATIVE OUTLINE

1 PROTECT AND MANAGE EXTANT POPULATIONS

1.1 Protect extant populations. Protection should be executed to the highest degree necessary at the Federal, state, and local levels. The private sector should be encouraged to participate in the protection of this species and its habitat. It is unknown what relative importance each subpopulation may have to the sustainability of the entire population. Recent research indicates that sink populations may play an important role in recolonizing source habitat after a sudden extirpation of a source population due to a chance event (Thomas *et al.* 1996). Because small populations can serve as sources for colonists, even small populations are valuable and should be protected. For example, some of the moderate-sized populations in Illinois are known to contain unique haplotypes based upon mitochondrial DNA analysis (Purdue *et al.* 1996). Protection efforts should target populations with genetically unique stocks.

1.1.1 Review Federal, state, and private activities. The extant populations occupy both public and private land. The public sites include Federal, state, and county government land holdings that have varying degrees of legal protection. Many of the identified threats to this species are from off-site activities, such as the alteration of water quality and quantity, and road maintenance and construction. All Federal, state, and private activities and permits should be carefully reviewed for direct and indirect impacts. ESA section 7 consultations should be used whenever appropriate, such as in conjunction with section 404 Clean Water Act permits administered by the United States Army Corps of Engineers, and roadway projects funded by the Federal Highway Administration.

For roadways of concern, the USFWS and state agencies should review road construction and maintenance plans including salt application, culvert maintenance or replacement, regrading, regravelling or resurfacing of the road, or other changes to the roads that could impact the habitat. Potential impacts from roadway activities include a decease in water quality due to salt input, contaminated surface runoff, alteration of hydrology, siltation, and loss of breeding habitat due to filling. The impounding effects of the road may also decrease larval habitat. Possible ways to enhance larval habitat by altering roadway and/or culvert placement should be assessed. Existing highways of concern include Highway 53 and Route 7 in Illinois, Highway 57 and County Q in Wisconsin, and Interstate 75 and Mackinac Trail in Michigan.

1.1.2 Develop recovery implementation strategies to promote recovery.
It is important to encourage public participation in implementation of recovery actions. Participation strategies/plans should be developed as appropriate that facilitate implementation of this plan. These efforts may focus on one aspect of recovery, such as a single population or a single task. Representatives of all interested parties that could be affected by implementation of the recovery actions and/or could assist with recovery implementation (include Federal and State

agencies, and members of the public including private landowners, companies, private citizens, and conservation groups) should be encouraged to participate. Education and outreach activities may provide a vital link for involving stakeholders in development of recovery strategies, especially in recovery areas that include or may affect private lands.

1.1.3 Determine watershed ownership. The ownership of all sites in Illinois is known and referenced in this Plan. The ownership of some Wisconsin sites needs to be determined to facilitate protection and management. Most of the Michigan sites are managed by the United States Forest Service's Hiawatha National Forest. Ownership of any new sites should be determined as soon as possible after the discovery to enable protection and management as appropriate. Ownership of important areas within watersheds supporting Hine's emerald dragonfly should also be determined to facilitate protection.

1.1.4 Long-term watershed habitat protection. It will be necessary to implement strategies to guarantee long-term habitat protection of the geographic land base (including recharge areas) necessary to support viable populations. This might be accomplished by land acquisition, conservation easements, management agreements, habitat conservation plans, or other means. Working cooperatively with landowners, other agencies (e.g., Natural Resources Conservation Service), and/or organizations may also facilitate habitat protection.

1.1.4.1 Land protection. All available measures should be explored to provide long-term protection and management of the private and public sites inhabited by Hine's emerald dragonfly and the important habitat within the watersheds that support these sites. Priority areas include non-protected existing breeding habitat and their associated groundwatershed. Measures to protect privately-owned habitat may include voluntary registries, management agreements, acquisition of development rights, easements, or purchase on a willing seller basis. Private non-profit organizations may also assist public agencies in protection and management efforts. For those public sites not currently protected under the highest level allowable in each state, higher levels of protection should be pursued.

1.1.4.2 Groundwater protection. Maintaining an appropriate amount of groundwater flow, as rivulets or as sheet flow, appears to be essential to the larval habitat. Since the larvae are believed to spend 2 to 4 years in aquatic systems supported by groundwater, the groundwater quantity and quality become important elements of the habitat. To protect this species, protection of groundwater quality and quantity is needed. Groundwatershed planning and protection is also needed so that groundwater discharge at breeding sites is not impacted. Baseline data gathered from conducting hydrologic studies would be valuable information in protecting the groundwater.

1.2 Monitor extant populations. Extant populations of Hine's emerald dragonfly should be monitored to estimate population size and track population stability and trends over time. It is recognized that not all sites may be intensively monitored to estimate population numbers on an annual basis due to resource constraints and fragility of habitat. Currently, Lockport Prairie Nature Preserve in Illinois and Mud Lake "North" in Wisconsin are proposed for intensive annual census surveys. A more general monitoring plan is recommended for land managers able to devote resources to tracking the population trends at their sites. Where no other monitoring is possible at a site, observations of the presence of Hine's emerald dragonflies at a site should be noted annually. Research to improve population census methods using both adults and larvae is a priority for this species; therefore, land managers and researchers intending to begin monitoring efforts on potential habitat should contact the USFWS, Chicago Illinois Field Office, 1250 South Grove, Barrington, Illinois 60010, for updated information on monitoring techniques and permit requirements.

1.2.1 Annual monitoring.

1.2.1.1 Presence/absence surveys. Presence/absence surveys should be conducted at all sites that are not otherwise being monitored.

1.2.1.2 Census surveys. Census surveys provide estimates of relative abundance. This survey is recommended when funding and effort are available.

1.2.2 Annual intensive monitoring. Annual intensive monitoring that provides more information on population health and population trends will be used to research monitoring methods and link larval and adult population estimates. One subpopulation within each of the populations in Illinois and Wisconsin should be monitored intensively each year. An appropriate area in Michigan for annual intensive monitoring has not been identified.

1.2.2.1 Intensive larval monitoring. Annual intensive larval monitoring is recommended at one of the subpopulations in each of the populations. Currently, the Illinois and Wisconsin populations are the only populations with known population sizes large enough to survey for larvae. Information from intensive larval monitoring will be used to correlate larval and adult population sizes in task 2.2.1 and will aid in tracking the population status and population trends.

1.2.2.2 Intensive adult monitoring. Annual intensive adult monitoring is recommended at one of the subpopulations in each of the populations. Currently, the Illinois and Wisconsin populations are the only populations with known population sizes large enough to survey for Hine's adults. Information from intensive adult monitoring will be used to correlate larval and adult population sizes in task 2.2.1 and will aid in tracking the population status and population trends.

1.3 Manage habitat. Caution should be taken when management techniques are executed within Hine's emerald dragonfly habitat due to the lack of information on the effects of management practices on this species. The effects on the dragonfly from habitat-altering management techniques should be monitored closely. Management actions should be reviewed by the USFWS and the state's Department of Natural Resources and appropriate Recovery Team experts. Section 10 permits will be required if management actions will result in harm to the dragonfly.

Habitat management plans should be developed to incorporate adaptive management techniques as habitat requirements for the Hine's emerald dragonfly become more clear and its responses to management techniques more evident. These plans should address promoting habitat diversity and reducing threats to this species.

A team of local site managers should work together to develop management plans and guidelines for each population on a landscape level to promote population recovery and health. For example, a team of local site managers could review options to increase connectivity between the Hine's emerald dragonfly sites in areas that are outside of their particular sites. An exchange of information between land managers and research scientists should be facilitated to promote the best use of management techniques and to potentially improve research application and design. The USFWS, Chicago Field Office, is currently a clearinghouse of information for the Hine's emerald dragonfly (task 6.1), which will increase the accessibility of updated information to both researchers and land managers.

Habitat management concerns differ between sites as well as the techniques used to remedy them. These concerns include brush encroachment, invasion of non-native species, hydrology alteration, siltation, and groundwater and surface water quality and quantity. Management techniques that might be implemented at some locations are prescribed burns, non-native plant control, and hydrologic controls. Managers using prescribed burns should consider the frequency and timing of burning so that it reduces potential adverse impact to dragonflies survival by removal of essential cover. Brush cutting should occur when the ground is frozen to reduce impacts to the substrate. Forest edges should be a component of the habitat as these areas provide perching, resting, and foraging habitat as well as cover and mating sites for the dragonfly. Management activities should be varied across each site and season, consistent with invertebrate conservation and ecosystem management theory, so that insect populations are not uniformly affected by the management activities. (Schlict and Orwig 1992, USFWS 1993b, Panzer *et al*. 1995, Swengel 1996, Packard and Mutel 1997, Schultz and Crone 1998).

1.3.1 Illinois. Management of the Hine's emerald dragonfly habitat is necessary to maintain proper conditions for successful breeding and foraging. A burn rotation may be beneficial to the dragonfly. However, further data is needed to determine the burn frequency, since too much thatch reduction may reduce habitat suitability and increase the potential for drought and dessication. Other threats such as hydrology alteration, siltation, and encroaching non-native species can also be

addressed to a limited degree through site management. The entity responsible for the management at each site is identified below within the parentheses in tasks 1.3.1.1 to 1.3.1.9.

1.3.1.1 Black Partridge Forest Preserve, Cook County (Cook County Forest Preserve District). Black Partridge Forest Preserve hosts a low density of Hine's emerald dragonflies. The dragonflies are not seen in some years. Management should focus on improving breeding habitat with the goal of increasing the population size at this site. Brush encroachment should be considered as a possible factor reducing habitat suitability. Threats that should also be considered include water quality degradation from a proposed multi-lane highway adjacent to the preserve and existing roadways.

1.3.1.2 Keepataw Forest Preserve, Will County (Will County Forest Preserve District). This site has a small confirmed breeding population. Brush cutting has already taken place outside a 25 foot buffer zone around several seeps emanating from the bluff as part of the mitigation for a local quarry expansion. Opening of the seep areas may benefit the dragonfly. Breeding was observed after brush cutting had occurred. Additional brush reduction should be considered. Erosion on the bluff face into seep areas is a threat in some areas. The bluff face is artificially steep from historic mining and some effort may be needed to keep hikers and others from exacerbating this erosion into the seeps.

1.3.1.3 Lockport Prairie Nature Preserve, Will County (Will County Forest Preserve District). This site has one of the largest confirmed breeding portions of the Illinois population. This Nature Preserve is managed by the Forest Preserve District under a long-term lease agreement with the Metropolitan Water Reclamation District of Greater Chicago. The primary management goal of the preserve incorporates an ecosystem based approach and involves the maintenance of all the state and federally listed threatened and endangered species populations that occur within the site, as well as the integrity of the natural plant communities.

The current rotational prescribed burn schedule should be coordinated with any further research on the effects of prescribed burn frequency upon the dragonfly's breeding habitat. Beaver management may also be needed to sustain appropriate hydrology. One beaver tube, a management device that allows water to flow through a beaver dam, has already been installed at this preserve. Ongoing monitoring of several structures installed to carry groundwater beneath the railroad to the breeding habitat will be needed. The purpose of these structures is to restore historic hydrology. Expected benefits from the water control structures include the enhancement of high quality wetland, reduction of non-native species encroachment, and enhancement of breeding and foraging habitat for

several endangered and threatened species, including the Hine's emerald dragonfly. The control of reed canary grass is a management need. The operational management of the railroad through this Nature Preserve is reviewed by a Right-of-Way Management Team that includes the USFWS (described below for the River South Parcel, Will County).

1.3.1.4 Long Run Seep Nature Preserve, Will County (Illinois Department of Natural Resources). Long Run Seep is a state-owned and managed nature preserve. This site has the third largest portion of the Illinois population. Similar to the other sites, ongoing management includes prescribed burns on a rotational schedule. Non-native species control for species such as purple loosestrife is ongoing and will continue to be needed. Woody non-native species such as buckthorn are starting to become a problem at this preserve and will need to be addressed in the future. The watershed to this preserve is undergoing rapid development and water quality and quantity should be monitored and managed.

1.3.1.5 McMahon Woods, Cook County (Cook County Forest Preserve District). No dragonflies have been reported at this site since 1993. McMahon Woods has potential Hine's emerald dragonfly breeding habitat. Male Hine's emerald dragonflies exhibiting territorial behavior and teneral adults have been observed at this site. This site may not produce Hine's emerald dragonfly adults every year because the water levels at this site fluctuate drastically from year to year. Management concerns that should be evaluated at this site include increasing cattail density around potential breeding habitat, controlling buckthorn encroachment, and addressing the degradation of water quality due to bluff erosion. A potential problem at McMahon Woods is the apparent lowering of the water table; therefore, the hydrology at this site should be examined and monitored closely.

1.3.1.6 Middle Parcel, Will County (Material Service Corporation). The Middle Parcel contains a relatively small breeding population and is near the River South Parcel, which contains one of the largest Illinois populations. Material Service Corporation, a mining company, operates an adjacent limestone quarry. The site is not actively managed and has been proposed for mining. Site management could include rotational prescribed burning, brush cutting at the base of the bluff/berm at the western edge, and water quality and quantity monitoring.

1.3.1.7 River South Parcel, Will County (Material Service Corporation). This site contains one of Illinois' largest breeding populations. The habitat and dragonflies at this site have been intensively studied and monitored. Two prescribed burns have been conducted over portions of the site, although no further management is planned by the landowner. A Commonwealth Edison (ComEd) utility corridor and railroad pass

through this site, between the bluff seeps and the wetland used by the dragonfly. As a result of a Clean Water Act permit, ComEd is conducting several studies assessing potential impacts from the railroad rehabilitation and operation. In addition, the USFWS coordinates a Right-of-Way Management Team, made up of railroad personnel, adjacent landowners, and resource agencies. The Management Team reviews and addresses all issues and concerns regarding the operational maintenance of the railroad and the management of the site, relative to potential benefits or impacts to the dragonfly. The ComEd studies, the Management Team, and any additional studies should guide management at this privately-owned site.

1.3.1.8 Romeoville Prairie Nature Preserve, Will County (Will County Forest Preserve District). A limited number of dragonfly observations have been reported from this site. The site is currently managed as a natural area with prescribed burns. The control of reed canary grass is a management need. As additional information on breeding habitat requirements becomes available, management should focus on increasing breeding habitat.

1.3.1.9 Waterfall Glen Forest Preserve, Du Page County (Du Page County Forest Preserve District). One small seep area within this preserve supports a small breeding population. This large preserve surrounds Argonne National Laboratory and is managed as a natural area. Management of the seep area and adjacent marsh with prescribed burning and brush cutting should be continued to maintain open habitat for breeding.

1.3.2 Wisconsin. The recommended management actions for each site are discussed below. General guidelines for new sites include continuing existing management techniques until further information about site enhancement is determined. Management plans should be adapted to identify and implement management actions that enhance the survival of the Hine's emerald dragonfly. If nearby areas have been quarried, measures should be taken to revegetate the quarry to enhance foraging habitat. The entity responsible for the management at each site is identified below within the parentheses in tasks 1.3.2.1 to 1.3.2.7.

1.3.2.1 The Ridges Sanctuary, Door County (The Ridges Sanctuary, Inc.). The Ridges is believed to support the largest Hine's emerald dragonfly population in Wisconsin. Larvae occur at this site. It is recommended that The Ridges continue to be managed as a natural area, maintaining breeding and adult foraging habitats. Management efforts should include the control of non-native species such as reed canary grass and purple loosestrife in the watershed. The presence of dense stands of purple loosestrife and/or reed canary grass may impair the ability of the

dragonfly to reach seeps or streams for egg laying (P. Regnier, The Ridges Sanctuary, pers. comm. 1999). Management should also focus on maintaining the hydrology of the site by supporting hydrologic research and working with the Town of Baileys Harbor in watershed protection efforts.

1.3.2.2 Mink River, Door County (The Nature Conservancy). The Nature Conservancy (TNC) owns this site, and it is recommended that TNC continue to manage the Mink River as a natural area. One Hine's emerald dragonfly adult was collected from Mink River in 1987.

1.3.2.3 Mud Lake "North", Door County (Wisconsin Department of Natural Resources). This site is part of the Mud Lake Wildlife Area (Mud Lake), owned and managed by the Wisconsin Department of Natural Resources (Wisconsin DNR). This site supports the largest known larval population in Wisconsin. It is recommended that the Wisconsin DNR continue to manage this area as a natural area, maintaining breeding areas and adult foraging habitat. Any management plans that may alter the hydrology of this site, or degrade breeding or adult foraging habitat (e.g. logging), should be coordinated with the USFWS, the Wisconsin DNR's Bureau of Endangered Species, and appropriate members of the recovery team. This includes removal of beaver impoundments or the adjustments of beaver control structures. Beaver impoundments may have created an open meadow at this site, which is considered desirable adult Hine's emerald dragonfly habitat. Wisconsin DNR should consider applying appropriate management techniques (e.g., allowing occasional beaver impoundments to exist) to keep trees from invading the meadow.

1.3.2.4 Mud Lake "South", Door County (Wisconsin DNR). This site is also part of the Mud Lake Wildlife Area, owned and managed by the Wisconsin DNR. The dragonfly breeds at this site. It is recommended that Wisconsin DNR continue to manage this site as a natural area. Any management plans that may alter the hydrology of the site or degrade breeding or foraging habitat should be coordinated with the USFWS, the Wisconsin DNR's Bureau of Endangered Species, and appropriate members of the recovery team.

1.3.2.5 Arbter Lake, North Bay, and Three Springs Creek, Door County (Private ownership). Arbter Lake, North Bay, and Three Springs Creek sites are privately-owned. Breeding has been confirmed at all three sites. North Bay and Three Springs Creek sites occur within a TNC project area. Landowners should be contacted to discuss opportunities for management to maintain dragonfly habitat.

1.3.2.6 Piel Creek, Door County (Private ownership; TNC project area). Piel Creek and adjacent wetlands are primarily in private ownership.

Landowners should be contacted to discuss opportunities for management to maintain dragonfly habitat. The north end of Kangaroo Lake and much of Piel Creek are within a TNC project area. Wetlands associated with the north end of Kangaroo Lake and the mouth of Piel Creek are contained within the Kangaroo Lake Land Trust. If it is determined that Hine's emerald dragonflies breed at this site, the creek should be checked yearly for beaver impoundments. Culvert replacement or construction projects that could affect the hydrology of the area (e.g., along Kuchar's old farm road) should be reviewed to ensure they do not negatively affect breeding habitat.

1.3.2.7 Cedarburg Bog, Ozaukee County (University of Wisconsin and Wisconsin DNR). Cedarburg Bog is jointly-owned and managed by the Wisconsin DNR and the University of Wisconsin-Milwaukee. The DNR land is designated a State Scientific Area and the university portion of the site is managed as a biological field station.

1.3.3 Michigan. The recommended management actions for each site are discussed below. General guidelines for new sites include existing management techniques until further documentation on larval habitats can be determined. Management plans should be adapted to identify and implement management actions that enhance the survival of the Hine's emerald dragonfly. The entity responsible for the management at each site is identified below within parentheses in tasks 1.3.3.1 to 1.3.3.4.

1.3.3.1 Acklund Road, Brevort Lake Road, Horseshoe Bay, I-75 East, I-75 West, Martineau Creek SW, and Summerby Swamp, Mackinac County (Hiawatha National Forest). All of the currently know sites in the Upper Peninsula are located on Hiawatha National Forest lands in Mackinac County and are managed by the U.S. Forest Service. These sites are fairly pristine and currently face fewer threats than the sites in other states. Management for invasion of non-native plant species, destruction of habitat by off-road vehicles, road and utility right-of-way maintenance, and logging can be addressed through site management plans and Michigan DNR environmental review process.

1.3.3.2 Snake Island Fens, Mackinac County (Michigan DNR-dedicated Natural Area; Private ownership). The potential breeding habitat at the Snake Island Fens site is split between land owned by the state of Michigan (Snake Island-Mud Lake Natural Area) and private lots (Steffens 1999). If it is determined that Hine's emerald dragonflies breed at this site, the creek should be checked yearly for beaver impoundments. Culvert replacement or road construction projects that could affect the hydrology of the area should be reviewed to ensure they do not negatively affect breeding habitat. Landowners should be contacted to discuss opportunities for management to maintain dragonfly habitat.

1.3.3.3 Loop 2 Fen, Presque Isle County (Michigan DNR Parks Division). This site is currently an undeveloped state park with a few hiking trails, parking areas, and a gravel road that transects the park. It is recommended that the Michigan DNR continue to manage this site as a natural area. Any management plans that may alter the hydrology of the site or degrade breeding or foraging habitat should be coordinated with the USFWS, Michigan DNR Endangered Species Coordinator, and appropriate members of the recovery team. Management to prevent destruction of habitat by off-road vehicles and road and utility right-of-way maintenance can be addressed through site management plans and Michigan DNR environmental review process.

1.3.3.4 Misery Bay, Alpena County (Private ownership). This wetland is owned by a group of individuals from Detroit known as the Beaumont Corp. The owners use the area for hunting and other outdoor recreational activities. There are no developments currently on the property other than narrow gravel roads and hunting camps (Steffens 1999). Landowner contact should be continued to discuss opportunities to maintain dragonfly habitat.

1.3.4 Missouri.

1.3.4.1 Grasshopper Hollow, Reynolds County (Doe Run Mining Company). The area where the Hine's emerald dragonflies were observed is owned by the Doe Run Mining Company and leased to The Nature Conservancy. At 10 acres, this is the largest prairie fen known in unglaciated North America. Historically the area was grazed and probably cut for hay. The surrounding forested areas have been logged. Deep hard rock mining for lead and other metals has been active for about 25 years in this area of the State. Beavers have impounded portions of the fens and deep muck fens adjacent to the prairie fen. Their impoundments change the water depth, flow, and vegetation. Occasional removal of beavers has helped reduce their activities. The Nature Conservancy plans to limit the beaver numbers. Alder and hazel growth has increased remarkably in recent years. Grazing, mowing, and fire probably kept these in check in the past. Control measures, particularly prescribed burns, are planned to help reduce the woody plants and open areas for other vegetation.

1.3.5 New sites as they are verified.

1.3.5.1 Additional Sites. Additional sites that should be assessed to determine habitat management needs are the Kellner Fen, Ephraim Swamp, and Big Marsh (Washington Island) in Door County, Cedarburg Bog in Ozaukee County, the Black Ash Swamp in Kewaunee County, and any new sites identified in the future. Landowners should be

contacted, as appropriate, to discuss opportunities for management to maintain breeding and adult Hine's emerald dragonfly habitats.

2 CONDUCT STUDIES

2.1 Population ecology. Where possible, unlisted species closely related to the Hine's emerald dragonfly should be used as surrogates in research projects. In addition, data from comparative studies with closely related species should be consulted.

2.1.1 Larval ecology. Conduct studies to determine larval ecology and abundance, larval life history, phenology, and interspecific interactions.

Larval ecology and abundance: Larval studies should continue to determine 1) which sites support reproducing populations, 2) which particular habitats within sites support larvae, 3) abundance of larvae within the particular habitats, 4) the diet of the larvae in comparison to prey abundance in the larval habitat, and 5) interspecific interactions. This information should provide insight on the habitat requirements of Hine's emerald dragonfly larvae. Studying the differences between habitat known to support Hine's emerald dragonfly larvae and similar habitat within sites known to be inhabited by adults also could provide information on larval habitat requirements. In addition to these studies, seasonal sampling should be conducted to examine changes in size distribution patterns, which will aid in determining growth rates and phenology. Information on larval ecology is essential for developing a more complete understanding of life history and ecological requirements, and also provides valuable information on population structure. If reintroduction or augmentation is needed for this species, information on larval ecology would be essential.

Larval life history: Research should be conducted to determine 1) period of egg development, 2) the proportion of eggs that survive to larval stage, 3) larval survivorship to adult stage, 4) the length of larval development. This information is important in determining this species' reproductive potential and constructing the life table in task 2.1.3.

Phenology: Studies to understand the role of drought tolerance in the population biology should continue. Hine's emerald dragonfly larvae have been observed to tolerate a certain amount of habitat drying, and it appears that most known sites are subject to periods of drought during the summer. Extension of ongoing studies, evaluating this species' behavioral and morphological adaptations to drought conditions is especially important. Additional studies to complement ongoing work that examines how potential competitors and predators are affected by drought are also important. Tracking drought frequency of known larval habitat is central to any ongoing research on Hine's emerald dragonfly populations. This information would also aid in understanding the hydrology of the wetland ecosystems inhabited by Hine's emerald dragonfly. Drought tolerance studies along with a long-term study that correlates drought periodicity

and larval densities may be used to determine when larval habitat becomes too dry for larval survival. This information is essential for assessing the risk to Hine's emerald dragonfly populations from any hydrological alteration of their habitat (groundwater pumping, diversion, draining, etc.), and is required before any management techniques that artificially manipulate wetland hydrology are implemented or developed.

Interspecific interactions: Little is known about the interactions between the Hine's emerald dragonfly larvae and their predators. Understanding how predators influence survival, growth rate, and/or reproduction is essential for understanding the population dynamics of this species (Wissinger 1992). Studies should be conducted to determine which predators may kill significant numbers of Hine's emerald dragonflies. A logical first step would be to conduct diet analysis of potential predators in the same habitat to determine which consume the dragonfly. Studies should also be conducted to determine if the presence of predators change the diet, food availability, and growth rate of the larvae. Enclosure experiments using species closely related to the Hine's emerald dragonfly may provide insight on its responses to predators.

The abundance and diversity of potential predators should be evaluated in larval habitat to determine if changes in the species composition and density of predators affect Hine's emerald dragonfly larval densities. If a substantial decline in larval densities occurs, the species composition should be assessed to determine if there have been changes in predator abundance or diversity. Management actions may result in shifts in species composition within larval habitat. This information could be useful in evaluating management techniques.

Little is known about how competitors affect Hine's emerald dragonfly larval development and survival. This information is useful when assessing population dynamics (Wissinger 1992). The abundance of competitors in a streamlet may influence the abundance of Hine's emerald dragonflies. Alterations of the hydrology or habitat may influence the type and/or abundance of competitors that may affect Hine's emerald dragonfly larval densities.

Diet analysis of potential competitors along with prey abundance is useful when determining which species are likely to be competitors and the level of impact a particular competitor species may have on Hine's emerald dragonfly larvae. Manipulative field experiments with the larvae and potential competitors are important in understanding the outcomes of competitive interactions (Johnson *et al*. 1995); however, these experiments may be difficult. A literature review on competitive interactions among dragonflies would be useful in evaluating possible impacts competitors may have on the larvae.

2.1.2 Adult ecology. Conduct studies to determine adult dispersal, habitat requirements, reproductive potential, and interspecific interactions.

Dispersal: Information on adult dispersal of Hine's emerald dragonflies is needed to identify if the patchy distribution of this species represents a metapopulation. An important element of metapopulation dynamics is the ability and tendency of the species to disperse. Research should concentrate on determining the distance Hine's emerald dragonfly adults will fly from a site, corridor use, what habitat types are effective corridors, barriers, and gender differences in dispersal. This information is needed if efforts are made to increase connectivity and dispersal within a population by creating effective corridors. If reintroduction of this species is needed, dispersal distances would be crucial in deciding where the new sites would be located. Mark-recapture studies provide this type of data; however, past mark-recapture studies for this species have identified only a few instances of dispersal. As technology and research advance in this area, new types of studies or methods should be considered as an alternative to the mark-recapture technique. Any type of study will be labor intensive and take multiple years to complete; however, acquiring dispersal data is essential in preserving this species. Genetic markers can also indicate dispersal between subpopulations and populations. Dispersal information would also improve the ability to manage this species and give valuable information on its habitat use.

Habitat requirements: Since it is unclear why Hine's emerald dragonfly does not occur in some areas of suitable habitat, studies should be conducted to better identify the specific habitat requirements of the adults. This information would be useful in management and could inform future habitat restoration and reintroduction attempts.

Reproductive potential: Studies should be conducted to determine the adult reproductive potential of Hine's emerald dragonfly females. Studies should concentrate on estimating the number of eggs laid by one female during one oviposition episode and how many oviposition episodes a female averages in a lifetime. The types of studies that should be conducted include dissections of freshly killed Hine's emerald dragonfly females (e.g., roadkills), when available, and/or females of closely related species to estimate total egg numbers per female. Eggs from induced oviposition by dipping abdomens of freshly killed females in water can also be used in larval ecology studies (task 2.1.1) and for potential reintroduction efforts. Larval studies using these eggs could be used to determine egg and larval development and survivorship, which would aid in evaluating reproductive potential. Determination of differential mortality rates of adult males and females would be important in assessing the recovery criteria. A literature review should be conducted on published studies on other species in the family that pertain to reproductive potential. Estimates of reproductive potential are necessary components of any population dynamics model. Justification of recommended management will be facilitated by the confidence in the population dynamics models. This task is essential to the recovery of this species.

Interspecific interactions: Information on the interspecific interactions of the

adult Hine's emerald dragonfly would be useful in identifying potential competitors and predators that may reduce this species' reproductive potential.

2.1.3 Model population dynamics. A metapopulation model should be developed to project population growth of the populations and of each of the subpopulations. Models should use both the present status and the population size from the recovery criteria in order to test for long-term viability (Burgman *et al*. 1993). Using the model, population dynamics would be projected to obtain a better understanding of metapopulation configurations that would promote a 95% probability of species persistence for 100 years, 90% probability of persistence for 100 years, 90% probability of persistence for 500 years, etc. The best available information on population structure and life history would be used for these calculations. Sensitivity analysis would be conducted on values such as dispersal (frequencies and distance), life span, variation in reproductive capability, and variation in mortality to determine which parameters were most influential in long-term persistence of the metapopulation.

Population viability modeling should be used to compare and identify alternative population and metapopulation structures that provide equivalent persistence probabilities. These results may be used to revise recovery criteria or to determine whether an alternative population distribution provides long-term stability equivalent to the recovery criteria.

An attempt should be made to construct a life-table for a typical cohort of Hine's emerald dragonflies (Ubukata 1981, Johnson 1986). Life-tables provide estimates of the proportion of a cohort surviving to each age class. Life-tables often present survivorship, average survivorship, mortality, age-specific mortality rate, and expectation of life throughout the age of a cohort. The survivorship curve, coupled with estimates of age-specific fecundity, provides the data from which estimates of the net reproductive rate and the intrinsic rate of increase may be calculated. These calculations would greatly increase the understanding of the dragonfly's population dynamics. This table would also aid in determining which life stages are most affected by year to year variation in environmental factors and/or are most vulnerable to various threats. Analysis of life-table responses to various threats and management alternatives will allow better decisions and recommendations for the recovery of this species. This task is essential to the recovery of this species.

2.2 Monitoring synthesis.

2.2.1 Correlate larval and adult population sizes. Methods should be developed to extrapolate population sizes from larval populations to adult populations. Larval monitoring provides data on population trends over multiple years, which can be applied to management. Larval surveys have advantages over adult surveys, in that larval surveys can be conducted in inclement weather and over a longer period of time. A link between larval and adult populations would allow adult

population estimates to be calculated from larval data; the adult estimates could then be used to determine if the recovery criteria have been met. Understanding the correlation between adults and larvae would be extremely useful in constructing a life-table and toward understanding and evaluating the dragonfly's population dynamics.

2.2.2 Analyze techniques for estimating population size. Examine the benefits of various alternative population estimate techniques for adults. Include in this analysis an evaluation of the risk of injury to Hine's emerald dragonfly individuals associated with each method. The alternatives for adults include mark-recapture, removal, transect sampling, exuviae counts, census route, and census stations. Mark-recapture is one of the standard methods of population size estimation. However, information on the dragonfly's population dynamics may need to be determined or calculated in order for the estimation to be accurate. Transect sampling of adults, while less invasive, has the potential to bias counts through double counting. Without handling and marking, however, identifying individuals or even identifying the correct species could be problematic. Platform sampling is a non-invasive, non-destructive method of estimating local adult densities, but it has some of the problems of transect sampling. Comparing the accuracy of each of these techniques would aid in understanding the trade-offs between approaches.

2.3 Hydrologic studies. Since it appears that maintaining an appropriate amount of surface and groundwater flow, as rivulets, sheet flow, seeps, and/or springs, is an essential element of breeding habitat, and since the majority of the life cycle of this species is spent as an aquatic life form, the hydrologic regime and water quality become important elements of the habitat. To protect this species, protection from alteration of water quality and quantity is needed. Baseline data should be assembled as to the water flow rates and volumes necessary to provide breeding habitat similar to what exists at the current breeding locations. Basic water chemistry data is needed to assess changes due to watershed development.

Studies should determine the surface and subsurface water regime of sites and recharge areas including quantity and quality. Land use types in the recharge area should be determined, including if the land use is compatible or incompatible with maintaining good water quality. Determine if the surface water or groundwater is contaminated especially with pesticides, herbicides, and fertilizers; if so, locate the source and remedy the situation. If there is a road in the area, determine if there are any hydrologic impacts to the site from the road. An assessment of past and present beaver activity would be beneficial when recommending management techniques to mimic the natural hydrologic cycles of the site. If lake water levels affect the site's hydrology, study the correlation between lake levels and both the site's water regime and larval densities if available.

2.3.1 Illinois.

2.3.1.1 Lockport Prairie Nature Preserve, Romeoville Prairie Nature Preserve, Middle Parcel, River South Parcel, and Keepataw Forest Preserve. These sites are all in close proximity to one another on the west side of the Des Plaines River in Will County and share a similar topographic and geologic setting. Other federally and state listed species and rare plant communities that also depend on the groundwater driven moisture regime occur at or near these locations (see Appendix 5). Therefore, the Lower Des Plaines River Groundwater Task Force has been initiated to assemble existing data and explore opportunities to collect additional data aimed at establishing a basic groundwatershed profile. The goal is to provide baseline data that will enable better monitoring of changes over time and more informed review of proposed activities in the groundwatershed. Proactive efforts will include using the results of any studies completed by the task force to enable informed land planning that will be protective of the dragonfly.

2.3.1.2 Waterfall Glen Forest Preserve. This preserve surrounds Argonne National Laboratory, which is a Department of Energy (DOE) facility. Argonne National Laboratory is currently engaged in various remediation projects to clean up contamination from earlier disposal programs that predated modern regulations and knowledge. These projects include a pump-and-treat remediation of groundwater contamination. Through section 7 consultation, it was determined that the current program will not affect the seep used by the dragonfly. DOE has agreed to water quality sampling of the seep used by the dragonfly to determine if any contamination is present. Monitoring of the seep and Argonne's activities should continue in consultation with DOE. The lab is also stopping use of their deep well as a potable water source and changing to Lake Michigan water that is piped to the facility. This may increase flows at the seeps, so water levels should be monitored.

2.3.1.3 Black Partridge Forest Preserve and McMahon Woods. These sites are both managed by the Cook County Forest Preserve District. No hydrologic studies are planned or occurring for these sites. As part of the environmental documentation for the proposed multi-lane highway adjacent to Black Partridge, a study of the groundwater-fed Black Partridge Creek was completed by the Illinois State Water Survey and Illinois State Geological Survey. This study addressed the amount of groundwater recharge potentially lost to the impervious roadway. Monitoring of the groundwater at these sites would help in their ultimate protection.

2.3.1.4 Long Run Seep Nature Preserve. This preserve is the only Hine's emerald dragonfly site located east of the Des Plaines River along its

north-south portion in Will County. Thus, it does not share surface or groundwatershed with the other sites. Development pressure continues within its watershed and monitoring of water quality and quantity should be undertaken to assess impacts.

2.3.2 Wisconsin. At this time, hydrology studies are not recommended for Mink River, given the low number of individuals observed at this site, or Piel Creek, because no known larval habitat exists in this area. If Hine's emerald dragonflies are re-discovered at Mink River in significant numbers, hydrology studies should be considered. If larval habitat is located in the Piel Creek area, hydrology studies should be considered.

2.3.2.1 The Ridges Sanctuary and Mud Lake "North." Hydrologic studies of The Ridges Sanctuary and Mud Lake "North" area are recommended to better understand the hydrology of this area, identify threats to the water quality, identify recharge areas, and to protect recharge areas, seeps, and springs that are important to Hine's emerald dragonfly habitat. Threats to recharge areas include development and road construction. Studies should include determining the water movement in the larval habitat and the surface and subsurface water regime of the site. This information would aid in the interpretation of the hydrology requirements of larval habitat. This information would also be used to identify the potential sources of water contamination or alterations in hydrology.

The Ridges Sanctuary is located along Lake Michigan's shoreline. Since the hydrology of this site may be affected by rising lake levels, information is needed on the effects Lake Michigan's water level has on the water regime of larval habitat and larval densities. This information would be useful in predicting larval densities and aid in recommending management techniques.

To better understand what hydrologic conditions the Hine's emerald dragonfly larvae have withstood in the Mud Lake "North" site, studies should be conducted to determine historical and present activities that have changed the hydrology of this site, including natural (e.g., beaver impoundments) and human-induced activities (e.g., road development). These studies should include the extent of each activity's alterations to the hydrology and the subsequent changes in habitat. The possible impacts Lime Kiln Road has had as an impoundment on the larval habitat should be evaluated. This information can be used to review potential ways to enhance larval habitat and to help management restore the natural hydrologic properties of this system.

Conduct studies to determine the surface and subsurface water regime of the larval habitat at Mud Lake "North." Evidence indicates the water level at this site varies. Information on water regime would aid in

understanding and maintaining Hine's emerald dragonfly larval habitat and could be used to assess future impacts from hydrologic changes.

2.3.2.2 Mud Lake "South." Conduct studies to assess the hydrologic properties of the quarried area. A survey should be conducted to determine if the ponds in the quarried area are increasing the groundwater temperature and lowering the groundwater table.

2.3.2.3 Arbter Lake. The surface and subsurface water regime should be assessed at this site to aid in protection and appropriate management actions.

2.3.2.4 North Bay. At North Bay, altering the road and/or culvert that presently act to impound water should be explored to increase breeding habitat. This site is located along Lake Michigan's shoreline. Since the hydrology of North Bay is affected by rising lake levels, information is needed on the effects Lake Michigan's water level has on the water regime of the larval habitat and the larval densities. This information would be useful in predicting larval densities and aid in recommending management techniques.

2.3.2.5 Three Springs Creek. Hydrologic studies of Three Springs watersheds are recommended to better understand the hydrology of this area and threats to the water quality, and to identify and protect recharge areas and seeps that are important in maintaining Hine's emerald dragonfly habitat. Threats to recharge areas include development and road construction.

2.3.3 Michigan. General hydrologic studies should be considered at known sites and new sites. Studies should determine the surface and subsurface water regime of the site and recharge areas including quantity and quality. Land use types in the recharge area should be determined, including if the land use is compatible or incompatible with maintaining good water quality. Determine if the surface water or groundwater is contaminated; if so, locate the source and remedy the situation. The hydrology of the sites has been modified by the construction of roads including a four-lane interstate which divides two known sites. Studies should determine if the hydrologic changes from the roadways have affected Hine's emerald dragonfly habitat and if so, provide potential actions to resolve the impacts. Logging roads and logging road construction may also be a concern to the hydrology of Michigan's sites.

2.3.4 Missouri. General hydrologic studies should be considered at known sites and new sites. Studies should determine the surface and subsurface water regime of the site and recharge areas including quantity and quality. Land use types in the recharge area should be determined, including if the land use is compatible or incompatible with maintaining good water quality. Determine if the surface water or groundwater is contaminated; if so, locate the source and remedy the

situation. Where the hydrology of the sites has been modified by the construction of roads, studies should determine if the hydrologic changes from the roadways have affected Hine's emerald dragonfly habitat and if so, provide potential actions to resolve the impacts.

2.3.5 New sites as they are verified. General hydrologic studies should be considered at other sites not individually listed here and for new sites that may be discovered in the future. Surface and groundwater regimes should be identified as well as recharge areas. Land use types in the recharge area and impacts on water quality should be determined.

2.4 Genetics. Past genetic research on Hine's emerald dragonfly has concentrated on the mitochondrial (mt) DNA, which is passed on by females to their offspring. This information has provided insight on the populations' genetic diversity, health, history, past female dispersal patterns, and phylogeny; however, information from the nuclear genome is needed. Most genetic information is inherited from DNA residing in the nuclei of the cells. Consequently, this DNA should be evaluated for genetic diversity. The nuclear data coupled with information from the mtDNA studies could identify populations with high genetic diversity to be targeted for protection and could guide reintroduction efforts.

2.5 Habitat management studies.

2.5.1 Evaluate responses to habitat management practices. Since there has been very little experimental testing of which management strategies are most effective for the Hine's emerald dragonfly, this species' larval and adult responses to habitat management practices need to be studied. This information is needed to develop management plans and strategies for site enhancement and maintenance. These studies should evaluate the short and long-term responses the larvae and adults have to habitat management practices (i.e., prescribed burns, herbicide application, brush removal, and methods for non-native species control). Since prescribed burns are used within Hine's emerald dragonfly habitat, responses from larvae and adults to prescribed burns should be evaluated to determine the positive and negative effects of prescribed burn location and frequency. This may include analyzing data on larval and adult abundances, adult use of burned areas, and fire events. This information would also be useful in predicting the Hine's emerald dragonfly's response to wildfires. A literature review on odonates' and/or other insects' responses to fire and other management techniques would also be useful.

2.6 Roadkill studies to include strategies for minimizing roadkills. Studies assessing Hine's emerald dragonfly mortality rate from motor vehicles should continue. Hine's emerald dragonflies have been found dead along roadways in Wisconsin and Michigan (refer to the section under THREATS TO THE EXISTENCE OF THE SPECIES, Significant threats to the existence of Hine's emerald dragonfly, Transportation). In Illinois, no Hine's emerald dragonflies have been collected dead along roads; however,

individuals have been observed flying over roads. The extent to which Hine's emerald dragonfly populations are affected by roadway mortality needs to be determined. The ability to link the mortality of adult individuals to a reduction in population size and/or a loss of genetic diversity is difficult due to the complex population dynamics and life cycle of this species. Ideally, surveys would determine 1) rate of mortality in different traffic conditions, 2) rate of mortality along different roadside habitats, 3) the relative abundance of Hine's emerald dragonfly near roadways, 4) flight behavior along roadways, and 5) how roadways are used by this species. These studies are needed to evaluate the effects from increases in traffic conditions such as speed and volume and to assess impacts from proposed roadway expansions and developments. Because the Hine's emerald dragonfly has been observed flying over railroad tracks used by high speed trains, railway surveys should be also be considered to evaluate the effects high speed trains have on this species.

Strategies and techniques to minimize roadkills should be developed and tested. Techniques may include reducing speed limits, establishing speed bumps, changing roadside vegetation, and placing flight barriers along roadsides to increase flight height across the road.

2.7 Water quality monitoring. It is important to monitor the water quality in Hine's emerald dragonfly larval habitats along roadways, as salt application, siltation, and contaminated surface runoff could negatively affect these habitats. Larval habitat that occurs near roadways or in areas that may be affected by roadways should be evaluated for water quality monitoring. The larval habitat located near the following roadways should be considered for water quality monitoring, as well as other roads that occur within close proximity to Hine's emerald dragonfly habitat.

> Illinois: Highway 53, Route 7, Bluff Road, Division Street, New Avenue, and park access roads in Waterfall Glen Forest Preserve
>
> Wisconsin: Lime Kiln Road, State Highways 42 and 57, County Route Q, County Route ZZ, Highland Drive (Door County), and County Route X (Kewaunee County)
>
> Michigan: Interstate 75, Mackinac Trail, and Highway M-123 near Summerby Swamp

It is recommended that water quality should be monitored at least twice a year in August (low flow) and in the spring (high flow). Sampling after a salt application or after a subsequent rain event, would help determine the amount of salt entering the system. If the water has elevated contaminant levels, water quality should be monitored more frequently; the source of contamination would determine the best time for additional samples.

Areas that may not be directly affected by roadways or other potential sources of contamination should also be monitored for water quality. This monitoring would take

place at least twice a year in the fall and in the spring to determine baseline water chemistry and assess shifts in water quality over time.

2.8 Effects of environmental contaminants.

2.8.1 Contaminants. Concern about possible harm to the dragonfly from organic contaminants initially arose when the railroad passing through the two largest Illinois population sites was proposed for rehabilitation. This work was originally going to involve replacement of railroad ties with new, creosote-treated ties. Since the evidence available was inconclusive about the mobility and toxicity of the organic components (polycyclic aromatic hydrocarbons) of creosote, steel ties were used instead. The project proponent also agreed to conduct water quality sampling, sediment sampling, and a creosote migration study to assist in determining the mobility of the creosote constituents for future projects. The results of these ongoing studies will be submitted to the USFWS, Chicago Field Office, per a Clean Water Act, Section 404 permit condition that was issued by the Army Corps of Engineers, and will be subsequently made available to the site managers and Recovery Team.

In addition to this forthcoming information on polycyclic aromatic hydrocarbon mobility, more specific data are needed as to the toxicity to the Hine's emerald dragonfly of these and other organic contaminants such as herbicides from lawn care and golf courses. Toxicity testing on closely related odonates would be very useful in assessing impacts from future development in the watershed. This information should be used in conjunction with the hydrologic studies described in task 2.3 to reduce indirect impacts and avoid/minimize harm.

In Wisconsin, contaminants that may be present in the Three Springs Creek watershed include lead and arsenic from an old pesticide mixing station that is upstream of the site near Stagecoach Road and County Highway ZZ, and oil from an old municipal landfill located less than 1 mile upstream on the northeast corner of County Highway ZZ and Sumac Road. Dust and runoff from a parking lot associated with a nearby solid waste transfer facility could also contaminate the watershed. Measures should be explored that could reduce potential contamination of the watershed from the solid waste transfer facility such as paving the parking lot and installing a containment system to hold runoff water. Periodic water quality monitoring should be conducted to determine the presence of pollutants in the watershed, and, if found, measures should be taken to eliminate or contain the contaminant sources. Water quality monitoring for contaminants can be coordinated with the water quality monitoring for roadways and hydrologic studies.

Contaminants present in Wisconsin's Mud Lake "North" watershed could include pesticide residues from the orchard (cherry and apple) industry and from nearby nursery operations. In Illinois, Lockport Prairie Nature Preserve could be affected by pesticides, herbicides, and fertilizers from a nearby golf course.

Other contaminants that could affect Illinois sites include agricultural and residential runoff. Habitat areas should be monitored for contaminants, and, if present, measures should be taken to eliminate or contain the threat.

2.8.2 Mosquito abatement programs. Mosquito control treatment methods currently in use include methoprene and the bacterial larvicides *Bacillus thuringiensis israelensis* and *B. thuringiensis sphaericus.* Adult mosquitoes are also controlled through other products such as Permethrin and Resmethrin. Potential threats to the dragonfly from mosquito abatement programs are of two kinds: 1) toxicity impacts from exposure to treatments, through external contact, ingestion, or ingestion of exposed prey items, and 2) potential food chain effects resulting from treatment impacts on both mosquitoes and non-target organisms, including scarcity of prey items and shifts in the species composition of prey, competitors, and predators in the aquatic ecosystem. While many mosquito control products are developed to minimize impacts to non-target organisms, the literature suggests the potential for impacts to Hine's emerald dragonflies from mosquito abatement (Hershey *et al*. 1998). A multi-year study of treated and untreated wetlands in Minnesota observed a response lag in changes in invertebrate communities after larvicide treatments (Hershey *et al.* 1998), indicating adverse impact to this community and the need for additional studies to understand the impact on the Hine's emerald dragonfly. Long-term studies should be conducted to understand impacts on dragonflies and to design abatement programs to avoid/minimize harm.

3 CONDUCT SEARCHES FOR ADDITIONAL POPULATIONS.

Searches for additional Hine's emerald dragonfly populations should be conducted in suitable habitat. Appendix 3 presents descriptions of suitable wetland complexes, descriptions of adult behavior, and other characteristics to consider when searching for Hine's emerald dragonfly. Collaboration with land managers in a potential area may be advantageous in identifying suitable habitat. Locating additional populations would provide information on life history, habitat characterization, and genetic diversity. Because additional populations would play an important role in meeting the recovery criteria, funding will need to be provided to survey for new populations. Dragonfly collections from museums, academia, and other sources should be reviewed to locate misidentified Hine's emerald dragonfly specimens. Locating collected individuals would also provide areas to search for this species. The Illinois State Museum is adding a page to the museum's web site that shows how the Hine's emerald dragonfly may be distinguished from congeners. Electronic listservs will be used to notify entomologists, taxonomists, and museum collection curators of the web page and encourage them to check existing collections for potential Hine's emerald dragonfly specimens.

3.1 Search for larval habitat within existing sites. Locating new larval habitat within existing sites would enable appropriate protection and management for these important areas. New larval sites may aid in meeting the recovery criteria and possibly improve the knowledge of larval habitat and life history.

3.2 Search for additional populations in Michigan. Wetland sites in the southern Lower Peninsula, particularly the interlobate region, should be evaluated for suitable habitat. The interlobate region is an area north, west, and southwest of Detroit, which includes St. Joseph, Branch, Kalamazoo, Calhoun, and Jackson Counties and portions of Hillsdale, Washtenaw, and Oakland Counties.

3.3 Search for populations in Alabama. Surveys for Hine's emerald dragonfly should be conducted in potential habitat in northern Alabama.

3.4 Search for additional populations in Missouri. Surveys for Hine's emerald dragonfly should be conducted in Missouri fens. Searches will first center around the site where a specimen was collected in 1999, then expand from there to include fens throughout the State.

3.5 Search for additional populations in Wisconsin. Wetland complexes with surface dolomite deposits along the eastern edge of the southern half of Wisconsin should be evaluated for potential Hine's emerald dragonfly habitat. Potential habitat in Door County should also be surveyed for Hine's emerald dragonflies.

3.6 Search for populations in Ohio. Searches for additional Hine's emerald dragonfly populations should be conducted in Ohio. Efforts to train qualified people to search for additional Hine's emerald dragonfly sites have brought forth suggestions on areas of potential habitat in Ohio.

3.7 Search for populations in Indiana. Searches for additional Hine's emerald dragonfly populations should be conducted in Northeast Indiana.

3.8 Search for populations in New York. Wetlands in New York are thought to be similar enough to the Hine's emerald dragonfly habitat to be surveyed for this species.

3.9 Search for populations in Maine. Wetlands in Maine are thought to be similar enough to the Hine's emerald dragonfly habitat to be surveyed for this species.

3.10 Search for populations in Arkansas, Iowa, Illinois, Kentucky, Minnesota, Tennessee, West Virginia, and Canada. Suitable habitat may exist in these States and in southern Canada. State heritage biologists should be contacted to identify potential habitat. The dolomite bedrock that underlies Hine's emerald dragonfly habitat in the United States extends into Canada in areas with high quality wetlands. Since the Hine's emerald dragonfly's potential range is believed to extend into Canada (see Appendix 3) and a population is located in Michigan near the US/Canadian border, it is highly possible that populations may exist in Canada.

3.11 Assess potential for Hine's emerald dragonfly in other states. Wetland complexes similar to Hine's emerald dragonfly habitat potentially occur in other states not previously mentioned. Possible sites should be identified using knowledge of habitats,

habitat maps, and aerial photographs. Geographic Information System tools such as landcover analyses would also be a useful in locating potential habitat.

4 REINTRODUCTION, INTRODUCTION, AND AUGMENTATION PROGRAM.

Surveys should be conducted to locate existing populations before reintroduction or introduction of Hine's emerald dragonfly is implemented. Unless an appropriate number of naturally occurring populations are found, establishing self-sustaining populations through reintroduction will be necessary to maintain the long-term viability of the dragonfly.

4.1 Develop captive rearing protocols. A captive rearing protocol should be developed in order to propagate Hine's emerald dragonfly larvae. Captive rearing could involve acquiring eggs from wild females and propagating them to a larval stage that will be released at a site. A successful protocol would be the foundation of any introduction, augmentation, or reintroduction efforts. This protocol is an important part of establishing new viable populations, which may be essential in meeting the recovery criteria for this species. This protocol should outline the steps taken to rear the dragonfly eggs through larval development and to transport larvae to release sites. The larval stage with optimal chances of survival to adulthood should also be determined. It may be necessary to use closely related *Somatochlora* spp. to develop a successful protocol before it can be used with Hine's emerald dragonfly. Because large numbers of Hine's emerald dragonfly larvae have not been reared, the protocol may take several years and moderate effort to develop.

4.2 Implement captive rearing program. If reintroduction, augmentation, or introduction is needed, a captive rearing program should be implemented after a successful protocol has been developed. Implementation would include rearing eggs from wild females to a larval stage appropriate for release. The implementation program should last as long as Hine's emerald dragonfly individuals are needed for reintroduction, introduction, or augmentation purposes.

4.3 Assess sites for reintroduction, introduction, or augmentation. Decisions about reintroduction, introduction, and augmentation sites should be based on the results of the habitat assessment and characterization studies discussed under the larval and adult ecology tasks, and upon genetic considerations. Since seemingly suitable habitats are not presently used by the dragonfly, there may be additional habitat requirements that need to be identified. Reintroduction (moving eggs, larvae, or adults to a separate geographic area within the historic range of the Hine's emerald) within historical range, if appropriate habitat is available, should be a priority. Sites selected for reintroduction should be legally or formally protected, and should have long-term assurances that appropriate management will be carried out for the protection of the new populations.

4.3.1 Illinois. Given the importance of the Illinois populations due to the high level of genetic diversity, maintaining and increasing this population seems extremely important for the recovery of the species. This might be a good area to select a

site for experimental reintroduction of Hine's emerald dragonflies, if suitable habitat exists or can be restored. The highly developed urban and industrial nature of the surrounding area, however, severely limit the opportunities for introduction of the dragonflies to new sites. Potential habitat in the lower Des Plaines River valley, such as the Midewin National Tallgrass Prairie, should be investigated for suitability for reintroduction efforts.

4.3.2 Wisconsin. Surveys of Door County and the eastern edge of the southern half of Wisconsin should be completed to identify any additional sites supporting Hine's emerald dragonfly populations. Potential reintroduction sites should be identified.

4.3.3 Michigan. Previously unknown populations of the Hine's emerald dragonfly have been discovered in 1997 and 1998 from surveys of potential habitat in the Upper Peninsula. Further surveys should be conducted to locate all existing populations before reintroduction is considered in this State.

4.3.4 Ohio and Indiana. Identifying suitable reintroduction sites in these two States will be even more difficult, since existing populations are not available for reference assessments and little is known about the reasons that Hine's emerald dragonflies are not currently found at sites with historical records of the species. Since the species is presumably extirpated from both States, future reintroduction efforts should focus on restoring reproducing populations within the historical ranges in each State.

4.4 Implement reintroduction, introduction, or augmentation. If the Hine's emerald dragonfly can be successfully propagated and appropriate introduction or reintroduction sites for population establishment have been located, larvae should be released into these sites to establish new populations or subpopulations. The desired goal of this action is to create self-sustaining populations. Due to the 3 year life cycle of Hine's emerald dragonfly larvae, at least 3 years of releases should be conducted. Unless an appropriate number of naturally occurring populations are found, establishing self-sustaining populations through reintroduction or introduction will be necessary to maintain the long-term viability of the dragonfly.

4.5 Monitor reintroduced, introduced, and/or augmented populations annually. Population monitoring should be conducted annually to determine the health of the population and the success of the reintroduction. Monitoring may include adult and/or larval surveys. Larval surveys are especially critical since they will detect evidence of reproduction first. This information will provide insight on whether more individuals need to be released at the site and if the population is self-sustaining. This is a long-term task that may take a moderate amount of effort per year.

5 CONDUCT AN INFORMATION AND EDUCATION PROGRAM

5.1 Encourage private landowners to conserve the Hine's emerald dragonfly. Provide education/outreach materials, including management recommendations, to private landowners, organizations, corporations, and other stakeholders to assist in the

development of their own Hine's emerald dragonfly conservation initiatives. Continue or initiate landowner contact to reach people in key habitat areas that are unprotected.

Private landowners with Hine's emerald dragonfly habitat should be contacted and encouraged to protect the dragonfly and its habitat through conservation agreements or deed restricted conservation easements. Landowners should be notified about the presence of the dragonfly and measures they can take to protect the Hine's emerald dragonfly. Coordination with private landowners could be achieved through implementation of a land owner contact program.

5.2 Inform local and county governments of Hine's emerald dragonfly recovery goals. Local units of government should receive information on the Hine's emerald dragonfly and the recovery goals, and the ways they can assist in achieving those goals. The potential for impacts through groundwater contamination and increased groundwater extraction should be prominent topics in this outreach effort. Development of effective partnerships with local governments will help ensure that local land-use decisions benefit the dragonfly's recovery.

5.3 Develop outreach material on Hine's emerald dragonfly life history and conservation. The fact sheet previously developed by the USFWS for the Hine's emerald dragonfly should be updated and revised. This revised fact sheet and other tools should be used in a public education program that includes outreach to schools, local governments, and private citizen organizations. In addition, the public sites in Illinois, Wisconsin, and Michigan can include information about the Hine's emerald dragonfly in their educational programs and in literature distributed routinely to tourists and the general public. People who visit and have an interest in such places as The Ridges Sanctuary, the Will County Forest Preserves, and Hiawatha National Forest should be encouraged to act as an advocacy group and volunteer pool for the protection and recovery of the dragonfly.

6 REVIEW AND TRACK RECOVERY PROGRESS

6.1 Maintain a clearinghouse for Hine's emerald dragonfly information. The USFWS should maintain a clearinghouse for Hine's emerald dragonfly data, progress reports, management plans, habitat conservation plans, guidance documents, and other relevant information.

6.2 Conduct Recovery Team meetings at least biannually to evaluate progress. The USFWS should continue to bring together species experts and land managers represented on the recovery team to evaluate progress toward recovery goals.

6.3 Revise plan as appropriate at 5 year intervals. As research provides more information on the specific requirements and status of this species, the plan should be updated to reflect relevant new information.

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PART III. IMPLEMENTATION

The Hine's emerald dragonfly Implementation Schedule outlines actions and estimated costs for the recovery program. It is a guide for meeting the objectives discussed in Part II of this Plan. This schedule indicates task priorities, task numbers, task descriptions, duration of tasks, the responsible agencies, and cost estimates. These actions, when accomplished, should bring about the recovery of the species and protect its habitat. It should be noted that the estimated monetary needs for all parties involved in recovery are identified and, therefore, Part III reflects the total estimated financial requirements for the recovery of this species for the time period noted. The USFWS Endangered Species Program in Region 3 is responsible for implementing the tasks marked "USFWS" in the Responsible Party column of the Implementation Schedule, unless otherwise noted.

Priorities in column one of the following Implementation Schedule are assigned as follows:

> Priority 1 - An action that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future.
> Priority 2 - An action that must be taken to prevent a significant decline in species population/habitat quality or some other significant negative impact short of extinction.
> Priority 3 - All other actions necessary to meet the recovery objective.

Key to abbreviations in the Implementation Schedule:

CCFPD	Cook County Forest Preserve District
FP	Forest Preserve
USFWS	U.S. Fish and Wildlife Service
HNF	Hiawatha National Forest, USDA Forest Service
IDNR	Illinois Department of Natural Resources
INHS	Illinois Natural History Survey, Illinois Department of Natural Resources
ISM	Illinois State Museum, Illinois Department of Natural Resources
ISWS	Illinois State Water Survey, Illinois Department of Natural Resources
MDC	Missouri Department of Conservation
MDNR	Michigan Department of Natural Resources
MDOT	Michigan Department of Transportation
MNFI	Michigan Natural Features Inventory
MSC	Material Service Corporation
NP	Nature Preserve
NPC	Nature Preserves Commission
ODOW	Ohio Department of Wildlife, Ohio Department of Natural Resources
TBD	To be determined
TNC	The Nature Conservancy
TRS	The Ridges Sanctuary, Inc.
WCFPD	Will County Forest Preserve District
WDNR	Wisconsin Department of Natural Resources

IMPLEMENTATION SCHEDULE FOR HINES EMERALD DRAGON FLY

Priority #	Task #	Task Description	Task Duration (Years)	Responsible Party	Total Cost	Cost Estimates ($000)			Comments
						Year 1	Year 2	Year 3	
1	1.1.1	Review Federal, state, and private activities	Ongoing	USFWS	100	5	5	5	
1	1.1.2	Develop recovery implementation strategies to promote recovery	5	USFWS	50	10	10	10	
1	1.1.3	Determine watershed ownership	2	USFWS TNC	10	5	5		
1	1.1.4.1	Land protection	3, +TBD	IDNR WDNR MDC MDNR MDOT HNF TNC	6,000+ TBD	2,000	2,000	2,000	Land Acquisition
1	1.1.4.2	Groundwater protection	TBD	TBD	TBD				
1	1.2.2.1	Intensive larval monitoring	3, +TBD	INHS	155	55	50	50	for Lockport Prairie and Mud Lake “North” Y1: initial equipment costs
1	1.2.2.2	Intensive adult monitoring	3, +TBD	INHS	165	45	40	40	for Lockport Prairie and Mud Lake “North” Y1: initial equipment costs
1	2.1.1	Conduct studies: Larval ecology	4	INHS	210	55	55	50	
1	2.1.2	Conduct studies: Adult ecology	4	INHS	134	35	33	33	

Priority #	Task #	Task Description	Task Duration (Years)	Responsible Party	Total Cost	Cost Estimates ($000)			Comments
						Year 1	Year 2	Year 3	
1	2.2.1	Conduct studies: Correlate larval and adult population sizes	2	INHS	40		20	20	
1	2.2.2	Conduct studies: Analyze techniques for estimating population size	3	INHS	135	55	40	40	Y1: initial equipment costs additional $15,000
1	2.3.1.1	Conduct hydrology studies in Illinois: Lockport Prairie NP, Romeoville Prairie NP, Middle Parcel, River South Parcel, and Keepataw FP	3	USFWS ISWS INHS	360	210	100	50	
1	2.3.2.1	Conduct hydrology studies in Wisconsin: The Ridges and Mud Lake "North"	3	TBD	360	210	100	50	
1	2.5.1	Conduct studies: Evaluate *S. hineana*'s responses to habitat management practices	Ongoing	TBD	400	20	20	20	
1	3.1	Search for *S. hineana* larval habitat within existing sites	2	WDNR INHS MNFI	30		15	15	
1	3.2	Search for additional *S. hineana* populations in Michigan	2	USFWS MNFI	60		30	30	
1	3.3	Search for *S. hineana* populations in Alabama	2	USFWS R4	60		30	30	
1	3.4	Search for *S. hineana* populations in Missouri	2	USFWS MDC	60		30	30	
1	3.5	Search for *S. hineana* populations in Wisconsin	2	USFWS WDNR	60		30	30	

Priority #	Task #	Task Description	Task Duration (Years)	Responsible Party	Total Cost	Cost Estimates ($000)			Comments
						Year 1	Year 2	Year 3	
1	5.1	Encourage private landowners to conserve the Hine's emerald	10	TNC WDNR NPC MDC	50	5	5	5	
2	1.2.1.1	Conduct presence/absence surveys	Ongoing	USFWS+ TBD	20	1	1	1	
2	1.2.1.2	Conduct census surveys	Ongoing	USFWS+ TBD	100	5	5	5	
2	1.3.1.1	Manage habitat: Black Partridge FP	Ongoing	CCFPD	20	1	1	1	
2	1.3.1.2	Manage habitat: Keepataw FP	Ongoing	WCFPD	10	.5	.5	.5	
2	1.3.1.3	Manage habitat: Lockport Prairie NP	Ongoing	WCFPD	50	2.5	2.5	2.5	
2	1.3.1.4	Manage habitat: Long Run Seep NP	Ongoing	IDNR	40	2	2	2	
2	1.3.1.5	Manage habitat: McMahon Woods	Ongoing	CCFPD	10	.5	.5	.5	
2	1.3.1.6	Manage habitat: Middle Parcel	TBD	MSC	TBD				
2	1.3.1.7	Manage habitat: River South Parcel	Ongoing	MSC	200	10	10	10	
2	1.3.1.8	Manage habitat: Romeoville Prairie NP	Ongoing	WCFPD	140	7	7	7	
2	1.3.1.9	Manage habitat: Waterfall Glen FP	Ongoing	DCFPD	10	.5	.5	.5	
2	1.3.2.1	Manage habitat: The Ridges Sanctuary	Ongoing	TRS	400	20	20	20	
2	1.3.2.2	Manage habitat: Mink River	Ongoing	WDNR	10	.5	.5	.5	
2	1.3.2.3	Manage habitat: Mud Lake "North"	Ongoing	WDNR	10	5.25	.25	.25	Y1: Potential culvert replacement cost

Priority #	Task #	Task Description	Task Duration (Years)	Responsible Party	Total Cost	Cost Estimates ($000)			Comments
						Year 1	Year 2	Year 3	
2	1.3.2.4	Manage habitat: Mud Lake “South”	Ongoing	WDNR	7	2.25	.25	.25	
2	1.3.2.5	Manage habitat: Arbter Lake, North Bay, Three Springs Creek	Ongoing	TBD	TBD				
2	1.3.2.6	Manage habitat: Piel Creek	Ongoing	TNC	TBD				
2	1.3.2.7	Manage habitat: Cedarburg Bog	Ongoing	WDNR	10	.5	.5	.5	
2	1.3.3.1	Manage habitat: Acklund Road, Brevort Lake Road, Horseshoe Bay, I-75 East, I-75 West, Martineau Creek SW, and Summerby Swamp	Ongoing	HNF	102	7	5	5	Y1:Prevent off road vehicle use
2	1.3.3.2	Manage habitat: Snake Island Fens	Ongoing	MDNR	10	.5	.5	.5	
2	1.3.3.3	Manage habitat: Loop 2 Fen	Ongoing	MDNR	10	.5	.5	.5	
2	1.3.3.4	Manage habitat: Misery Bay	Ongoing	TBD	TBD				
2	1.3.4.1	Manage habitat: Grasshopper Hollow	Ongoing	TNC	10	.5	.5	.5	
2	1.3.5.1	Manage habitat: Additional sites	Ongoing	TBD	TBD				
2	2.1.3	Conduct studies: Model population dynamics	2	TBD	70		35	35	
2	2.4	Conduct studies: Genetics	3	USFWS ISM	18	6	6	6	
2	2.6	Conduct studies: Roadkill studies to include strategies for minimizing roadkills	3	INHS	60	20	20	20	
2	2.7	Conduct studies: Water quality monitoring	10	INHS	150	15	15	15	

Priority #	Task #	Task Description	Task Duration (Years)	Responsible Party	Total Cost	Cost Estimates ($000)			Comments
						Year 1	Year 2	Year 3	
2	2.8.1	Conduct studies on effects of environmental contaminants: Contaminants	3	TBD	45	15	15	15	
2	3.6	Search for *S. hineana* populations in Ohio	2	USFWS	60		30	30	
2	3.7	Search for *S. hineana* populations in Indiana	2	USFWS	60		30	30	
2	3.8	Search for *S. hineana* populations in New York	2	USFWS R5	60		30	30	
2	3.9	Search for *S. hineana* populations in Maine	2	USFWS R5	60		30	30	
3	2.3.1.2	Conduct hydrology studies in Illinois: Waterfall Glen FP	3	USFWS ISWS INHS	360	210	100	50	
3	2.3.1.3	Conduct hydrology studies in Illinois: Black Partridge FP and McMahon Woods	3	USFWS ISWS INHS	360	210	100	50	
3	2.3.1.4	Conduct hydrology studies in Illinois: Long Run Seep NP	3	USFWS ISWS INHS	360	210	100	50	
3	2.3.2.2	Conduct hydrology studies in Wisconsin: Mud Lake “South”	3	TBD	360	210	100	50	
3	2.3.2.3	Conduct hydrology studies in Wisconsin: Arbter Lake	3	TBD	360	210	100	50	

Priority #	Task #	Task Description	Task Duration (Years)	Responsible Party	Total Cost	Cost Estimates ($000)			Comments
						Year 1	Year 2	Year 3	
3	2.3.2.4	Conduct hydrology studies in Wisconsin: North Bay	3	TBD	360	210	100	50	
3	2.3.2.5	Conduct hydrology studies in Wisconsin: Three Springs Creek	3	TBD	360	210	100	50	
3	2.3.3	Conduct hydrology studies in Michigan	3	TBD	210			210	
3	2.3.4	Conduct hydrology studies in Missouri	3	TBD	TBD				
3	2.3.5	Conduct hydrology studies in new sites as they are verified	3	TBD	TBD				
3	2.8.2	Conduct studies on the effects of environmental contaminants: Mosquito abatement programs	3	TBD	45	15	15	15	
3	3.10	Search for *S. hineana* populations in Arkansas, Iowa, Illinois, Kentucky, Minnesota, Tennessee, West Virginia, and Canada	2	USFWS R3, R4, R5 TBD	170		85	85	
3	3.11	Assess potential for *S. hineana* in other states	2	USFWS R3, R4, & R5)	50		25	25	
3	5.2	Inform local and county governments of Hine's emerald dragonfly goals	5	USFWS WDNR MDNR NPC	5	1	1	1	
3	5.3	Develop outreach material on *S. hineana* life history and conservation	3	WDNR IDNR MDNR	6	1	1	4	

Priority #	Task #	Task Description	Task Duration (Years)	Responsible Party	Total Cost	Cost Estimates ($000)			Comments
						Year 1	Year 2	Year 3	
2	4.1	Develop captive rearing protocols	TBD	INHS	TBD				
3	4.2	Implement captive rearing programs	TBD	USFWS	TBD				As needed basis
3	4.3	Assess sites for reintroduction, introduction, or augmentation	TBD	USFWS	TBD				As needed basis
3	4.4	Implement reintroduction, introduction, or augmentation	TBD	USFWS	TBD				As needed basis
3	4.5	Monitor reintroduced, introduced, and/or augmented populations annually	TBD	TBD	TBD				As needed basis
3	6.1	Maintain a clearinghouse for *S. hineana* information	Ongoing	USFWS	10	.5	.5	.5	
3	6.2	Conduct Recovery Team meetings at least biannually to evaluate progress	Ongoing	USFWS	10		2		Biannual Meeting
3	6.3	Revise plan as appropriate at five year intervals	Ongoing	USFWS	TBD				

APPENDIX 1

Glossary

adaptive management	habitat management techniques that are updated to incorporate new information
augmentation	moving eggs, larvae, or adults to a site with an existing subpopulation
crepuscular	occurring at twilight or dusk
environmental stochasticity	the random occurrence of common climatic events (i.e., drought occurring four years in a row)
exuvia; exuviae (pl.)	the “skin” that remains after an insect molts
fen	wetlands dominated by grass or grass-like plants and fed primarily by water from a mineral source (Windell *et al.* 1986)
graminoid	plants belonging to the grass (Poaceae (Gramineae)) family
instar	larval stage between molting
introduction	moving eggs, larvae, or adults from one or more existing populations to help create another population at a separate geographic area outside of the current range of the Hine’s emerald
larva	immature stage of development in insects
marl	unconsolidated clays, silts, sands, or mixtures that contain a variable content of calcareous material (Keller 1985)
metapopulation	set of local populations within some larger area, where typically migration from one local population to at least some other patches is possible (Hanski and Gilpin 1997)
minerotrophic	adjective describing a wetland that is fed by groundwater
molt	to shed exoskeleton
natural catastrophe	a severe, uncommon climatic event (i.e., 100 year flood)
ombrotrophic	adjective describing a wetland that is fed by sources other than groundwater (e.g., rain water)

oviposit	to lay eggs
ovipositor	female apparatus used to lay eggs
population	for this Plan, population is defined as a group of individuals of the same species that are capable of interbreeding and coexist at the same time and in the same geographic area
reintroduction	moving eggs, larvae, or adults from one or more existing populations to help create another population at a separate geographic area within the historic range of the Hine's emerald where there are no contemporaneous populations of the dragonfly
subpopulation	for this Plan, subpopulation is defined as a group of individuals of the same species that have frequent interactions among individuals, which may inhabit more than one geographic site separated by roads or short distances if individuals move between sites; genetic exchange is more frequent than between populations
teneral	stage of a newly emerged adult; typical characteristics for dragonflies include glassy, fragile wings and, in some species, different colored body and/or eyes

APPENDIX 2

Sites surveyed for Hine's emerald dragonfly

*** Historic Site** (documented before 1963).
Life stages: A, adult; L, larva; E, exuviae; All, all stages. ?, unconfirmed sightings.
Behavior: TR, transient flight; FF, feeding flight; PE, perched; TP, territorial patrol; CP, copulation; OV, oviposition; TN, teneral adult; MF, maiden flight; ALL, all listed; ?, unknown; DOR, dead on road.
Years visited: years when species not observed in regular type; years present in **bold.**
Total hours (estimated staff hours/site): B (brief, 1-25); M (moderate, 26-200); E (extensive, over 200); ? (unknown).

State County	Site	Life stage(s)	Behavior	Year(s) visited	Total hours
Alabama Jackson	Robinson Springs	A	FF	**1978**, 1993, 1994	B
Illinois Cook	Black Partridge Woods Nature Preserve	A	PE, TP, FF	**1990**, **1991, 1993**, 1995, **1999**	E
	Bluff Springs Fen Nature Preserve			1990	B
	Burnham Woods Nature Preserve			1990	B
	Palos Park Woods			1990, 1999	B
	Sag Bridge			1992	B
	Willow Springs			1992	B
	Mt. Assissi			1992	B
	Eggers Grove			1990	B
	McMahon Woods	A	FF, TN, TP	**1992**, **1993,** 1994, 1995, 1996, **1999**	E
	Palos Fen Nature Preserve			1990, 1999	B
	Wampum Lake			1991, 1999	B
	Zander Woods			1999	B

APPENDIX 2 Continued

Sites surveyed for Hine's emerald dragonfly

State County	Site	Life stage(s)	Behavior	Year(s) visited	Total hours
Illinois Du Page	Dragon Lake Forest Preserve			1990	B
	McDowell Grove Forest Preserve			1990	B
	West Branch Lower Forest Preserve			1990	B
	Waterfall Glen Forest Preserve, southwest corner	A	FF, PE	**1990**, 1991, 1992, **1994-1999**	E
	West Chicago Prairie Forest Preserve			1990	B
	West Du Page Woods			1990	B
Illinois Grundy	Goose Lake Prairie State Park			1999	B
Illinois Kankakee	Kankakee River State Park			1999	B
Illinois Kendall	Yorkville			1993	B
Illinois Lake	Chain O' Lakes State Park			1990	B
	DesPlaines River Wetland Demonstration Project			1999	B
	Spring Bluff Preserve			1999	B
	Van Patton Woods			1990, 1999	B
	Wadsworth Prairie			1999	B
Illinois McHenry	Alden Sedge Meadow			1990	B

APPENDIX 2 Continued

Sites surveyed for Hine's emerald dragonfly

State County	Site	Life stage(s)	Behavior	Year(s) visited	Total hours
	Elizabeth Lake Nature Preserve			1990	B
	Lake-in-the-Hills Fen Nature Preserve			1990	B
	Oakwood Hills Fen Nature Preserve			1990	B
	Spring Grove Fen Nature Preserve			1990	B
Illinois Will	Black Road			1990	B
	Chicago Gravel Co. marsh			1992	B
	Crest Hill Park			1990, 1992	B
	DesPlaines State Conservation Area			1999	B
	Texaco Refinery			1992, 1995	B
	Houbolt Prairie			1990,1992	B
	Houbolt Avenue			1992	B
	I & M Canal, Channahon			1992	B
	Joliet Army Training Area			1992	B
	Jackson Creek			1993, 1997	M
	Keepataw Forest Preserve	A, L	CP, FF, PE, TP, TR	1990, 1991, 1992, 1993, **1995-1999**	E
	Lockport Prairie East			1990	B

APPENDIX 2 Continued

Sites surveyed for Hine's emerald dragonfly

State County	Site	Life stage(s)	Behavior	Year(s) visited	Total hours
	Lockport Prairie Nature Preserve	A, L, E	ALL	**1983, 1989-1999**	E
	Long Run Seep Nature Preserve	A	CP, FF, OV, PE, TP, TR	**1990-1996**, **1999**	E
	Lower Rock Run Creek Preserve			1999	B
	Material Service Corporation, Yard 61, Middle Parcel	A, E	FF, TN, TP, PE, TR	**1993-1999**	E
	Material Service Corporation, Yard 61, North Parcel			1993	B
	Material Service Corporation, Yard 61, River South Parcel	A,E,L	ALL	**1994 -1999**	E
	Persico Property at Theodore & Gaylord Rds.			1992	B
	Rock Run Creek, North			1992, 1999	B
	Romeoville Prairie Nature Preserve	A	FF?, TR?	**1989**, **1990**, 1995, 1999	E
	Romeoville Road, between Rt. 53 & New Ave.			1994, 1995	E
	Sidekick's Lounge	A	TR?	**1994**	B
	Uno-Ven Refinery	A	FF?	**1995**	B
	Vulcan Material Co., Yard 6			1990	M

APPENDIX 2 Continued

Sites surveyed for Hine's emerald dragonfly

State County	Site	Life stage(s)	Behavior	Year(s) visited	Total hours
Indiana Lake	*Gary	A	?	1945	?
	Clark and Pine Nature Preserve			1995	B
	Clark and Pine East (Baaing Tract)			1995	B
	Clarke Junction			1995	B
Michigan Alger	Star Creek fen			1999	B
Michigan Alpena	Misery Bay	A	TR,TP	**1999**	B
Michigan Chippewa	Beavertail Creek - Prentiss Bay			1997	B
	Detour State Park			1997	B
	Drummond Island - Grand Marais Lake			1998	B
	Drummond Island - Isaacson Lake			1998, 1999	B
	Hendrie River			1991	B
	M-134 west from Detour Village toward the Cedarville			1999	B
Michigan Delta	Casey Creek			1991	B
	Garden Corners			1997	B
	Garden Creek #1			1991	B
	Garden Creek #2			1991	B
	Garden Creek #3			1991	B

APPENDIX 2 Continued

Sites surveyed for Hine's emerald dragonfly

State County	Site	Life stage(s)	Behavior	Year(s) visited	Total hours
	Garden Creek #4			1998	B
	Lake Michigan			1991	B
	Marsh Lake			1997	B
	Nahma			1997	B
	Squaw Creek			1991	B
	Valentine Creek #1			1991	B
	Valentine Creek #2			1991	B
Michigan Luce	Soo Junction Wetlands			1991	B
Michigan Mackinac	Ackland Road	A	FF, OV, TP, CP	**1997-1999**	B
	Big Knob fen			1997	B
	Bois Blanc Island - Snake Island Fens	A	TP, PE, FF	**1999**	B
	Brevort Lake Road	A	FF	**1997**, 1998	B
	Carnegie Trail - Hiawatha Sportsman Club			1997	B
	Castle Rock Road	A	?	**1999**	B
	Castle Rock/I-75 swales			1999	B
	Cataract River to Needle Point			1997	B
	Charles Road Fens			1999	B
	Cranberry Lake Bog			1991	B
	Dinkey Line Road			1999	B

APPENDIX 2 Continued

Sites surveyed for Hine's emerald dragonfly

State County	Site	Life stage(s)	Behavior	Year(s) visited	Total hours
	East Naubinway swales			1997	B
	Fiborn Karst Preserve			1999	B
	Foley Creek Wetland	A?	TR	1997	B
	Great Lakes Transmission pipeline between Brevort Lake Road & East Lake Road, various sites			1999	B
	Hay Lake railroad grade			1997	B
	Heinz Lake			1998	B
	Hog Island Point			1991	B
	Horseshoe Bay	A	OV?	**1997**, 1998	B
	Horseshoe Bay, North Unit			1998	B
	I-75/ Castle Rock road area			1997	B
	I-75 East	A	FF, TP	**1997**, 1998, 1999, **2001**	B
	I-75 West	A	TP	**1997**, 1998	B
	Inglesbe Swamp	A	TR	**1997**, 1998	B
	Kitchens Creek area	A?	?	1997	B
	M-134 from Cedarville east toward Detour Village			1999	B
	Marquette Island - Voight Bay			1998	B

APPENDIX 2 Continued

Sites surveyed for Hine's emerald dragonfly

State County	Site	Life stage(s)	Behavior	Year(s) visited	Total hours
	Marquette Island - Peck Bay			1998	B
	Marsh Lakes and Big Knob coastal fens			1997	B
	Martineau Creek SW	A	TP, TR	**1998**	B
	Mead Paper Company			1998	B
	Mismer Bay Wetlands			1997	B
	Point Aux Chenes River and adjacent wetlands				B
	Point LaBarbe			1999	B
	Portage Creek			1991	B
	Rabbit Back and Borrow Pit swales			1997	B
	St. Martin Point			1998	B
	Summerby Swamp	A	FF	**1997**, **1998**	B
	Voight Bay			1999	B
	3116 Swamp			1998	B
Michigan Presque Isle	Ferron Point fens			1999	B
	Thompson's Harbor State Park - Loop 2 Fen	A	FF	**1999**	B
Michigan Schoolcraft	Bursaw Creek			1991	B
	Creighton River			1991	B
	Dead Horse Creek			1991	B

APPENDIX 2 Continued

Sites surveyed for Hine's emerald dragonfly

State County	Site	Life stage(s)	Behavior	Year(s) visited	Total hours
	Gulliver Lake to Seul Choix Point			1997	B
	Iron Creek			1991	B
	Mead Creek			1991	B
	Port Inland			1997	B
	Rainey Wildlife Area			1997	B
	Seney National Wildlife Refuge			1997	B
	Silver Creek			1991	B
	Smith Creek			1991	B
	Snyder Creek			1991	B
	Thompson area			1997	B
Minnesota Beltrami	Hwy 72, Red Lake			1998	B
Minnesota Dakota	Black Dog Preserve			1998	B
Minnesota Koochiching	Lost River			1998	B
Minnesota Lake of the Woods	Lost Lake Trail			1998	B
	Winter Lake Road			1998	B
Minnesota Roseau	Pine Creek			1998	B
	Sprague Creek			1998	B
Minnesota Scott	Savage Fen			1998	B

APPENDIX 2 Continued

Sites surveyed for Hine's emerald dragonfly

State County	Site	Life stage(s)	Behavior	Year(s) visited	Total hours
Missouri Carter	Chilton Creek Preserve			2001	B
	Peck Ranch Conservation Area - Pritchard Hollow			2001	B
	Pump Hollow			2001	B
Missouri Crawford	James Branch Hollow			2001	B
Missouri Dent	Bates Hollow Seep Fens			2001	B
	West Fork Huzzah Valley			2001	B
	Indian Trail Conservation Area			2001	B
Missouri Franklin	Little Indian Creek Conservation Area			2001	B
	Meramec State Park			2001	B
Missouri Iron	Barton Fen	A	FF, TP	**2001**	B
Missouri Laclede	Flagmire Hollow			2001	B
Missouri Phelps	Kaintuck Hollow			2001	B
	Apple Tree Farm			2001	B
Missouri Reynolds	Clearwater Conservation Area			2001	B
	Nancy B Altvater Grasshopper Hollow	A, All (2001)	TR, All (2001)	**1999, 2000,** 2001, **2001**	M

APPENDIX 2 Continued

Sites surveyed for Hine's emerald dragonfly

State County	Site	Life stage(s)	Behavior	Year(s) visited	Total hours
	Fletcher Landing Strip Fens			2001	B
	Husman Fen Natural Area			2001	B
	Ruble Meadow	A	FF	**2001**	B
	Swamp Hollow			2001	B
Missouri Ripley	Blue Flag Fen			2001	B
	Little Black Conservation Area			2001	B
	Mud Branch Fen 1			2001	B
	Mud Branch Fen 2			2001	B
	Mud Branch Fen 3			2001	B
	Mud Branch Fen 4			2001	B
	Wells Branch Fen			2001	B
Missouri Shannon	Shut-In-Mountain Fen			2001	B
Missouri St. Francois	St. Francois State Park			2001	B
Missouri Washington	Cruise Meadow			2001	B
Missouri Wayne	Haite's Ford Fen			2001	B
Ohio Fulton	Fulton Pond, Ohio Turnpike & Co. Rd. 3			1994	B
Ohio Hancock	Blanchard River at Twp. Rd. 166			1994	B

APPENDIX 2 Continued

Sites surveyed for Hine's emerald dragonfly

State County	Site	Life stage(s)	Behavior	Year(s) visited	Total hours
	Van Buren State Park, East Marsh			1994	B
Ohio Henry	Ditch off Twp. Rd. 2			1994	B
Ohio Huron	Willard Marsh Wildlife Area			1994	B
Ohio Logan	*Indian Lake, North Fork Great Miami River Channel W of Rt. 117	A	PE	**1929, 1930,** 1996	M
Ohio Lucas	Irwin Prairie State Nature Preserve			1994	B
	Lou Campbell Nature Preserve			1994	B
	*Oak Openings Preserve Metropark, old RR bed between Wilkins Rd. & Hwy. 64, Wintergreen Lake	A	FF, OV?, PE	**1952, 1953, 1956, 1958 - 1961,** 1994, 1996	E
	Toledo Express Airport			1994	B
Ohio Putnam	Pond at Blanchard River & SR15			1994	B
	Riley Creek upstream from bridge on Twp. Rd. K-6			1994	B
Ohio Seneca	Mohawk Lake: Stream W & between Honey Creek and Mohawk Lake			1994	B

APPENDIX 2 Continued

Sites surveyed for Hine's emerald dragonfly

State County	Site	Life stage(s)	Behavior	Year(s) visited	Total hours
	Springville Marsh State Nature Preserve			1994	B
Ohio Williams	*Bridgewater Township Pond	A	OV?	**1956**	?
	Lake La-Su-An Wildlife Area			1992, 1994, 1996	B
	*Mud Lake Bog Nature Preserve	A	PE	**1949**, 1992, 1993, 1994, 1995, 1996	M
	Pond at Co. Rds. 8 & S			1994	B
Ohio Wood	Tow Path, Maumee River			1994	B
	Weir Rapids on the Maumee River			1994	B
Wisconsin Brown	Green Bay Shores Wildlife Area, Sensiba Unit			2000	B
Wisconsin Calumet	Killsnake Wildlife Area			2001	B
Wisconsin Dodge	Waterloo Fen & Springs			1990	B
Wisconsin Door	Ahnapee River and Silver Creek, south of State Highway 57			2001	B
	Appleport Lane, Sand Lane			1998	B
	Arbter Lake	A	OV	1990, **1997**	B

APPENDIX 2 Continued

Sites surveyed for Hine's emerald dragonfly

State County	Site	Life stage(s)	Behavior	Year(s) visited	Total hours
	Baileys Harbor Twp., cedar swamp N of Co. Rd. Q			1992	B
	Baileys Harbor Twp., marsh N of Co. Rd. Q	A	FF, TR	**1992**	B
	Bailey's Harbor Twp., along Co. Rd. Q	A	TR	**1997-1999**	M
	Baudhin Creek			1990	B
	Big Marsh, Washington Island	A	OV, TP	**2000**	B
	Button Marsh	A		1998	B
	Clark Lake			1998	B
	Coffee Swamp, Washington Island			2000	B
	Cunningham Swamp			2001	B
	Dolan's Creek			1990	B
	Duvall Swamp			1998	B
	Ephraim Swamp	A	FF, TN	1998, **2000, 2001**	B
	Forestville Pond, upper reaches			1998	B
	Frog Station, Kewaunee River State Fish & Wildlife Area			1998	B
	Gardner Swamp Wildlife Area			1990, 2001	B
	Garret Bay			1998	B

APPENDIX 2 Continued

Sites surveyed for Hine's emerald dragonfly

State County	Site	Life stage(s)	Behavior	Year(s) visited	Total hours
	Gravel Pits, Mud Lake West			1998	B
	Gregorville, Black Ash Swamp			1998	B
	Hibbard Creek			1990, 2001	B
	Kangaroo Lake North			1995	B
	Kellner Fen	A	TP	**2001**	B
	Kewaunee River Marsh			1998	B
	Keyes Creek			1990	B
	Lake Lane			2001	B
	Lake Michigan Drive			1998	B
	Little Lake, Washington Island			2000	B
	Logan Creek			1990, 1998	B
	Lower Gardner Swamp State Wildlife Area			1998	B
	Lower Reiboldt's Creek			1998	B
	Marshall's Point			1990	B
	Meridian Co. Park #1	A?		1995	B
	Meridian Co. Park #2			1995	B
	Mink River (Lower)	A	TR	**1987**, 1989-1991, 1995, **2001**	M
	Mink River (Upper)	A, A	FF, TN (2001)	1998, **1999, 2001**	B

APPENDIX 2 Continued

Sites surveyed for Hine's emerald dragonfly

State County	Site	Life stage(s)	Behavior	Year(s) visited	Total hours
	Mud Lake "North" (Grove Road)	A		**2001**	B
	Mud Lake "North" (Pioneer Rd.)	A	FF	**1992**	B
	Mud Lake "North" (Lime Kiln Rd.)	A, E, L	CP, OV, FF, TR	**1990, 1991, 1992**, 1993**, 1995 - 1999**	E
	Mud Lake "South" (Mystery Creek)	A	CP, FF, TN, TR,	**1990, 1991,** 1992 (B), 1993**,** 1994**, 1995, 1996,** 2001(B)	E
	North Bay	A, L	FF, OV	**1995-1999**	E
	North Kewaunee River State Fish & Wildlife Area			1998	B
	North Point Beach State Forest			1998	B
	Pickerel Lake			1992	B
	Piel Creek	A	FF, TR, PE	**1990**, **1991,** 1995, 1998, **2001** (B)	M
	Sherwood Point			2001	B
	Shivering Sands #1			1995	B
	Shivering Sands #2	A?		1995	B
	South Kewaunee River State Fish & Wildlife Area			1998	B

APPENDIX 2 Continued

Sites surveyed for Hine's emerald dragonfly

State County	Site	Life stage(s)	Behavior	Year(s) visited	Total hours
	South Point Beach State Forest			1998	B
	Spring Road and Access road off Spring Road	A	PE, DOR	**2001**	B
	Stony Creek, near Carnot			1998	B
	Stony Creek Swamp			1998	B
	Strawberry Creek			2001	B
	Sturgeon Bay Ship Canal			1998, 2001	B
	The Ridges Sanctuary	A, E, L	ALL	**1992, 1995 - 1999**	E
	Three Springs Creek	A	FF, TR, OV	**1990, 1991, 1995**	E
	Thorp Pond			1995, 1998	B
	Toft Point	A	FF	**1991, 1995**	B
	Upper North Bay			1998	B
	White Cliff Fen	A	PE	2001	B
Wisconsin Fond du Lac	Mauthe Lake			1990, 2001	B
Wisconsin Kewaunee	Ahnapee River Wetlands (near Algoma)			2001	B
	Alaska Lakes			2000	B
	Black Ash Swamp	A	TR/FF	**2001**	B
	Duvall Swamp			1990, 2001	B
	East Twin River			2001	B

APPENDIX 2 Continued

Sites surveyed for Hine's emerald dragonfly

State County	Site	Life stage(s)	Behavior	Year(s) visited	Total hours
	Kewaunee Fish and Wildlife Area, Little Scareboro Unit			2000, 2001	B
	Krohn Lake			2000	B
	Three Mile Creek, mouth			2000	B
Wisconsin Manitowoc	Cleveland Hardwood Swamp			2000	B
	Fisher Creek			2000	B
Wisconsin Manitowoc	Manitowoc School Forest			2001	B
	Point Beach State Forest			1990	B
	Point Beach State Park, Molash Creek			2000	B
	Point Beach State Park, South Dunes			2000, 2001	B
	Point Beach State Park, West Dunes			2000, 2001	B
	West Twin River			2000	B
	Woodland Dunes			2001	B
Wisconsin Marinette	Ansul Patterned Dunes Area			2000	B
	Green Bay Shores State Wildlife Area, Pestigo Harbor Unit			2000	B
	Lake Mary			1990	B
	Lake Noquebay			1990, 2000	B

APPENDIX 2 Continued

Sites surveyed for Hine's emerald dragonfly

State County	Site	Life stage(s)	Behavior	Year(s) visited	Total hours
	Spur Lake			1990	B
Wisconsin Oconto	Charles Pond			1990	B
Wisconsin Ozaukee	Cedarburg Bog	A	FF, TN, OV, TP, PE	**1999, 2001**	M
	County Trunk I and State Highway 33			2001	B
Wisconsin Sheboygan	Kohler-Andrae State Park			2000, 2001	B
	Muehl Springs			2000	B
	Sheboygan Marsh, County Park			2000	B
	Sheboygan Marsh, National Wildlife Area			2001	B
Wisconsin Walworth	Bluff Creek Fen & Springs			1990	B
	Clover Valley Fen			1990	B
	Lulu Lake Fen			1990	B
	Pickerel Lake Fen			1990	B
Wisconsin Waukesha	Genesee Oak Opening & Fen			1990	B
	Ottawa Lake Fen			1990	B
Wisconsin Washington	Allenton Wildlife Area			2001	B

APPENDIX 2 Continued

Sites surveyed for Hine's emerald dragonfly

State County	Site	Life stage(s)	Behavior	Year(s) visited	Total hours
CANADA Ontario Bruce	Dorcas Bay, Singing Sands fens, Bruce Peninsula Park			1999	B
Manitoulin	Michael Bay			1999	B
	Misery Bay Provincial Nature Reserve			1999	B

APPENDIX 3

Guidelines for locating Hine's emerald dragonfly adults

Below are guidelines for locating adult Hine's emerald dragonflies and potential habitat. It has been compiled from Part I of this Plan with additional information. It includes descriptions of Hine's emerald dragonfly habitat, a list of dragonfly species co-occuring with Hine's emerald dragonfly, a map of surface dolomite deposits, and descriptions of adult Hine's emerald dragonfly behaviors. Illustrations of a Hine's emerald dragonfly adult and larva are presented in Figures 1 and 2 of this Plan. This guide will aid in distinguishing suitable Hine's emerald dragonfly habitat. Due to the difficulty in identifying this species in flight, a description of flight behaviors are provided below to help distinguish this species from others while in flight. It should be noted that a USFWS permit is required to capture, even temporarily, Hine's emerald dragonfly individuals. If potential habitat is located, please contact the USFWS, Chicago Field Office, Barrington, Illinois at (847) 381-2253 for further information. TTY users may contact the Chicago, Illinois Field Office through the Federal Relay Service at 1-800-877-8339.

Locations to Consider

Potential Range. The potential historical range of Hine's emerald dragonfly is presented in Figure 6. The potential range was estimated from the known occurrences of Hine's emerald dragonfly occurrences, the range of a closely related species, and Bailey's (1995) ecoregions as modified by Keys *et al.* (1995). Hine's emerald dragonfly has been collected from Illinois, Wisconsin, Michigan, Ohio, Missouri, Indiana, and Alabama. *Somatochlora tenebrosa* was identified as the closest related species to the Hine's emerald dragonfly, *S. hineana,* based on mitochondrial DNA analysis (Purdue *et al.* 1996). *S. tenebrosa*'s distribution includes Alabama, Arkansas, Connecticut, Georgia, Illinois, Indiana, Iowa, Kansas, Kentucky, Maine, Maryland, Massachusetts, Mississippi, Missouri, New Hampshire, New Jersey, New York, North Carolina, Ohio, Oklahoma, Pennsylvania, Rhode Island, South Carolina, Tennessee, Texas, Virginia, and Wisconsin in the United States and New Brunswick, Nova Scotia, Ontario, and Quebec in Canada. Hine's emerald dragonfly could potentially occur within this area. It should be noted that *S. tenebrosa* inhabits both alkaline and acidic systems, and it appears that *S. hineana* inhabits alkaline systems. Incorporating *S. hineana* occurrences and *S. tenebrosa*'s range, Bailey's (1995) ecoregions, as modified by Keys *et al.* (1995), were used to estimate the potential range of Hine's emerald dragonfly. The upper portion of the range is made up of the Warm Continental Division, and the Hot Continental Division makes up the lower portion. The Warm Continental Division is comprised of the Laurentian Mixed Forest Province and the Adirondack-New England Mixed Forest-Coniferous Forest-Alpine Meadow Province. The Warm Continental Division has both boreal and broadleaf deciduous forests and is characterized by warm summers and cold winters with ample rainfall. The Hot Continental Division consists of the following provinces: Eastern Broadleaf Forest (Oceanic), Eastern Broadleaf Forest (Continental), Central Appalachian Broadleaf Forest-Coniferous Forest-Meadow, and Ozark-Broadleaf Forest-Meadow. The Hot Continental Division is characterized by winter deciduous forests, dominated by broadleaf trees, and a climate of hot summers and cool winters.

Geological Characteristic. Known Hine's emerald dragonfly populations occur in association with dolomitic bedrock. Wetlands meeting the description below that occur near surface dolomite deposits should be considered potential habitat. Figure 7 presents large areas of surface dolomite deposits within the potential range of this species. Areas near these deposits may be more likely to have Hine's emerald dragonfly populations. Smaller dolomite deposits are not illustrated on this map and can also represent suitable locations to search for this species. Areas of surface dolomite deposits should be determined on a local level. State Geological Surveys are good source of information regarding locations of surface dolomite deposits on a local level.

Habitat Descriptions.

The General Habitat section has been compiled from the following reports: Vogt and Cashatt (1990), Kirk and Vogt (1995), Mierzwa *et al.* (1995a), Cashatt and Vogt (1996), Soluk *et al.* (1996, 1998).

General Habitat. Known Hine's emerald dragonfly sites are made up of a mosaic of the following community types: fen, marsh dominated by cattails, sedge meadow, swamp dominated by northern white cedar, wet prairie, thicket/brush, floodplain forest, wet-mesic and mesic upland forest, and pond/pool. Typically, a site will be composed of at least one wetland community type with a forest community nearby. It appears that the wetland community is the most important aspect of the habitat because it provides appropriate larval habitat. Floral composition and substrate types are some of the visible differences among the Hine's emerald dragonfly sites in Illinois, Wisconsin, and Michigan. Forested areas near or adjacent to the Illinois' sites are mainly floodplain deciduous forests, while in Wisconsin and Michigan conifer swamps and forests are common. In Michigan, marl is a common substrate type in the wetland communities, and in Illinois and Wisconsin, muck is the predominant substrate.

The wetland community is the critical component for Hine's emerald dragonfly habitat because it provides appropriate conditions for larval development. Hine's emerald dragonfly larvae often have been found in wetland complexes that can be broadly characterized as fens. Fens are defined as wetlands dominated by graminoid or graminoid-like plants and fed primarily by calcareous groundwater through seeps and/or springs. The microhabitats this dragonfly appears to use for breeding are small channels flowing through seepage fed marshes and sedge meadows dominated by graminoid and graminoid-like plants. The flowing water can range from barely detectable sheet flow to deeper, well-defined streamlet channels. These slow-moving aquatic systems provide appropriate habitat for larval development. Parts of the streamlet channels are usually covered by vegetation such as cattails or sedges. Small sections of the streamlet channel with exposed water also appears to be important for oviposition (Mierzwa *et al.* 1998). The substrate of these channels is usually comprised of fine silt or muck and detritus from partially decomposed cattails and sedges. Soil types of these aquatic systems can range from organic muck to mineral soils like marl. It is important to note that larvae have been collected from streamlets that have been observed to dry up and appear uninhabitable.

Two important characteristics common to wetlands inhabited by this species appear to be underlying dolomitic bedrock or calcareous limestone and cool, shallow water slowly flowing

through vegetation. Two other important components of Hine's emerald dragonfly habitat appear to be open, vegetated areas and nearby or adjacent forest edge. Areas of open vegetation serve as places for adults to forage. Forests, trees, or shrubs provide protected, shaded areas for adult Hine's emerald dragonflies to perch and roost.

Adult Breeding and Foraging Habitat. In 1996, habitat preference studies in Illinois were conducted at Material Service Corporation sites (TAMS 1997) and at Lockport Prairie Nature Preserve (Soluk *et al.* 1996, 1998) . At Material Service sites, Hine's emerald dragonfly was shown to prefer sedge meadow and sweet flag (*Acorus calamus*) marsh for breeding habitat. Foraging habitat was fairly evenly distributed over the following nine community types sampled (in order of high to low percent observed use): sedge meadow, reed canary grass marsh, isolated shrubs/trees, cattail marsh, sweet flag marsh, floodplain forest, dolomite prairie, successional field, and disturbed land. At River South, almost 90% of adult observations occurred within 15 meters of habitat edge, "defined as a change in vegetation height" (e.g., cattail marsh/sedge meadow borders). An apparent correlation between habitat edge and the number of adult Hine's emerald dragonfly observations was also identified by Nuzzo (1995). In 1996 at River South, approximately 60% of the foraging observations occurred within 60 m of known breeding sites. At Lockport Prairie Nature Preserve, most observations also took place near edge habitat in both the forest edges and at the borders of cattail marsh and sedge meadows versus pond, seep outlet, dry prairie fields, and streamlet channel habitats (Soluk et al 1996,1998). In each habitat type, breeding behaviors represented up to 13% of the observations, and foraging and transient flight made up to 83% to 100% of the observations.

Oviposition has been documented in cattail seepage marshes, seepage sedge meadows, sedge hummocks near a marshy stream edge, near the edge of a swale, in muck in sluggish water at the margin of a spring run, in small puddles, and in streamlets (Vogt and Cashatt 1994, Soluk *et al.* 1996, 1998). Numerous females have also been observed ovipositing between the hummocks in the shallow water of the sheet flow in seepage sedge meadows (Vogt and Cashatt 1997, 1998 in progress).

Associated Species. Species associated with Hine's emerald dragonfly habitat may also be useful in determining appropriate locations to search for this species. Odonate species co-occuring with Hine's emerald dragonfly are listed in Table 3. Searches for additional populations should be considered in an area fitting the habitat description above with at least three of the species listed in Table 3. Locations with increased number of the odonate species may be more likely to support Hine's emerald dragonflies. Due to the lack of information on the habitat requirements for the Hine's emerald dragonfly, areas fitting the habitat description above with none of the odonate species listed in Table 3 should still be considered as potential habitat. Rare species associated with Hine's emerald dragonfly sites are listed in Appendix 5.

Behavior Considerations:

Optimal Times to Search for Adults. During Hine's emerald dragonfly peak flight season, searches should be conducted in the morning between 9:00 a.m. and 12:00 p.m. under ideal weather conditions. Ideal weather conditions are subjectively defined as follows: cloud cover < 20%, temperature 70-90E F, and wind < 10 MPH. Peak flight season usually varies between

late June through July depending on the weather and the location of the sites. Locations further north may have peak flight seasons later in the season than locations in the south. Hine's emerald dragonflies have been observed from late May to early October in Illinois and late June to late August in Wisconsin.

Flight Behavior. On days when maximal temperatures reach 35-38°C, Hine's emerald dragonflies are observed occasionally before 7:00 a.m. feeding on small dipterans. Williamson (1922) observed morning (5:00-9:00 a.m.) activity of *S. linearis* and *S. ensigera* in Indiana when daily maximal temperature ranged from 30-38°C. Hine's emerald dragonfly frequently flies over open fields at most sites. These flights typically cover a range of 10-25 m at a height of 1-3 m. Flight courses are irregular and often near clusters of shrubs or the forest edge. At Lockport Prairie Nature Preserve (Illinois) and Mud Lake Wildlife Area (Wisconsin) they also fly at 1-3 m height over narrow roads (grass/dirt, gravel, or paved).

Adult crepuscular and midday feeding swarms have been observed in Illinois and Wisconsin (Vogt and Cashatt 1992,1994, Kirk and Vogt 1995). These feeding swarms ranged from 12 to 70 individuals. A feeding swarm describes a group of individuals that are foraging, usually on a swarm of prey, within in a localized area. A crepuscular feeding swarm occurs at twilight or dusk. The location, time of day, and flight height of the dragonfly's feeding swarm may vary depending on their prey. Feeding swarms also can be influenced by climate. Hine's emerald dragonfly crepuscular feeding swarms have been observed just after sunset and a light, brief rain and also after a light rainshower. Hine's emerald dragonflies have been observed swarming over a sedge meadow and a narrow road while foraging on small dipterans. Observed flight heights of Hine's emerald dragonfly swarms ranged between 0.1-3.0 m. Other odonate species have been both present and absent from observed *S. hineana* feeding swarms; a few *S. walshii*, *S. williamsoni*, and *Aeshna umbrosa* were observed with *S. hineana* in a crepuscular feeding swarm in Wisconsin. A. F. Combs (Walker 1925:145) observed similar flights along Lake Superior by *S. incurvata*, *S. franklini*, *S. williamsoni*, and *Aeshna* spp.

In cattail seepage marshes, territorial patrols are usually within small clearings of cattails, just above lower emergent vegetation (*Sagittaria* sp.), or just above cattails. Males often assume territorial patrols over a streamlet and hover within 0.3 m of the surface. Occasionally they perch near the top of cattail floral spikes. Territorial patrols are similar in seepage sedge meadows in that males fly just above emergent vegetation (tussock sedge). In contrast, at The Ridges Sanctuary, patrols are frequently one m above emergent vegetation in swales.

Figure 6. Map of Hine's emerald dragonfly populations, occurrences, and identified search area. The survey area is based on known locality, distribution of a closely related species (*Somatochlora tenebrosa*), ecoregions from Bailey (1995), and as modified by Keys *et al.* (1995). The two divisions used from Bailey's ecoregions were the Warm and Hot Continental Divisions.

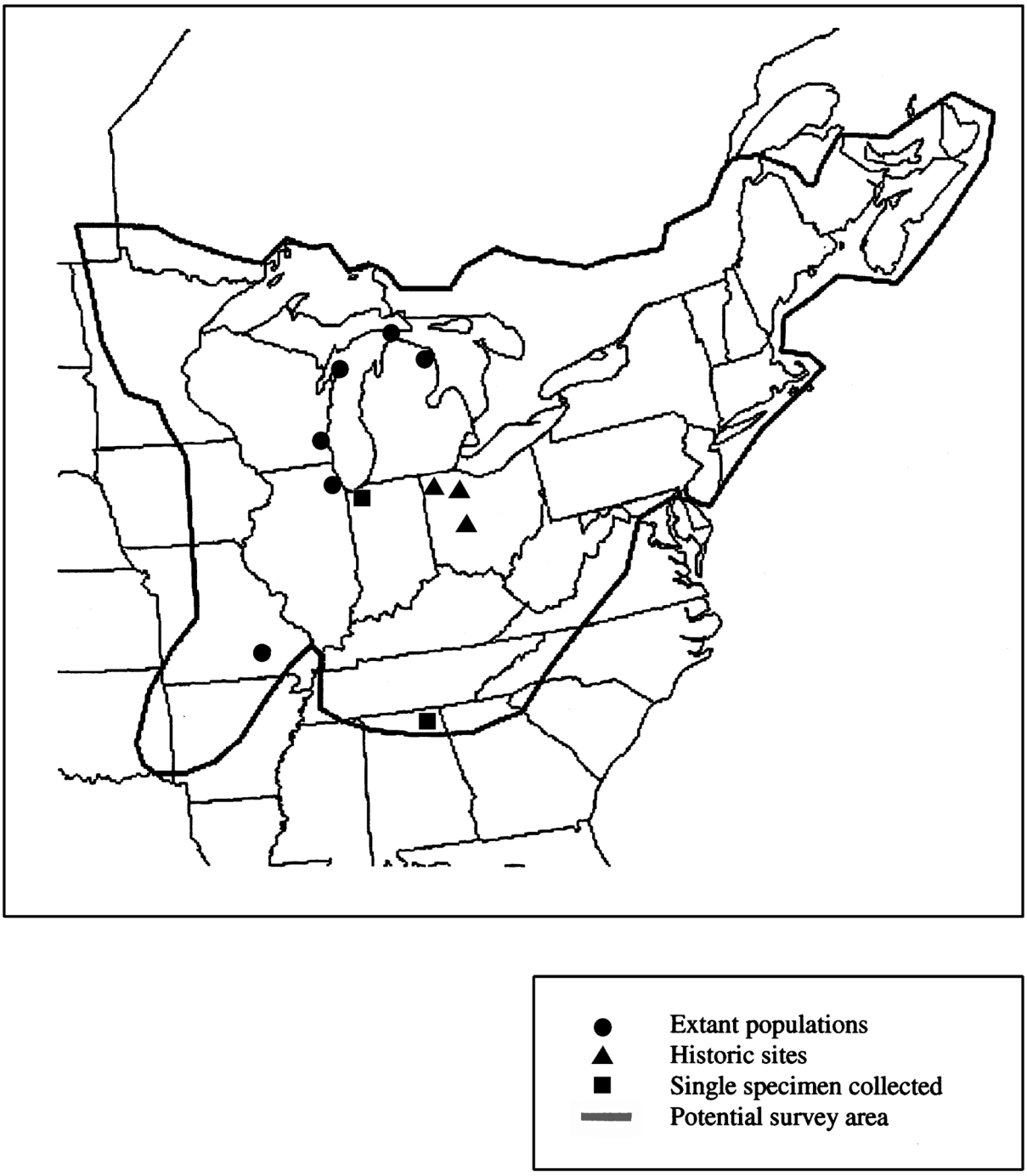

Figure 7. Locations of surface dolomite deposits within the potential range of Hine's emerald dragonfly. The surface dolomite deposits represent areas that may have greater potential to be inhabited by Hine's emerald dragonfly. This map presents large areas of surface dolomite deposits and does not show smaller deposits that may also be appropriate locations to search for this species. Upper Silurian deposits are the youngest rocks and Lower Silurian deposits are the oldest. Map prepared by R. Krumm, Illinois State Geological Survey, from King and Beikman (1974).

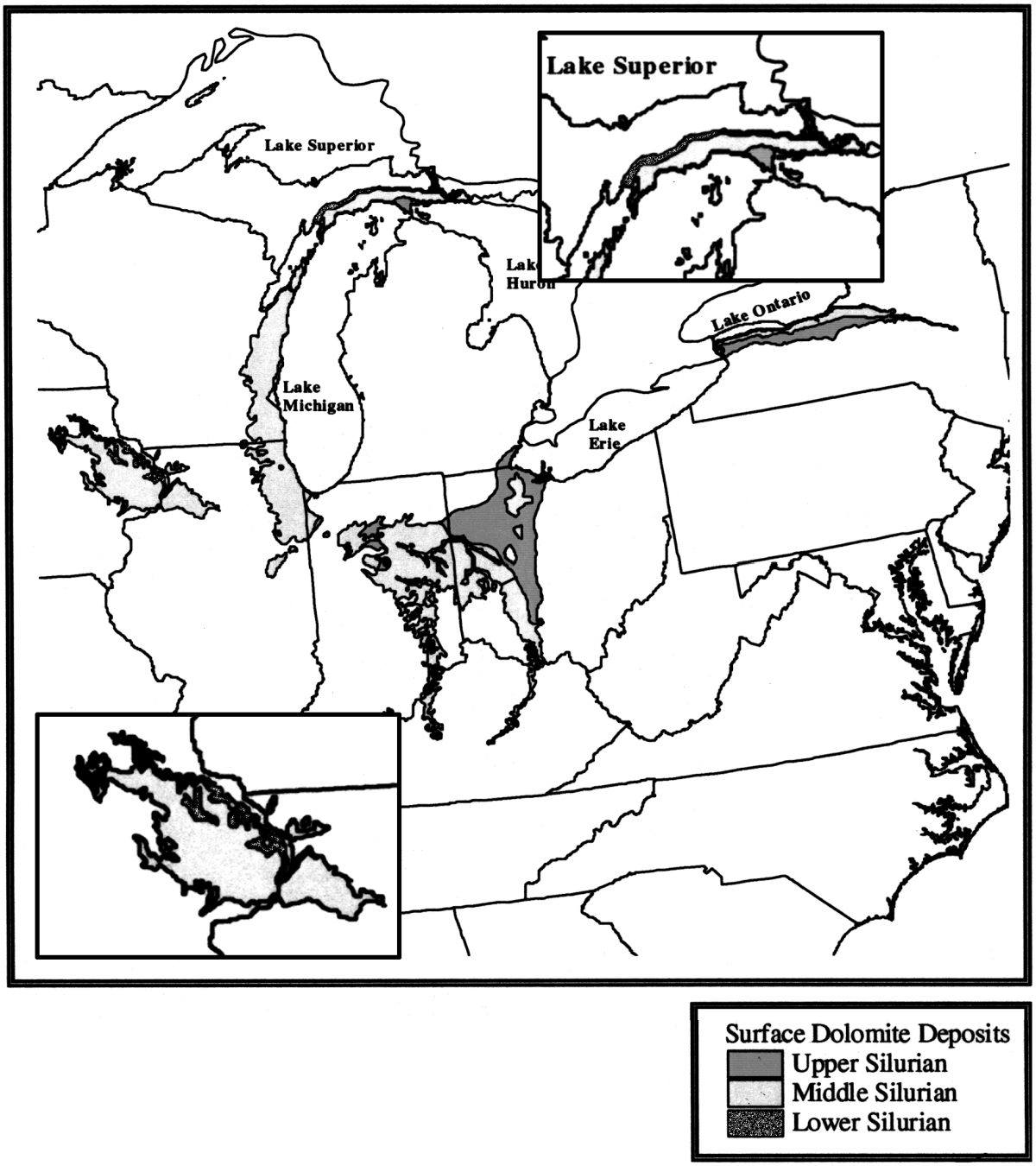

Table 3. Odonates indicative of Hine's emerald dragonfly habitat. The listed odonate species are indicative of areas where *S. hineana* may be found. These species can aid in identifying suitable *S. hineana* habitat. This table is not a complete list of odonate species associated with *S. hineana*.

	Illinois	**Wisconsin**	**Michigan**
ANISOPTERA - DRAGONFLIES			
Aeshnidae - Darners			
Aeshna canadensis		X	X
Aeshna constricta	X		
Aeshna sitchensis			X
Aeshna umbrosa	X	X	X
Aeshna verticalis			X
Corduliidae - Green-eyed Skimmers			
Epitheca (Tetragoneuria) canis		X	
Somatochlora forcipata			X
Somatochlora incurvata			X
Somatochlora kennedyi			X
Somatochlora walshii		X	X
Somatochlora williamsoni		X	X
Libellulidae - Common Skimmers			
Leucorrhinia hudsonica			X
Leucorrhinia proxima			X
Libellula semifasciata	X		
Nannothemis bella			X
Sympetrum costiferum		X	X
Sympetrum danae		X	X
Sympetrum rubicundulum	X	X	
Sympetrum semicinctum	X	X	
ZYGOPTERA - DAMSELFLIES			
Lestidae - Spreadwing Damselflies			
Lestes dryas	X	X	X
Lestes forcipatus	X		X
Lestes unguiculatus	X		
Coenagrionidae - Narrow-winged Damselflies			
Amphiagrion saucium	X		X
Chromagrion conditum		X	

APPENDIX 4

Water chemistry from Hine's emerald dragonfly sites

This table presents the water chemistry from known and potential larval habitat sites in Illinois and Wisconsin as reported in Soluk *et al.* (1998). Sampling occurred between 24 July 1996 and 22 July 1997. In Illinois, sampling usually occurred monthly, and in Wisconsin, sampling occurred between May and November. Parameters are presented in ranges. No attempt was made to analyze this data to determine reasons for unusually high or low values. Sampling may have occurred after rain or snow events that would alter the normal chemical parameters, especially the turbidity and alkalinity. An "n" represents the number of samples taken for each test. Water chemistry for Hine's emerald dragonfly sites are also presented in the following reports: Cashatt *et al.* 1991, Cashatt and Vogt (1992), Lin *et al.* (1993), Vogt and Cashatt (1994), Midwest Environmental Services (1995), Mierzwa *et al.* (1995b), Soluk and Swisher (1995), Soluk *et al.* (1996,1998), and TAMS (1997).

Parameter	n	Range of Values for Illinois Sites	n	Range of Values for Wisconsin Sites
pH	95	6.26 - 8.13	12	7.17 - 7.92
Dissolved Oxygen (mg/L)	86	0.46 - 20.42	12	4.17 - 11.74
Salinity (%)	95	0.02 - 0.59	12	0.01 - 0.03
Specific Conductance (mMHOS)	95	230 - 1720	12	168 - 735
Turbidity (NTU)	86	0 - 523	9	0 - 8
Water Temperature (C)	86	3.00 - 24.90	12	5.90 - 17.30
Nitrate (mg/L)	95	<DL - 18.50	12	<DL - 0.25
Chloride (mg/L)	95	15.10 - 138.00	12	0.59 - 35.20
Hardness (mg/L)	95	119.71 - 693.88	12	166.90 - 432.76
Total Alkalinity (mg/L)	87	85.7 - 409	12	149 - 420
Calcium (mg/L)	95	27.4 - 153.0	12	37.8 - 102.0
Iron (mg/L)	95	<0.01 - 1.28	12	<0.01 - 0.67
Lead (mg/L)	95	<0.04 - <0.05	12	<0.04 - <0.05
Magnesium (mg/L)	95	12.4 - 75.7	12	17.6 - 44.8

APPENDIX 5

Rare species associated with Hine's emerald dragonfly

An annotated list of Federal and state rare, threatened, and endangered species known to occur within or located near areas inhabited by *S. hineana*. State status is presented only if the species is known to occur within or located near *S. hineana* sites. Definitions of abbreviations and references follow the table.

Species Name	Common Name	Federal Status	G Rank	Illinois Status	Wisconsin Status	Michigan Status
Plants						
Amelanch1ier interior	Shadbush		G5	E		
Arenaria patula	Slender sandwort		G4	T		
Arethusa bulbosa	Swamp pink		G4		SC	
Calamagrostis stricta ssp inexpansa	New England northern reed grass		G5		SC	
Calamintha arkansana	Low calamint		G5		SC	
Calopogon tuberosus	Grass pink orchid		G5	E		
Calypso bulbosa	Calypso orchid		G5		T	
Cardamine pratensis	Cuckooflower		G5		SC	
Carex capillaris	Hair-like sedge		G5		SC	
Carex concinna	Beautiful sedge		G4G5		T	
Carex garberi	Elk sedge or Garbers sedge		G4		T	
Carex gynocrates	Northern bog sedge		G5		SC	
Carex livida var radicaulis	Livid sedge		G5T5		SC	
Carex scirpoidea	Bullrush sedge		G5			T
Carex tuckermanii	Tuckman's sedge		G4	E		
Carex weigandii	Weigand's sedge		G3			T

APPENDIX 5 Continued

Rare species associated with Hine's emerald dragonfly

Species Name	Common Name	Federal Status	G Rank	Illinois Status	Wisconsin Status	Michigan Status
Plants						
Cypripedium arietinum	Ram's head lady's slipper		G3		T	
Cypripedium candidum	White's lady's slipper orchid		G4	T	T	
Cypripedium reginae	Showy lady's slipper		G4		SC	
Dalea foliosa	Leafy prairie clover	E	G2G3	E		
Deschampsia cespitosa	Tufted hairgrass		G5		SC	
Eleocharis pauciflora	Few flowered spike rush		G5		SC	
Eleocharis rostellata	Beaked spike rush		G5	T	T	
Empetrum nigrum	Black crowberry		G5			T
Equisetum palustre	Marsh horsetail		G5		SC	
Equisetum variegatum	Variegated horsetail		G5		SC	
Erigeron hyssopifolius	Hyssop-leaved fleabane		G5			T
Erythronium americanum	Adder's tongue		G4T5		SC	
Geocaulon lividum	Northern comandra		G5		E	
Hymenoxys acaulis var glabra	Lakeside daisy	T	GU	E		PE
Iris lacustris	Dwarf lake iris	T	G3		T	
Leucophysalis grandiflora	Large flowered ground cherry		G3?		SC	
Liatris scariosa var nieuwlandii	Blazing star		G5?TU	T		

APPENDIX 5 Continued

Rare species associated with Hine's emerald dragonfly

Species Name	Common Name	Federal Status	G Rank	Illinois Status	Wisconsin Status	Michigan Status
Plants						
Muhlenbergia richardsonis	Mat muhly		G5		E	T
Orobranche uniflora	One-flowered broomrape		G5		SC	
Pinguicula vulgaris	Butterwort		G5		E	SC
Plantanthera dilatata	White bog orchid		G5		SC	
Plantanthera hookeri	Hooker's orchid		G5		SC	
Plantanthera orbiculata	Round leaved orchid		G5?		SC	
Primula mistassinica	Bird's eye primrose		G5		SC	
Pterospora andromeda	Pine-drops		G5		E	T
Ribes hudsonianum	Northern black currant		G5		SC	
Scirpus cespitosus	Tussock bulrush				T	
Selaginella selaginoides	Low spike moss		G5		E	
Solidago ohioensis	Ohio goldenrod		G4		SC	
Solidago houghtonii	Houghton's goldenrod	T	G3			T
Solidago sempervirens	Seaside spurge		G5?		SC	
Solidago simplex var gillmanii	Sticky goldenrod		G5T3		T	
Sphaeralcea angusta	Globe mallow		G?Q	E		

APPENDIX 5 Continued

Rare species associated with Hine's emerald dragonfly

Species Name	Common Name	Federal Status	G Rank	Illinois Status	Wisconsin Status	Michigan Status
Plants						
Tanacetum bipinnatum spp huronense	Lake Huron tansy		G3		E	T
Tomanthera auriculata	Earleaf foxglove		G3	T		
Triglochin maritimum	Common bog grass		G5		SC	
Triglochin palustre	Slender bog arrow grass		G5	T	SC	
Trilochin palustris	Arrow-grass		G5	E		
Trisetum melicoides	Purple false oats		G4		E	
Veronica scutlellata	Marsh speedwell		G5	T		
Viola canadensis	Canada violet		G5	E		
Animals						
Buteo lineatus	Red-shouldered hawk		G5	T	T	
Chromagrion conditum	Aurora damselfly		G5		SC/N	
Clemmys guttata	Spotted turtle		G5	E		
Clonophis kirtlandii	Kirtland's snake		G2	T		
Cordulagaster obliqua	Arrowhead spiketail		G4		SC/N	
Epiaeschna heros	Swamp darner		G5		SC/N	
Euphyes bimacula	Two spotted skipper		G4		SC/N	
Euphyes dion	Dion skipper		G4		SC/N	
Gallinula chloropus	Common moorhen		G5	T		
Gavia immer	Common loon		G5			

APPENDIX 5 Continued

Rare species associated with Hine's emerald dragonfly

Species Name	Common Name	Federal Status	G Rank	Illinois Status	Wisconsin Status	Michigan Status
Animals						
Ixobrychus exilis	Least bittern		G5	T		
Lutra canadensis	River otter		G5	T		
Pandion haliaetus	Osprey		G5		T	T
Podilymbus podiceps	Pied-billed grebe		G5	T		
Rallus elegans	King rail		G4G5	E		
Trimerotropis huroniana	Lake Huron locust		G5			T
Somatochlora incurvata	Warpaint emerald dragonfly		G2G3			SC

Appendix 5 Continued

Definitions of abbreviations used

E	Federal and/or state listed endangered
T	Federal and/or state listed threatened
SC	State special concern
SC/N	State special concern: no laws regulating use, possession, or harvesting
PE	Proposed for endangered status

G Rank (Global Rank): The Nature Conservancy's global conservation status rank

G1	Critically imperiled globally because of extreme rarity or because of some factor(s) making it especially vulnerable to extinction. Typically five or fewer occurrences or very few remaining individuals (<1000).
G2	Imperiled globally because of extreme rarity or because of some factor(s) making it especially vulnerable to extinction. Typically 6 to 20 occurrences or few remaining individuals (1,000 to 3,000).
G3	Vulnerable globally either because very rare and local throughout its range, found only in a restricted range (even if abundant at some location), or because of other factors making it vulnerable to extinction. Typically 21 to 100 occurrences or between 3,000 and 10,000 individuals.
G4	Uncommon but not rare, and usually widespread. Possibly cause for long-term concern. Typically more than 100 occurrences globally or more than 10,000 individuals.
G5	Common, typically widespread and abundant.
G#G#	A numeric range rank is used to indicate uncertainty about the exact status of taxon.
?	Denotes inexact numeric rank.
Q	Questionable taxonomy that may reduce conservation priority.
T	The status of infraspecific taxa (subspecies or varieties) are indicated by a "T-rank" following the species' global rank. Rules for assigning T-ranks follow the same principles outlined above. For example, the global rank of a critically imperiled subspecies of an otherwise widespread and common species would be G5T1.
U	Do not know how to rank.

Data compiled from information provided by the Illinois Department of Natural Resources, Wisconsin Department of Natural Resources, and Michigan Natural Features Inventory.

APPENDIX 6

Agency and public comment on the draft plan

Summary of Agency and Public Comment on the Hine's Emerald Dragonfly Technical/Agency Draft Recovery Plan

In July 1999, the U.S. Fish and Wildlife Service (Service) released the Technical/Agency draft recovery plan for the Hine's emerald dragonfly for review and comment by Federal agencies, state and local governments, and members of the public. The comment period ended on September 13, 1999. Thirty-eight letters commenting on the draft were received. In the time since the comment period closed, additional comments and information or updates to the plan have been received by the Service. These comments have also been considered and reflected in the approved recovery plan.

This section provides a summary of general information about the comments the Service received during the comment period, including the number of letters from various sources. Fourteen odonatists provided peer review comments. Three of the letters were from state conservation agencies, one letter was received from a state department of transportation. Three letters were received from county forest preserve districts. Two letters were submitted on behalf of a private industry. Fourteen letters were received from residents, organizations, and municipalities in Door County, Wisconsin. One letter was received from a professional in the field commenting as a private citizen. Each letter contained one or more comments. Some letters raised similar issues. Most letters requested explanation of various points made in the draft plan and included suggestions for clarity, other information sources, or future research, or shared lessons learned from their own conservation experience. A few letters provided updated information on population occurrences. Many Door County, Wisconsin residents expressed strong support for the conservation of this species and associated wetland ecosystems, and surface and groundwater resources. Many peer reviewers commented on the thoroughness, usefulness, and sound documentation of the plan. Most comments were incorporated into the approved recovery plan. Information and comments not incorporated into the approved plan were considered and noted. Significant comments that were not incorporated or that require clarification in addition to their incorporation are addressed below.

Summary of Comments and Service Responses

Comment: Many commenters expressed concern that the "total cost of recovery," estimated at around ten million dollars, is unrealistic and unlikely to ever be allocated to the conservation measures proposed in the plan. One citizen expressed opposition to spending so much on a dragonfly.

Response: The total cost of recovery is calculated by adding up the estimated costs of every recovery task described in the plan, for a period of 10 years. The amount of the overall price tag attached to recovery of the Hine's emerald dragonfly may be misleading, for several reasons.

Some of the tasks included in the plan are actions that are ongoing, and are already incorporated into the budgets of the necessary agencies. For example, management of many of the natural areas supporting the dragonfly on county forest preserve district lands is already allocated in the district budgets. In addition, many of the estimated recovery costs, such as land acquisition, represent the entire cost of an action that will benefit not just the dragonfly, but a whole natural community or preserve. It is true that there are many endangered species and that the budget of the Service is inadequate to accomplish the needed recovery tasks, but it is the responsibility of the Service to identify actions that, if taken, would recover this species. The Service works with other government agencies, conservation organizations, private industry and individual landowners, to seek funding or support to accomplish recovery of these species. Actions to conserve the Hine's emerald dragonfly have already been funded by diverse entities such as the Wisconsin Department of Natural Resources, The Nature Conservancy, Material Service Corporation and Commonwealth Edison.

Comment: Several reviewers addressed the requirement that a subpopulation contain at least 500 adults before it is counted toward meeting the recovery criteria. It was suggested that this number seems arbitrary, is too large, and will not be easy to satisfy.

Response: The number 500 is based on the best available information and theory found in the conservation biology literature on minimum viable population size. The number does not seem unreasonable when compared with the population estimates at some of the larger sites, which figure in the thousands. Several comments seemed to address the number of individuals that would likely be seen at a site at a given time, and that 500 seems inordinately large by that standard. The text that accompanies the recovery criteria has been rewritten to clarify what is meant by a population of 500 adult dragonflies. The text emphasizes that the number 500 is meant to represent the annual brood of dragonflies that emerge as adults over a summer flight season and live long enough to mature sexually and be capable of producing offspring. It is expected that far fewer than 500 dragonflies will be observed on any given day and that census methods that estimate population size will be needed to determine whether or not a population meets this size criterion. The recovery outline and narrative include a task (Model population dynamics task 2.1.3) to work on population size estimation techniques for this species. It is also understood that population numbers will fluctuate from year to year, and intended that 500 sexually reproductive adults represents a threshold above which the population numbers should be fluctuating to meet this criterion.

Comment: Another general comment made in various forms by several reviewers was that the recovery criteria are too narrowly defined, and do not incorporate the possibility of reintroductions or the discovery of new populations.

Response: The criteria for reclassifying the status of this species from endangered to threatened have been rewritten in response to this comment to provide greater flexibility in determining whether the reclassification threshold has been crossed. The reclassification criteria establishes a certain number, size, sustainability and distribution of populations needed to consider this

species removed from the danger of extinction in the foreseeable future. The reclassification criteria attempt to describe a population status that would meet this goal. Recognizing that there can be trade-offs between different elements that contribute to the security of the species, such as between the number and the arrangement of populations, additional flexibility has been incorporated into the reclassification criteria. At present, this additional flexibility has not been incorporated into the criteria for eventually delisting the species from the protection of the Act. The recovery task 2.1.3 Model population dynamics, is intended to address this by generating information that could be used to determine which alternative combinations of the required components mentioned above provide equivalent long term security and sustainability. In addition, if further research provides new information that justify changing one of these required components, for example information on the distances that Hine's emerald dragonfly will travel between sites, the recovery criteria can be revised to reflect that.

Comment: Several commenters, aware that new population occurrences were discovered during the open comment period, suggested that the plan be updated to provide information on the new sites, and to discuss changes to the approach outlined in the draft for searching for new populations.

Response: The approved plan has been updated to incorporate new information on the Hine's emerald dragonfly populations discovered during the open period for submitting comments on the draft plan. In addition, the implications of the new sites were considered in terms of the distribution of populations required by the recovery criteria, resulting in the increased flexibility incorporated into the criteria as discussed above. The new population survey tasks in the implementation schedule have also been revised to reflect the need to search more broadly for this species.

Comment: One commenter suggested that the Service waive collecting permits for Hine's emerald dragonfly specimens collected from new sites, and another commenter recommended that more people be "deputized" to search for new populations.

Response: Activities that may result in the death or injury of any wildlife species listed as threatened or endangered are unlawful unless authorized by a permit issued by the Service under the Endangered Species Act. Since accurate identification of Hine's emerald dragonfly adults requires netting and handling, the potential for harm to the dragonfly exists and permits are required. Permit applications may be received by calling regional or field Service offices.

Comment: Two commenters suggested that the Service consider reclassifying the status of the Hine's emerald dragonfly from endangered to threatened, based on the new sites discovered in 1999 and the potentially greater range of the species.

Response: Though additional populations have been discovered since the Hine's emerald dragonfly was listed, the known populations still do not meet the criteria for reclassifying the

status of the species from endangered to threatened. In addition, many of the known sites that support this species remain threatened by development or by degradation of the groundwater supply supporting its unique habitat.

Comment: Many commenters emphasized the need for guidelines for habitat management practices at sites that support this species. Issues of concern include the use of herbicides, prescribed burns, and threats to native plant communities from aggressive non-native plant species. Commenters variously recommend very conservative management, express concern that misplaced caution would prevent needed management such as prescribed burns, suggest an adaptive management strategy, and advocate funding research to guide management plans. One commenter suggested that evaluation of current management practices be a Priority 1 task.

Response: The approved recovery plan does not include guidelines for management of sites supporting the Hine's emerald dragonfly because empirical data to determine appropriate management practices do not currently exist. A conservative approach to natural areas management is often recommended, yet the "no action" alternative may have severe adverse impacts to the species at some of these sites. For example, we lack the data needed to balance the threat to the species from loss of habitat degraded by aggressive non-native vegetation, with the potential harm to the species if the herbicides used to control the non-native vegetation were to contaminate its habitat. Fire is a historical component of some of the natural communities where the Hine's emerald dragonfly resides, and prescribed burns are an important tool for maintaining these habitats, yet questions about the appropriate frequency and extent of these burns remain. Addressing these questions is extremely important for the continued conservation of this species. Recovery task 2.5.1 "Evaluate responses to habitat management practices" has been changed to Priority 1 from Priority 2 to reflect this urgency.

Comment: One commenter asked whether the habitat restoration work funded by a quarry operator was successful in creating new habitat.

Response: The work reduced brush encroachment in the natural area but was probably neutral in terms of impacts to Hine's emerald dragonfly larval habitat in the spring fed seeps.

Comment: One commenter asked whether brush clearing and burning pose a risk by eliminating sites for perching, roosting and copulation.

Response: Forest edges, brush, or small trees in some proximity to larval habitat appear to be important, based on observations of Hine's emerald dragonflies using those habitat features. These habitat features exist at or near many of the sites being managed by brush clearing and burning. This is another habitat management question that could be addressed by task 2.5.1.

Comment: One commenter asked whether cattail marshes should be a desirable or mandatory habitat component, and stated that cattail invasion can be "deleterious or catastrophic" to natural areas.

Response: The habitat requirements section of this plan describes cattail marshes as an existing component of sites that support the Hine's emerald dragonfly. Essential reproductive behaviors, such as egg laying, larval foraging, and adult emergence, occur in the cattail-dominated areas of the dolomite prairie, wet meadow, and marsh complexes where the Hine's emerald dragonfly survives in Illinois. The relative importance of the species composition and/or habitat structure in these areas is not clearly understood. References in the plan to larval habitat structure have been modified to emphasize the importance of the presence of a thatch and detritus layer of decaying vegetation rather than the species composition of the parent plant material.

Comment: One commenter recommended that the approved plan contain language that "privately controlled sites that harbor the Hine's emerald dragonfly would be considered for additional protection on a strictly "voluntary basis," and that private landowners be included in all discussions of implementation strategies."

Response: The Endangered Species Act prohibits "take" of an endangered species, including harm through actions that degrade or destroy habitat used by an endangered species for necessary life functions, such as foraging, roosting, and reproducing. Compliance with this take prohibition is mandatory. The additional actions outlined in this recovery plan, to recover the species by managing and improving habitat, are voluntary.

Comment: Two commenters questioned why the plan lacks specific habitat restoration recommendations. One commenter contended that the presence of Hine's emerald dragonflies at a restored site adjacent to an existing population in Illinois shows that the species is able to quickly colonize even less than pristine habitat as long as it is near existing population structures, has suitable hydrology, and has suitable vegetation structure.

Response: The plan does not include specific habitat restoration guidelines or recommendations because the Service is not aware of any site to date that has been restored to fully support the life requirements of the Hine's emerald dragonfly. Though adults are frequently observed foraging along roadways, railroad tracks, and other far from pristine habitats, the used of a previously degraded site for successful production of a brood through emergence from the larval stage into adult dragonflies is not known to the Service. This species appears to require very specific and unique habitats, the exact components of which are not completely understood. One component that appears important is the shallow surface water fed by springs or groundwater. If this is the case, hydrological restoration of a degraded site would be far more difficult than is true for systems supported simply by surface water. However, the plan certainly does not preclude nor is intended to discourage restoration attempts. As noted by one commenter, the Midewin National Tallgrass Prairie, located south of the Illinois populations along the Des Plaines River, may provide restoration opportunities.

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