ISSN 1061-3781

BULLETIN OF AMERICAN

ODONATOLOGY

Volume 5 Number 3
20 November 1998

THE DRAGONFLY SOCIETY OF THE AMERICAS

Business address: c/o T. Donnelly, 2091 Partridge Lane, Binghamton NY 13903

JOURNALS PUBLISHED BY THE SOCIETY

ARGIA, the quarterly news journal of the **DSA**, is devoted to non-technical papers and news items relating to nearly every aspect of the study of Odonata and the people who are interested in them. The editor especially welcomes reports of studies in progress, news of forthcoming meetings, commentaries on species, habitat conservation, noteworthy occurrences, personal news items, accounts of meetings and collecting trips, and reviews of technical and non-technical publications. Articles for publication in **ARGIA** should preferably be submitted as hard copy and (if over 500 words) also on floppy disk (3.5" or 5.25"). The editor prefers MS DOS based files, preferably written in WORD, WORD for WINDOWS, WordPerfect, or WordStar. Macintosh WORD disks can be handled. All files should be submitted **unformatted and without paragraph indents**. Each submission should be accompanied by a text (=ASCII) file. Other languages should be submitted only as text (=ASCII) files. Line drawings are acceptable as illustrations.

T. Donnelly (address below) is the interim editor of **ARGIA.**

BULLETIN OF AMERICAN ODONATOLOGY is devoted to studies of Odonata of the New World. This journal considers a wide range of topics for publication, including faunal synopses, behavioral studies, ecological studies, etc. The **BAO** publishes taxonomic studies but will not consider the publication of new names at any taxonomic level. Enquiries and submission of manuscripts should be made to **BAO** editor T. Donnelly, 2091 Partridge Lane, Binghamton NY 13903. Final submissions (after review) should be made on floppy disk, as above, with illustrations in final form and preferably adjusted to final size.

MEMBERSHIP IN THE DRAGONFLY SOCIETY OF THE AMERICAS

Membership in the **DSA** is open to any person in any country. Dues for individuals in the US, Canada, or Latin America are $15 for regular membership and $20 for contributing membership, payable annually on or before 1 March of membership year. Dues for members in the Old World are $20. **ARGIA** is mailed Air Mail outside of the US and Mexico, and First Class in those countries.

The **BULLETIN OF AMERICAN ODONATOLOGY** is available by a separate subscription at $15 for members and $18.75 for non-members and institutions.

ADAPTING THE TOWNES MALAISE TRAP FOR COLLECTING LIVE ODONATA[1]

Robert C. Glotzhober and Dan Riggs
Ohio Natural History Society, 1982 Velma Ave., Columbus OH 43211-2497

ABSTRACT

The Townes lightweight malaise trap has long been used to collect a variety of insects. We have expanded upon modifications made to these traps by other workers in recent years, making them functional for live capture of large Odonates for mark and recapture studies.

INTRODUCTION

Henry Townes designed a small, lightweight malaise trap for capturing insects (1972). This trap is made of dacron netting with 25 meshes per inch. The assembled trap is approximately 2 meters high at the upper end and 2 meters long, with baffles on each end and a single collecting head. The standard Townes trap uses a one pint (apx.473 ml) nalgene plastic jar collecting head with an opening from the net to the jar about 2.25 inches (5.72 cm) in diameter. A second nalgene plastic jar is attached below the upper jar to hold alcohol or other preservative / killing agent and the trapped insects. Several workers have collected Odonata in unmodified or slightly modified malaise traps (Johnson et al., 1995; Roble, 1995; Muzón et al., 1995; and Flint, 1996). In most cases these were incidental to collecting other insects. Flint (1996) reported that malaise traps he set routinely collected damselflies and small dragonflies, and, rarely a large dragonfly hanging from the fabric inside the trap.

John Shuey and David Banks of the Indiana Field Office of The Nature Conservancy used malaise traps to collect a variety of Odonata at the Pigeon River wetlands in northeastern Indiana during the summer of 1995. Their traps used a large opening into a gallon-sized upper collecting head, with an alcohol-filled lower head. In 1992 and 1993 Johnson and Kovarik (Johnson, et al., 1995) used a Townes malaise trap with the lower head replaced by a fine-meshed bag to capture live adult specimens of the rare *Merope tuber* Newman (Mecoptera: Meropeidae). While collecting, they incidentally collected several ***Cordulegaster erronea*** Hagen, 1878, also very rare in Ohio as well as in other parts of its range in the eastern United States. Previous to these collections, there had been only seven records of ***C. erronea*** in Ohio. We spent one unsuccessful season trying to duplicate the success of Johnson and Kovarik in collecting ***C. erronea***. The major reason for lack of success was that the highly restrictive habitat for this species had not been clearly identified. During the summer of 1996 we returned to the precise location used by Johnson and Kovarik in 1992 and 1993, and subsequently determined the correct habitat for this rare dragonfly (Glotzhober & Riggs, 1996). Riggs continues a study to define the parameters of the larval habitat of ***C. erronea***, while Glotzhober is working on mark and recapture studies with the adults. Adult ***C. erronea*** are large, having a body length measuring 65-76 mm, and hind wings 42-51 mm (Needham & Westfall, 1955), and they fly long stretches of streams at irregular intervals. Capturing this species both efficiently and undamaged required modifications to the standard Townes trap.

TRAP MODIFICATIONS

Two series of changes were made to the standard Townes lightweight malaise traps. Debbie H. Focks of the John W. Hock Company, Gainesville, Florida, did some of these design changes under our direction. John Shuey of the Indiana Field Office of The Nature Conservancy, who was also experimenting with these traps for collecting Odonata, suggested the first change to us. They replaced the pint jars with one-gallon jars (3.8 liter) with the opening into the jar from net 3 inches in diameter (7.62 cm). We used traps with the one-gallon collecting heads in 1996. Our modified traps have a 3.5-inch (8.89-cm) diameter opening. Figure 1 shows the parts

[1] Bulletin of American Odonatology, 1998, 5(3): 43-48

modifications made from Townes (1972. Townes' Figure 2 is reproduced here as Figure 4.). The first time we successfully captured specimens, we realized that they did not survive well, even overnight, inside the doubled one-gallon jars. Dropping into the lower collecting jar, the dragonflies could not gain a foothold and battered their wings. The double-jar head also was prone to excessive humidity causing the dragonflies to become saturated with dew. We therefore replaced the lower collecting head jar with an old, worn out 12-inch diameter "student" insect net bag, cutting the bottom of the bag to connect to the jar mouth (Figure 2). The opening of the bag hung down, and was kept open with a standard net rim wire. To close off the normal opening, we sewed a large, circular piece of cotton muslin fabric across the opening. This gave us a large, well-vented net to contain trapped insects, and also provides plenty of room for the dragonflies to perch on the sides of the net. We have subsequently replaced the modified student nets with similar bags using elastic necks made by the John W. Hock company.

TRAP INSTALLATION AND LOCATIONS

The malaise traps were set up using expandable tent poles on each end, and tent stakes on the various guy ropes leading to the ground. The trap should be installed across a narrow flight path, in our case across narrow streams. For our target species, ***C. erronea***, this meant streams often less than one foot wide and from a fraction of inch to three inches deep. These were typically in narrow ravines near the headwaters of small streams. Shuey and Banks (personal communication) set a single trap across small streams in fen meadows that they were studying. Caution should be taken to make sure these flight paths do not also serve as runways for deer. Shuey and Banks had their trap shredded by a deer that became entangled in it. We have tried to locate places away from deer trails or, if that was not possible, we made an effort to leave human scent near the trap and on trails leading to it. With two traps set during 1996 (one for several months continuously) and five traps set during 1997 (four for 21 days, another for three full months) we have had no deer damage. It appears that the Odonates we captured were either males patrolling territory along the stream or females searching for oviposition sites. In both cases, the species we have worked with fly low. The bottom edge of the was kept as close as possible to the surface of the water. Despite this, Riggs observed one ***C. erronea*** (sex unknown) wiggle under the bottom of the net and continue along the stream. Despite many successful captures, each of us observed a number of individuals fly up to the net, back off, fly over the top, and continue upstream. Glotzhober followed one male ***C. erronea*** that avoided the net in this manner. Twenty yards upstream of the trap, a large boulder had rolled into the ravine and laid above the stream with very little clearance. The male flew within a few inches of the overhanging boulder, backed up, then flew over the boulder and continued upstream. This behavior is likely commonly used by ***C. erronea*** to avoid boulders and tree-falls blocking the stream - both of which are common in its habitat.

RESULTS WITH MODIFIED MALAISE TRAPS

Shuey and Banks collected from several small fens in LaGrange County in northeastern Indiana. During a single summer they collected 14 species of Odonata in the malaise trap (Table 1, identifications by the senior author and R. A. Restifo, Ohio Department of Health),

species	N
Calopteryx maculata	12
Amphiagrion sauicum	13
Enallagma ebrium	1
Ischnura posita	4
Ischnura verticalis	9
Aeshna umbrosa	1
Gomphus exilis	1
Cordulegaster bilineata	5
Cordulegaster obliqua	3
Leucorrhinia intacta	2
Libellula lydia	6
Libellula pulchella	6
Sympetrum rubicundulum	3
Tramea lacerata	1

Table 1. Odonata taken in 1995 with malaise traps by The Nature Conservancy in LaGrange County, Indiana

supplementing other species which they collected with aerial nets. During the seasons of 1996 and 1997, we worked with our modified malaise traps at three sites: Wahkeena Nature Preserve, Clear

Creek Metro Park (both in Fairfield County, Ohio), and Crane Hollow Nature Preserve (in Hocking County, Ohio). During this period Glotzhober, Riggs, and Tom Shisler (the latter assisting us at Wahkeena Nature Preserve) captured 142 individuals of *C. erronea*. Of this number, four died in the traps the first year prior to replacing the gallon plastic collecting jar with the net bag. After this change was made, only two died in the traps, one of which was killed and collected after multiple handlings caused significant wing damage. An additional four specimens were uninjured in the traps, but collected as voucher specimens. Discounting the first four, and the second four collected by choice, the traps resulted in a loss of 2 individuals from 134 total. This equals a known loss of about 1.5 percent of the individuals captured. Sixty-six (66) individuals were captured more than once, with a number of individuals captured 6 or 8 times, with a total number of captures at 281. The known survival times for individuals reached up to 34 days from initial capture. Of the total of 142 captures of *C. erronea* in malaise traps, 115 were males and 27 were females (Table 2). More information on

Site, Year	N ♂	N ♀	Total N
Barnaby, 1996	8	-	8
Crane Hollow, 1996	6	--	6
Wahkeena, 1996	26	10	36
Wahkeena, 1997	15	5	20
* Crane Hollow, 1997	60	12	72
Column Totals =	115	27	142

* In 1997, 4 malaise traps were used simultaneously in different side hollows of Crane Hollow for 21 consecutive days. After a 2 week pause, one trap was used for 5 additional days.

Table 2. Sex ratios of ***Cordulegaster erronea*** in malaise traps.

C. erronea will be published after the end of our ongoing study. The location of our malaise traps during most of 1996 and all of 1997 was selected specifically for *C. erronea*. Visual inspection of these locations seldom showed any other Odonates present. The long-term use of these traps, however, resulted in the collection of a number of other Odonates (Table 3). Three species were collected in two of the four malaise traps at Crane Hollow Nature Preserve Nature Preserve during 1997. All of these were females, including ***Cordulegaster obliqua, Somatochlora tenebrosa***, and the only female ***Tachopteryx thoryei*** that either author had ever collected.

Species	Number/Sex	Location	Year
Cordulegaster obliqua	1 ♀*	Crane Hollow	1997
Somatochlora tenebrosa	4 ♀♀	Crane Hollow	1997
Stylurus laurae **	5 ♀♀/ 1 ♂	Wahkeena	1996
Tachopteryx thoreyi	1 ♂	Wahkeena	1997
Tachopteryx thoreyi	1 ♀	Crane Hollow	1997

* One other probable female of this species was in the same malaise trap, but escaped.
** This species was caught in a different habitat/location than others. See text.

Table 3. Other Odonata caught in malaise traps set for ***Cordulegaster erronea***.

Prior to our identification of the correct habitat for *C. erronea*, in 1996 at Wahkeena Nature Preserve, a malaise trap set on a small, 18-inch-wide tributary to a pond caught five females and one male Stylurus laurae, a species previously unknown for Wahkeena, and a rare inhabitant of the region. These findings, in addition to the species reported by Shuey and Banks, suggest that the modified malaise traps have significant potential in collecting a variety of Odonates. With the addition of the net-bag collecting head, the traps can be useful in live capture, mark and release projects.

ACKNOWLEDGEMENTS

The authors wish to thank the Ohio Division of Wildlife, Wildlife Diversity Program for funding to the Ohio Odonata Survey, and to the Ohio Biological Survey who coordinated portions of this multi-year grant. We also thank Bill and Jane Ellis of the Crane Hollow Nature Preserve Foundation for their support of portions of this project. We are indebted to Tom Shisler, area manager of the Wakeena Nature Preserve for his cooperation and help in checking the trap set at Wahkeena.

LITERATURE CITED

Flint, Oliver S. Jr., 1996, Odonata taken in malaise traps, with special reference to Virginia. Banisteria 8: 37 - 43

Glotzhober, Robert C. and Dan Riggs, 1996, ***Cordulegaster erronea*** finds in Ohio. ARGIA 8 (2): 4-5.

Johnson, N.F., P.W. Kovarik, and R. C. Glotzhober, 1995, Dragonflies in malaise traps. ARGIA 7 (1): 21-22.

Muzón, Javier and Gustavo R. Spinelli, 1995, Patagonian Odonata in Malaise traps. ARGIA 7(3): 22-23.

Needham, J.G. and M.W. Westfall Jr., 1955, A Manual of the Dragonflies of North America (Anisoptera), Berkeley California, Univ. of California Press, 615 p.

Roble, Steven M, 1995, Notes on Odonata records taken by David Smith with malaise traps in Virginia. ARGIA 7(2):3.

Townes, H., 1972, A light-weight malaise trap. Entomological News 83: 239-24

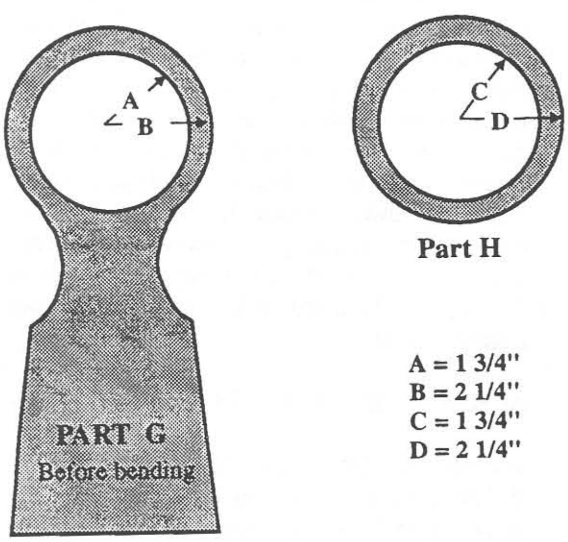

Figure 1. Patterns for the metal parts that connect to the collecting head in the new design. See Townes (1972, Figure 2) for the remainder of the parts and assembly directions.

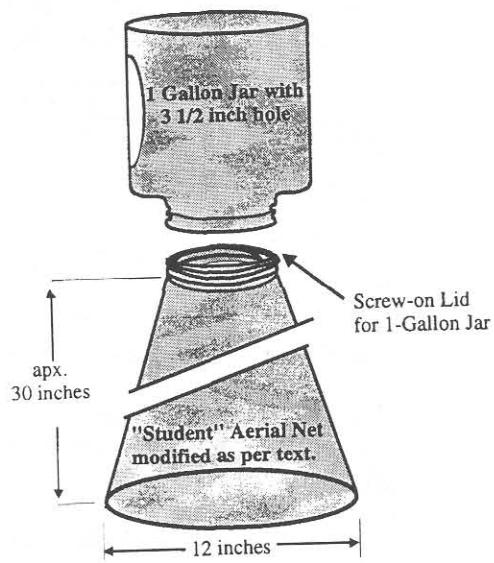

Figure 2. Net to replace lower collecting jar. The tip of the net is cut off, and sewn or glued to the screw cap for the gallon jar. The bottom of the net has a net ring inside to keep it open, and cotton muslin fabric sewn across the opening.

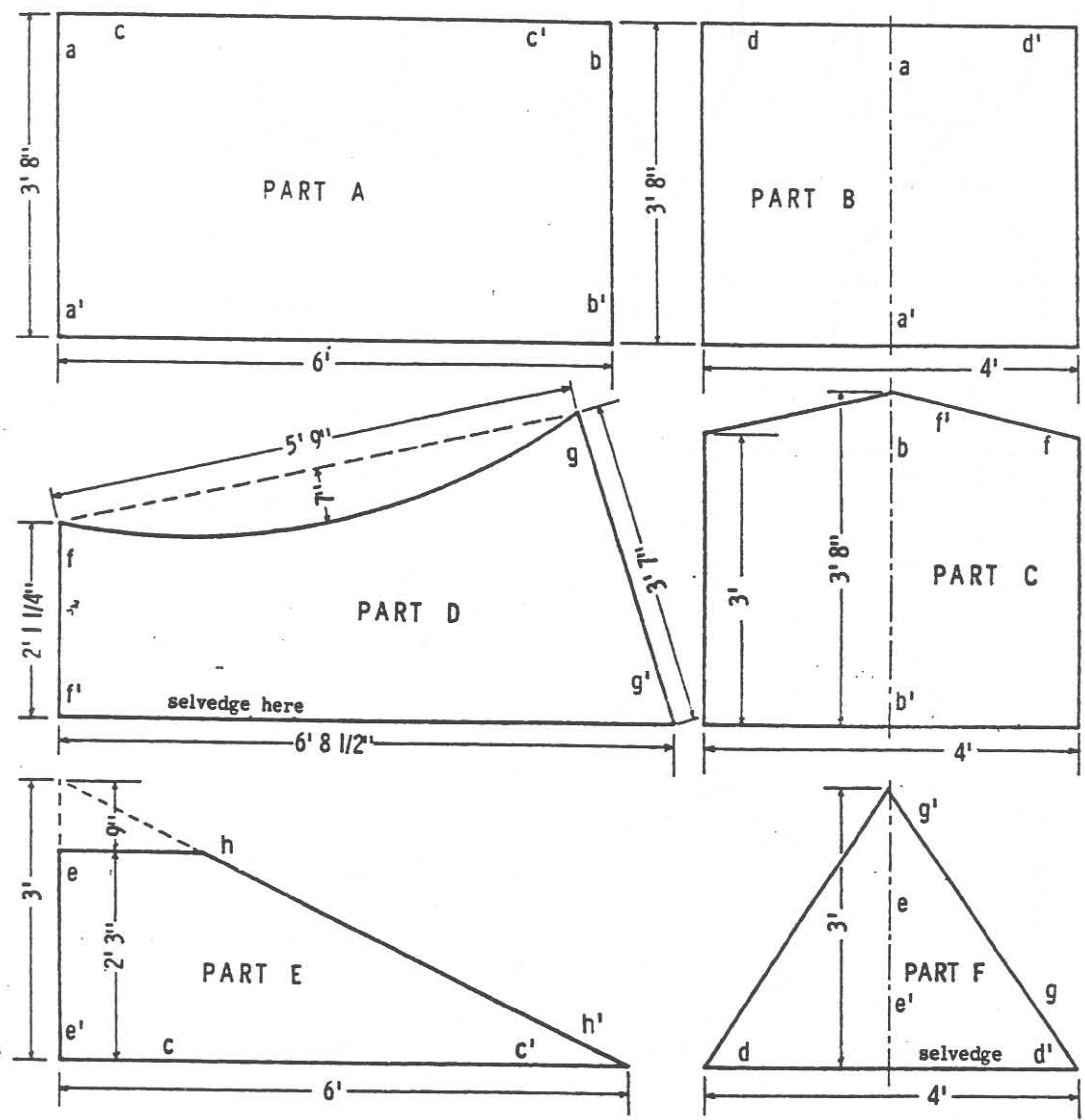

Figure 3. Patterns for the fabric parts of a Malaise trap. Reprinted from "Figure 1" in Townes (1972).

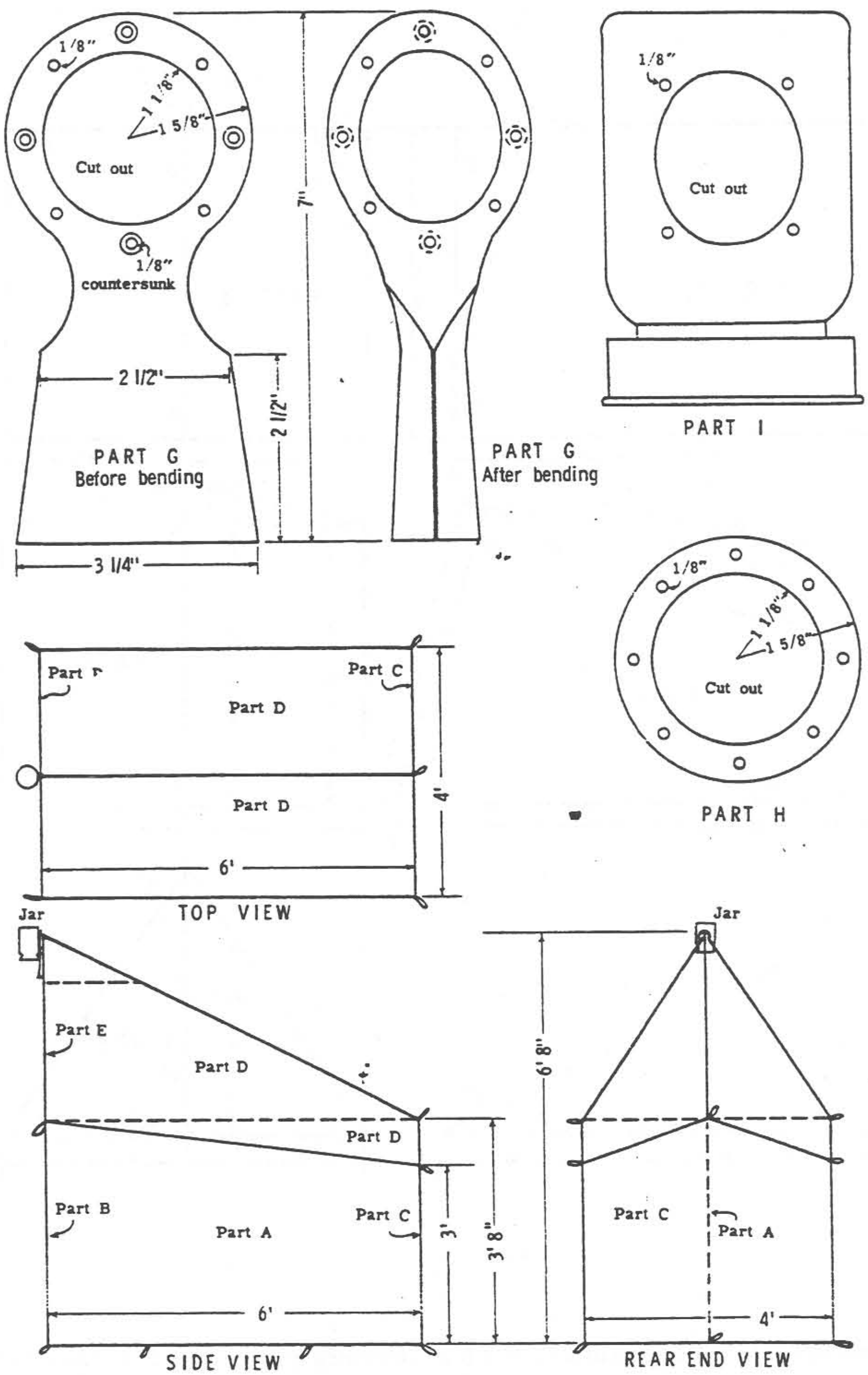

Figure 4. Patterns for the metal parts and modified plastic jar for a Malaise trap. Three views of the complete trap. Reprinted from "Figure 2" in Townes (1972).

ARCHILESTES GRANDIS (GREAT SPREADWING) IN CENTRAL NEW JERSEY, WITH NOTES ON WATER QUALITY[1]

David P. Moskowitz and David M. Bell

EcolSciences, Inc., 75 Fleetwood Drive, Suite 250
Rockaway, New Jersey 07866

ABSTRACT

Archilestes grandis has undergone extensive range expansion during this century. ***A. grandis*** has been documented in a wide variety of aquatic habitats often with varying degrees of degradation or contamination, and biotic indices for this species based on relative water quality tolerances tend to vary widely. Water quality data for ***A. grandis*** habitats is limited, particularly in the northeast. We evaluated various water quality parameters at three man-made aquatic habitats in central New Jersey that support ***A. grandis***. These evaluations and those of others suggest that ***A. grandis*** is very tolerant of water conditions generally considered "poor" by conventional water quality indices; this apparent tolerance of ***A. grandis*** to degraded water quality may explain its recent range expansion. The occurrence of this species in habitats generally depauperate in other, less tolerant odonate and other macroinvertebrate species may be a useful indicator of "poor" water quality in biotic "index" systems. Moreover, the facility with which the adult odonate community of an aquatic system can be characterized suggests, as other investigators of odonates have proposed, that "odonate metrics" would be ideal for the rapid biological assessment of such ecosystems.

INTRODUCTION

Archilestes grandis (Rambur), the Great Spreadwing damselfly, has undergone remarkable range expansion during this century. Early in the century, the species was apparently restricted to the southwestern United States, Central America, and northern South America (Needham, 1929; Gloyd, 1980). ***A. grandis*** was first recorded east of the Mississippi River in Ohio in 1927 (Williamson, 1931). Subsequent sightings included those in western Pennsylvania in 1935 (Ahrens, 1935), Washington, D.C., in 1949 (Donnelly, 1962), and Philadelphia in 1951 (Ferris, 1951). By the mid-1960's, ***A. grandis*** had been collected in New Jersey, and is now widely, but patchily, distributed in this state, with populations known from seven counties (May, 1996). The first New York record was established in 1992 (Blanchard, 1992) and, apparently, the species has also recently been collected in Vermont (pers. comm., Donnelly, 1996).

Throughout its range, ***A. grandis*** has been documented in a wide variety of habitats, including slow-moving forested streams with silt substratum (Orr, 1996a), rocky pools of streams or ponds (Tennessen *et al.*, 1995), pristine streams in Costa Rica (pers. comm.; Donnelly, 1996), permanent ponds or impoundments (Westfall and May, 1996), artificial ponds (Ingram, 1976), canals (Orr, 1996b), temporal bodies of water in open areas (pers. comm.; E. Esquivel, 1997), and drainage and irrigation ditches (pers. comm.; Donnelly, 1996). ***A. grandis*** is also often noted in waterbodies with varying degrees of degradation or contamination, including brooks adjacent to animal pens, open bodies of water with urban and industrial contamination (Ramirez, 1994), ponds subject to fish kills from agricultural runoff (Lasswell *et al.*, 1995), stream pools with high temperatures (pers. comm.; D. Huggins, 1997), and dirty creeks around cities and towns in Costa Rica (pers. comm.; C. Esquivel, 1997). The observations of Williamson (1931) on the habitat of ***A. grandis*** in Ohio are particularly illustrative:

> "There is a little brook which runs through the west side of the campus at the Western College, and which at its head is merely a draw. One branch of this draw goes back of some houses on the campus, and is apparently little more than a sewer; septic tanks are located on it. Another branch of the draw goes back into the Miami campus, and receives refuse liquids from the chemical laboratory and the power house. [the creek] never froze but "steamed" all winter...[and] the chemicals it carried killed all the goldfish, planted in the pool, several times."

Perhaps as a consequence of the sometimes patchy distribution of this species and its observed occurrence in a wide variety of aquatic habitats, "biotic index"

[1] Bulletin of American Odonatology, 1998 5(3): 49-54

systems based on relative water quality tolerances tend to attribute rather widely varying index values to this odonate. The biotic indices for *A. grandis* specifically, the genus *Archilestes*, and the family Lestidae are listed below as assigned by a range of federal and state resource agencies (all indices use a smaller numerical value to designate less tolerance of degraded water quality; the range of the particular index is indicated in parentheses following the index value). In all indices cited, the lower integer values indicate intolerance, and high integer values indicate tolerance.

EPA (1989) Rapid Biological Assessment (for family Lestidae) = 9 (scale of 1-10)

State of Illinois Environmental Protection Agency (1987) (genus *Archilestes*) = 1 (scale of 1-10)

State of Kansas Department of Health and Environment (1985) (for *A. grandis*, genus *Archilestes*) = 3 (scale of 1-5)

Kansas Biological Survey (1988) (for *A. grandis*,
Agricultural Pesticides = 5 (scale of 0-5)
Heavy Metals = 1 (scale of 0-5)
Persistent Organic Compounds = 3 (scale of 0-5)
Salinity = 3 (scale of 0-5)
Suspended Solids and Sediments = 4 (scale of 0-5)
[Average] 3.2 (scale of 0-5)

Based on this array of indices, one might infer **that** *A. grandis* might be intolerant, moderately tolerant, or very tolerant of degraded water quality conditions; no consensus is evident in these various indices.

During various field investigations and sampling trips over several years, one of us (D. Moskowitz), noted the occurrence of *A. grandis* in a variety of degraded aquatic habitats in central New Jersey. Many of these habitats were artificial aquatic environments created by man for stormwater detention, or degraded natural habitats receiving significant anthropogenic loadings. The occurrence of *A. grandis* in such habitats qualitatively attests to a broad tolerance for this species; however, although the above-referenced indices may provide a relative rating of the species with respect to general aquatic conditions, quantitative water quality data from *A. grandis* habitats are limited (Bick, 1958; Hart and Fuller, 1974; Lasswell et al., 1995) and are lacking for the northeast. The following discussion provides a quantitative assessment of water quality in three man-made aquatic habitats that support populations of *A. grandis*.

METHODS AND STUDY AREA

During the summer/fall of 1996, eight adult populations of *A. grandis* were located in central New Jersey. Four of the populations were found in Middlesex County, three in Somerset County, and one in Mercer County. The habitats included a small intermittent stream through a horse pasture, a farmland ditch, an irrigation pond, two stormwater detention basins, a small impounded roadside wetland, a large river (North Branch Raritan River), and a small woodland stream.

All of the waterbodies appeared by inspection to possess degraded water quality. The woodland stream, farm pond, roadside wetland, and the stormwater detention basins receive extensive stormwater runoff from roadways and developed areas. The woodland stream also flows through a large automobile junkyard and a scrap metal processing facility and floatable litter was abundant in the stream. Canada goose (*Branta canadensis*) droppings were extensive on the maintained lawns surrounding one of the Somerset County detention basins. This detention basin is treated twice annually with the herbicide Diquat and with a copper-based algicide. The horse pasture stream receives some runoff from roadways, is completely surrounded by maintained equestrian fields and pasture, and is subjected to significant runoff from these areas. The farmland ditch abuts an active cornfield and is fed primarily by agricultural runoff. The large river has been classified by the New Jersey Department of Environmental Protection as an FW2 Non-Trout water (NJDEP, 1994), which reflects water quality appropriate for warm-water fish species, but which is adequate only for temporarily supporting stocked trout.

At most of these sites, fewer than 10 individuals of *A. grandis* were observed. The greatest abundance was encountered on October 10, 1996, at the large stormwater detention basin in Somerset County, where more than thirty individuals were found, including numerous pairs in tandem. As a result, this detention basin was selected for an initial analysis of various trophic-state water quality parameters.

On December 2, 1996, surface water samples were collected from the detention basin, and were submitted to a New Jersey-certified laboratory for an analysis of fecal coliforms, chlorophyll *a*, nitrate-nitrogen and five-day biochemical oxygen demand (BOD_5 = a measure of the biodegradable organic loading in a water sample). Meteorological conditions were: air temperature of 50°F, breezy wind, and antecedent rainfall as recent as the preceding night. The water samples were obtained by hand by immersing prepared sample bottles to a depth of approximately eight inches below the water surface.

The water samples were placed on ice in a cooler in the field, and were delivered to the laboratory within three hours of the sampling. Field measurements of surface temperature and dissolved oxygen were also obtained using a YSI Model 55 Dissolved Oxygen Meter. The transparency of the water was measured using a Secchi disk.

On October 28, 1997, additional water quality measurements and samples were taken from a detention basin and an irrigation pond located in Middlesex County, New Jersey. At both sites adult ***A. grandis*** were observed in tandem and larvae have been found in a short drainage ditch feeding the irrigation pond (pers. comm., M. May, 1997). The sample methodology and water quality parameters were the same as in 1996. Meteorological conditions were: air temperature of 55°F, and breezy wind.

The analytical values for DO saturation, nitrate-nitrogen and total phosphorus concentration, BOD_5, and fecal coliforms can be used to generate water quality subindex values according to charts prepared by the National Sanitation Foundation (Brown *et al.*, 1970). This index was first proposed by Brown *et al.* as a method of facilitating the interpretation of water quality data sets. For the full index computation, nine water quality parameters quantified are converted to subindex values according to curves relating the value of a particular water quality variable with the sense of that value in terms of water quality. The curves were the result of Delphi polling of 142 water quality experts by the NSF. The nine parameters measured as the basis for the full NSF-WQI are: temperature (as deviation from ambient), dissolved oxygen saturation, pH, biochemical oxygen demand (BOD_5), total phosphorus, nitrate, turbidity, total solids, and fecal coliforms. In this case, because the full set of nine parameters were not run on the water samples, the subindex values are evaluated without aggregation. Additionally, for nitrate-nitrogen and total phosphorus, the inner limiting curve for the subindex was used because the range of nutrient concentrations evaluated in the NSF subindex curves extends to very high concentrations of these ions not often found in non-process waters.

The analytical or field values for chlorophyll *a*, total phosphorus and Secchi disk depth can be used to generate Trophic State Indices (TSI's) according to formulae presented by Carleson (1977). Carleson evaluated the relationships between the trophic state of lakes and three important water quality parameters: summer surface orthophosphate concentration [P], summer Secchi disk depth (Z), and summer chlorophyll concentration [B], and found that lake trophic status had a pronounced relationship to the logarithm of each of these values. Carleson established a Trophic State Index that varied from 0 to 100 (with the state of eutrophy increasing as the index increased), and was related to these three parameters by the following equations:

$I(P) = 4.2+33.2 \log[P]$,
where [P] is the orthophosphate concentration in milligrams per cubic meter (ppb)

$I(T) = 60-33.2 \log Z$,
where Z is the Secchi disk transparency in meters

$I(B) = 30.6+22.6 \log [B]$,
where [B] is the chlorophyll *a* concentration in milligrams per cubic meter (ppb)

The NSF-WQI subindices (as interpolated from the NSF curves) and Carleson's TSI's are summarized for the three surface water samples in Table 2.

RESULTS AND DISCUSSION

Table 1 presents the results of the field and laboratory water quality measurements in the three surface waters sampled.

Inspection of the water quality data from Table 1 indicates that aquatic habitats in which ***A. grandis*** were found generally had dissolved oxygen concentrations well below saturation (28 - 58%), reduced transparency (0.25 - 0.91 m), high five-day biochemical oxygen demand (5.0 - 7.0 mg/l), and high concentrations of

WATER QUALITY PARAMETER	Somerset County basin (12/2/96)	Middlesex County basin (10/28/97)	Middlesex County Irrigation Pond (10/28/97)
Temperature (°C)	9.7	11.0	11.1
Dissolved Oxygen (mg/l)	6.80	4.13	6.7
Dissolved Oxygen Saturation (%)	60.2	37.3	61.3
Nitrate-Nitrogen (mg/l)	<0.50	<0.50	0.88
Five-day Biochemical Oxygen	5.0	5.0	7.0
Fecal coliforms (MPN/100 ml)	>2400	900	>2400
Chlorophyll a (mg/m^3)	3.74	2.17	3.74
Secchi disk depth (m)	0.25	0.61	0.91
Total Phosphorus (mg/l)	ND	0.051	0.233
Alkalinity (mg/l as $CaCO_3$)	ND	9.2	43.5

Table 1 Water Quality Analysis at selected ***A. grandis*** habitats

fecal coliforms (900 - >2400 MPN/100 ml). These are general properties expected in degraded surface waters. Biogenic nutrients were variable, with only the irrigation pond showing elevated phosphorus concentrations. Chlorophyll *a* concentrations were not excessive at any of the sample locations.

The NSF-WQI subindices (Table 2) confirm the occurrence of generally poor water quality in these ***A. grandis*** habitats, although the range of these subindices is pronounced, from 15 (very poor) for fecal coliforms to >92 (very good) for nitrate-nitrogen. The Carleson's Trophic State Index values are also variable, with the chlorophyll *a* indices indicating mesotrophy, but the Secchi disk and total phosphorus indices indicating eutrophy. These apparently disparate results are likely the result of reduction in water clarity due to the presence of elevated suspended solids, both organic and inorganic, rather than a reduction of clarity due to elevated primary production. Such a condition would likely yield an elevated BOD_5 value and undersaturation of dissolved oxygen, both of which were documented in the field or laboratory determinations of water quality. Such conditions would also be anticipated in surface waters that receive runoff from developed or farmed areas, where suspended sediment and BOD_5 loadings are commonly elevated.

These evaluations of the water quality in man-made or degraded aquatic habitats supporting substantial numbers of ***A. grandis*** in New Jersey indicate that this odonate species is very tolerant of water conditions generally considered "poor" by conventional water quality indices. These specific observations, when combined with the observations and biotic indices reported by others, portray ***A. grandis*** as an odonate species with broad tolerances and the ability to flourish in a wide variety of degraded aquatic habitats. This apparent adaptability may explain the rapid range expansion ***A. grandis*** has undergone this century. As the anthropogenic influences on aquatic environments increased through most of the century, ***A. grandis*** may have been able to utilize habitats that proved intolerable to other odonate species, possibly diminishing competitive interactions and promoting range expansion in this species.

The proportion of tolerant species to the total number of species in a particular community is often used as an ecological or biotic metric - a value that can be used, generally with other independently-derived metrics, to evaluate the general "health" of a particular ecosystem. Based on the observations detailed herein, ***A. grandis*** would clearly be assigned to the "tolerant" category as used in several biotic metrics, e.g., EPA's Rapid Bioassessment Protocols, or RBP's (EPA, 1989), or Pennsylvania's Fish Metrics Development Project (Smith et al.; 1997). Interestingly, because the odonates have relatively long-lived, conspicuous adult stages that can be recognized, and even censused, by visual observation, the derivation and/or refinement of odonate metrics for surface waters could provide a mechanism for "rapid biological assessment" of such

NSF-WQI SUBINDICES[1]	**Somerset County basin (12/2/96)**	**Middlesex County basin (10/28/97)**	**Middlesex County Irrigation Pond (10/28/97)**
Dissolved Oxygen Saturation	56	28	58
Nitrate-Nitrogen	>92	>92	84
Total Phosphorus	ND	91	57
BOD_5	55	55	44
Fecal coliforms	15	21	15
CARLESON'S TSI[2]			
Chlorophyll a	43.5	38.2	43.5
Total Phosphorus	ND	60.9	82.8
Secchi disk depth	80.0	67.1	61.4

[1] NSF-WQI values range from 0-100, with higher values indicating better water quality.
[2] Carleson's TSI's range from 0-100, with lower values indicating more oligotrophic conditions

Table 2 . Water Quality and Trophic State Indices for Selected *A. grandis* Habitats

waters without the need for extensive underwater sampling or detailed taxonomic experience in the identification of benthic macroinvertebrates. In essence, odonate assemblages could be surveyed in a manner similar to that used by experienced "birders," and the survey information could be used in the derivation of an odonate metric for a particular water body. We support the efforts of those authors (Carle, 1979; Minter and May, 1996; Sprandel, 1996; Daigle, 1998) who have proposed such metrics, and advise that, to this end, the collection of quantitative water quality data should be an integral component in the description of distributions of various odonate species.

ACKNOWLEDGEMENTS

We would like to express our appreciation to Roy Beckemeyer and Michael May for their assistance in locating and providing numerous difficult to obtain references about *A. grandis*. We would also like to thank Michael May for providing the location of the irrigation pond site and Nick Donnelly for his encouragement during this project as well as to both for their review of the manuscript.

REFERENCES

Bick, G.H. and J.C. Bick. 1958. The Ecology of the Odonata at a Small Creek in Southern Oklahoma. Journal of the Tennessee Academy of Science 33(3): 252.

Blanchard, S. 1992. *Archilestes grandis* in New York. ARGIA, News and Noteworthy, Vol. 4(3): 14.

Brown, R.M., N.I. McClelland, R.A. Deininger, and R.G. Tozer. 1970. A Water Quality Index - Do We Dare? Water Sewage Works, Oct. 1970: 339-343.

Carle, F.L. 1979. Environmental Monitoring Potential of the Odonata, With a List of Rare and Endangered Anisoptera of Virginia, United States. Odonatologica 8 (4): 319-323.

Carleson, R.E. 1971. A Trophic State Index for Lakes. Limnol. Oceanog. 22(2): 361-369.

Daigle, Jerrell. 1998. The Use of Odonates to Assess Lake Quality in Florida. Argia 10 (2): 4.

Ferris, C.D. 1951. The Discovery of *Archilestes grandis* in Eastern Pennsylvania (Odonata). Entomological News 62: 304.

Gloyd, L.K., 1980. The Taxonomic Status of the Genera ***Superlestes*** and ***Cyptolestes*** Williamson, 1921. (Odonata: Lestidae). Occasional Papers (Number 694) of the Museum of Zoology University of Michigan, Ann Arbor, Michigan.: 1-3.

Hart, C.W., Jr. and S.L.H. Fuller. 1974. Pollution Ecology of Freshwater Invertebrates. Academic Press, New York, New York.

Ingram, B.R. 1976. Life Histories of three species of Lestidae in North Carolina, United States (Zygoptera). Odonatologica 5: 231-244.

Lasswell, J.L., Mitchell, F.L., Kenimer, A.L., Hauck, L.M., and K.K. Kresta, 1995. Biology of Dragonfly Naiads in Relation to Habitat and Water Quality. In Proceedings of the 24th Water for Texas Conference, Austin Texas. : 19-26.

May, M. 1997. Personal communication.

Needham, J.G. and H.B. Heywood. 1929. A Handbook of the Dragonflies of North America. Charles C. Thomas Publisher, Springfield, Illinois. 378pp.

New Jersey Department of Environmental Protection (NJDEP). 1994. Surface Water Quality Standards.

Orr, R.L., 1996a. The Dragonflies and Damselflies of Patuxent Wildlife Research Center and Vicinity. Patuxent Wildlife Research Center Report, USDA APHIS PPD, Riverdale, Maryland. 54 pp.

Orr, R. 1996b. The Odonata of the Chesapeake and Ohio Canal National Historical Park. ARGIA, Vol. 8 (3) : 6-10.

Ramirez, A. 1994. Descripcion E Historia Natural De Las Nayades De Odonatos De Costa Rica, II: Archilestes Neblina (Garrison, 1982) (Odonata, Lestidae), Con Una Clave Para Las Especies Del Genero En Costa Rica. Folia Entomol. Mex. 90:9-16.

Smith, Gary A., C.L. Wright, and R.M. Spear. 1997. Pennsylvania Fish Metrics Development Project: Final Report. Prepared by the Pennsylvania Fish and Boat Commission, Bellefonte, PA, for the Pennsylvania Department of Environmental Protection, Harrisburg, PA. September 1997.

Sprandel, Gary. 1996. Dragonfly Occurrence on a North Florida Pond, With Notes on Monitoring Techniques. Argia 8 (2): 26-29.

Tennessen, K.J., Harper, J.D., and Krotzer, R.S. 1995. The Distribution of Odonata in Alabama. Bulletin of American Odonatology. Volume 3(3): 49-74.

United States Environmental Protection Agency (EPA). 1989. Rapid Bioassessment Protocols for Use in Streams and Rivers. Benthic Macroinvertebrates and Fish. Washington, D.C.

Westfall, M.J. and M.L. May, 1996. Damselflies of North America. Scientific Publishers, Gainsville, Fl. 649 pp.

Williamson, E.B., 1931. ***Archilestes grandis*** (Ramb.) in Ohio (Odonata: Agrionidae). Ent. News, 43: 63-64.

VARIATION IN HEAD SPINES IN FEMALE *OPHIOGOMPHUS*, WITH A POSSIBLE EXAMPLEOF REPRODUCTIVE CHARACTER DISPLACEMENT (ANISOPTERA: GOMPHIDAE)[1]

Dennis R. Paulson
Slater Museum of Natural History University of Puget Sound Tacoma, WA 98416

ABSTRACT

Females of at least 8 of the 19 species of ***Ophiogomphus*** in North America vary in presence or absence, as well as size and shape, of spines on the occiput or rear of the head. In most cases spines that may be absent are only poorly developed when present, but in ***O. morrisoni*** Selys, females are either spineless or have well-developed occipital spines. At one locality intermediate specimens occur, but at another the population is dimorphic, either spineless or spined. The presence of both continuous variation and discrete polymorphism in different populations of a species has not been reported in dragonflies and is considered quite unusual in animals. The spined females occur only in the part of the range of ***morrisoni*** that overlaps that of ***O. severus*** Hagen, the only consistently spineless species of the genus, and they may represent an example of reproductive character displacement, also rarely reported for dragonflies and other animals.

INTRODUCTION

The females of a number of genera of gomphids possess spines on the vertex, occiput, and/or rear of the head. One of these genera is ***Ophiogomphus***, in which the spines (also called "horns") vary in presence and number. Kennedy's (1917) females of ***O. morrisoni*** from Elko and Washoe Counties, Nevada, and Nevada County, California, were all spineless, and the species has been so characterized ever since (Needham and Westfall 1955). Of specimens I have examined, 14 females from Inyo County, California (DRP, LACM, R. Garrison, pers. comm.), three from Mono County, California (R. Garrison, pers. comm.), and one from Lyon County, Nevada (R. Garrison, pers. comm.), lack spines as well. On the contrary, one female from Deschutes County, Oregon (TWD), two from Shasta County, California (CAS), and one from Plumas County, California (UMMZ), have well-developed occipital spines. Thus this species varies dramatically.

The spines project posterodorsally from the occipital ridge, one adjacent to each eye. Their bases are moderately swollen, about the diameter of an ocellus, and are circular in cross section but quickly become flattened perpendicular to the body axis, with almost knife-like black tips. There is some variation, the tips being more pointed in some individuals and bent slightly posteriad or laterad in some. In one female, one of the spines is forked at the tip.

Of 30 females from four miles east of the Eagle Lake Field Station, Lassen County, California (CAS), all are spined, but in three specimens the spines are much reduced, in the most extreme case little more than conspicuous bumps on either end of the occipital ridge with one or two denticles taking the place of the darkened blade-like tips of full-sized spines. This variation occurs in a series of 11 females collected 2 August 1974, whereas 19 females collected 6 July 1970 and 12 July 1973 all possess full-sized spines. However, the variation is not seasonal, as both forms occur evenly spread through the flight season. Three additional specimens from Lassen County (2 mi E Eagle Lake Field Station, R. Garrison, pers. comm.) are spined, but another from that county (Norval Flats, CAS) is spineless.

Of specimens from the Klamath River, Siskiyou County, California (DRP), six females are spined and three spineless, some of them collected in sight of one another. When I first detected this dimorphism, I speculated that two species might be involved, but there are no other apparent differences between spined and spineless females, and only a single kind of male has been taken with both types.

At first sight, this seems to be a classical example of geographic variation, with females of northern

[1] Bulletin of American Odonatology, 1998 5(3): 55-58

and western populations being spined and those of southern and eastern populations spineless. However, at one locality (Eagle Lake Field Station), intergradation appears to occur, with the expected intermediate specimens, while at another locality (Klamath River), females are dimorphic for this characteristic, with both types but no intermediates occurring. Such a situation, in which some populations of a species are discretely polymorphic and others vary continually in a character, is quite unusual, and, I can think of no other example among dragonflies or other animals. Sizable samples, and from additional localities, are needed to confirm this apparently anomalous situation.

OTHER SPECIES

Several other ***Ophiogomphus*** vary in the presence or absence of spines. ***O. arizonicus*** Kennedy is dimorphic, with females having short occipital spines or none. Kennedy's (1917) single females from the Huachuca Mountains (Cochise County, Arizona) and Oak Creek Canyon (Coconino County, Arizona) were spined, but additional specimens from Coconino and Apache Counties, Arizona, and Catron County, New Mexico, lack the spines (R. Garrison, pers. comm.) Spined and spineless females were taken together in Oak Creek Canyon.

Other species of the genus have long been known to be dimorphic, for example ***O. carolus*** Needham (Needham and Westfall 1955; Walker 1958) and ***O. rupinsulensis*** (Walsh) (Walker 1958). Of 17 female ***carolus*** examined (TWD, DRP), 10 have spines and seven do not. Of those with spines, one has four spines and one has one spine. Both spined and spineless individuals occur in Tioga County, New York. Of eight ***rupinsulensis*** examined (TWD, DRP), two lack occipital spines entirely (all have well-developed spines on the rear of the head), and two others have the spines much reduced, in one case a spine on one side accompanied by a still smaller spine just lateral to it. The sample size is too small to detect geographic variation in the character if it occurs.

In ***O. westfalli*** Cook and Daigle, occipital spines are prominent, but one of the type series of three also had vestigial postoccipital spines (Cook and Daigle 1985). Female ***O. mainensis*** Packard in Walsh usually have a small and inconspicuous pair of postoccipital spines along with larger occipital spines. These spines are "generally present" (Needham and Westfall 1955: 133), but the rear pair is lacking in a specimen from Aroostook County, Maine (TWD). ***O. colubrinus*** Selys is typically spineless, but four specimens from Essex County, New York, have occipital spines (D. Wagner, fide T. W. Donnelly, pers. comm.). ***O. anomalus*** Harvey is typically spined, but a specimen from Orange County, New York, lacks spines on the rear of the head (T. W. Donnelly, pers. comm.).

species	occiput	rear *
acuminatus	+	0
alleghaniensis	+	0
anomalus	+	±
arizonicus	±	0
aspersus	0	+
australis	+	+
bison	+	0
carolus	±	0
colubrinus	±	0
edmundo	0	+
howei	+	0
incurvatus	+	0
mainensis	+	±
morrisoni	±	0
occidentis	+	+
rupinsulensis	±	+
severus	0	0
susbehcha	0	+
westfalli	+	±

Table 1. Variation in number of head spines in female Ophiogomphus. See text for sample sizes examined for this study. Other information comes from the literature, with sample sizes unclear. KEY: + spines always present; ± spines variably present; 0 spines not presently known to occur.
* Note that the ornamentation on the rear of the head is quite variable and ranges from blunt spines to raised rounded prominences.

Female specimens in my collection of ***O. aspersus*** Morse (3), ***O. bison*** Selys (3), ***O. occidentis*** Hagen (28), and ***O. severus*** (7) are consistent with literature descriptions that indicate no variation, and a series of 17 females of ***O. susbehcha*** Vogt and Smith was uniform in possessing only postoccipital spines (Vogt and Smith 1993). Although sample sizes for ***occidentis*** and ***susbehcha*** seem large enough to indicate invariability, others are sufficiently small that variation, both geographic and within populations, cannot be ruled out. In fact, as more specimens are examined, it seems that variation may be common in the genus (Table 1). Five of 19 species (26%) show variation in occipital spines, and three of 19 (16%) show variation in those on the rear of the head.

One anomaly in female spines remains unexplained. ***O. incurvatus*** Carle and ***O. alleghaniensis*** Carle were originally considered as subspecies of a single species (Carle 1982), occurring on either side of the Appalachian chain. However, they are now considered separate species (Cook and Daigle 1985, Carle 1992). Although both have occipital spines, they are quite different in the two species, but no explanation has been forthcoming of the presence of females from Alabama with head-spine morphology intermediate between the two taxa (Carle 1982).

Some keys to female ***Ophiogomphus*** (e. g., Walker 1958, Carle 1981, Cook and Daigle 1985, Carle 1992) have not taken the variation described here into account. Table 1 indicates the present state of knowledge of variation in number of spines on North American ***Ophiogomphus*** females, and studies of larger samples are likely to show additional variation. At our present state of knowledge, spines on the occipital ridge may be present (10 species), absent (5), or variably present (4). Those on the rear of the head may be present (8 species), absent (9), or variably present (2). Usually it is the smaller spines that vary in their presence, but in ***O. morrisoni***, the spines, when present, are quite well developed (except for the intermediate females described above).

DISCUSSION

The head spines of females presumably interact with the male appendages during mating (Corbet 1962). Their approximation may ensure a firm grasp during tandem flights, although there is no indication that these flights are any more stressful on the male-female connection in the genera that possess spines than in those that lack them. Alternatively, they may function to ensure reproductive isolation, as has been suggested for species-specific fitting of male and female structures in other Odonata (Williamson 1906, Paulson 1974, Tennessen 1982). Calvert (1912, 1920) showed the complexity of the fit of male appendages and female head spines in species of ***Erpetogomphus*** and ***Epigomphus***, and Kennedy (1917) did the same for ***Octogomphus***. In the first two genera, as well as in ***Ophiogomphus***, similar-appearing species occur on the same streams, and reproductive isolation may depend at least in part on the inability of heterospecific males and females to achieve tandem, as in similar species of Zygoptera (Paulson 1974).

If this is the case, however, the variation in the spines within one species is puzzling. The presence or absence of poorly developed spines may not be highly significant, but the dimorphism in ***O. morrisoni*** is striking. The only hypothesis I can suggest is one of reproductive character displacement, as ***O. morrisoni*** appears to be spined only where it comes into contact with ***O. severus***, the only consistently spineless species of the genus. The only region in which ***morrisoni*** is known to be sympatric with ***severus*** is the Cascades of southern Oregon and Siskiyous of northern California (Kennedy 1917, Schuh 1936, TWD specimen), and it is in that region that ***morrisoni*** is spined. The latter species occurs at least as far east as Carlin, Nevada (where it is unspined; Kennedy 1917), and ***severus*** occurs throughout Utah (Musser 1962), so overlap is to be looked for at the border between these states. If ***morrisoni*** were spined in that area as well, substantial support would be provided for the character displacement hypothesis.

Examples of reproductive character displacement are still few in the Odonata and in animals in general (Waage 1979), and if ***Ophiogomphus*** presents such an example it should be thoroughly documented. This species may present an elegant example of reproductive character displacement, especially if the hypothesis of the significance of the spines for reproductive isolation cannot be refuted. It would be worthwhile to examine this genus further and to conduct field experiments on ***morrisoni*** and other species to define if possible the function of these head spines. Eastern species might prove especially interesting, as two or more species of ***Ophiogomphus*** coexist on many rivers in the East. For one example, ***O. mainensis*** is a spined species, and a prediction could be made that the variable ***O. carolus*** would be consistently spineless where it occurred with mainensis. That this is not the case (T. W. Donnelly, pers. comm.) furnishes evidence against character displacement, at least in this species pair. One further conclusion is warranted. That the variation discussed herein is so widespread in this genus indicates a need for caution in diagnosing species of Gomphidae on the basis only of female head armature (e.g., Watson 1991).

ACKNOWLEDGEMENTS

I would like to thank the following people for the loan of specimens: T. W. Donnelly (TWD); P. Arnaud and E. Smith, California Academy of Sciences (CAS); L. K. Gloyd, University of Michigan Museum of Zoology (UMMZ); and C. L. Hogue, Los Angeles County Museum of Natural History (LACM). Additional specimens cited are in my own collection (DRP). T. W. Donnelly and R. W. Garrison kindly sent me information about female ***Ophiogomphus*** in their collections. Finally, J. C. Schultz gave me the first "aberrant" ***O. morrisoni***, and E. O'Connor helped collect the series from the Klamath River that stimulated the writing of this paper.

LITERATURE CITED

Calvert, P.P., 1912, Studies on Costa Rican Odonata. IV. ***Erpetogomphus*** in Costa Rica, with descriptions of a new species having complex structural mating adaptation, Ent. News 23: 289-293.

Calvert, P.P., 1920, The Costa Rican species of ***Epigomphus*** and their mutual mating adaptations (Odonata), Trans. Am. Ent. Soc. 46: 323-354.

Carle, F. L., 1981, A new species of ***Ophiogomphus*** from eastern North America, with a key to the regional species (Anisoptera: Gomphidae), Odonatologica 10: 271-278.

Carle, F. L., 1982, Ophiogomphus incurvatus, a new name for Ophiogomphuscarolinus Hagen (Odonata: Gomphidae), Ann. Ent. Soc. Am. 75: 335-339.

Cook, C., and J. J. Daigle, 1985, ***Ophiogomphus westfalli*** spec. nov. from the Ozark region of Arkansas and Missouri, with a key to the ***Ophiogomphus*** species of eastern North America, Odonatologica 14: 89-99.

Corbet, P.S., 1962, A Biology of Dragonflies, Witherby, London, xvi + 247 pp.

Kennedy, C.H., 1917, Notes on the life history and ecology of the dragonflies (Odonata) of central California and Nevada, Proc. U.S. Nat.Mus. 52: 483-635.

Musser, R.J., 1962, Dragonfly nymphs of Utah (Odonata: Anisoptera), Univ. Utah Biol. Ser. 12: 1-66.

Needham, J.G., and Westfall, M.J., Jr., 1955, A Manual of the Dragonfliesof North America (Anisoptera), Univ. California Press, Berkeley, xi + 615
pp.

Paulson, D.R., 1974, Reproductive isolation in damselflies, Syst. Zool. 23: 40-49.

Schuh, J., 1936, A contribution to the knowledge of the Odonata of Oregon., M.S. thesis, Oregon State Univ., Corvallis, 214 pp.

Tennessen, K. J., 1982, Review of reproductive isolating barriers inOdonata, Adv. Odonatol. 1: 251-265.

Vogt, T. E., and W. A. Smith., 1993., Ophiogomphus susbehcha spec. nov.from North Central United States (Anisoptera: Gomphidae), Odonatologica22: 503-509.

Waage, J.K., 1979, Reproductive character displacement in Calopteryx (Odonata: Calopterygidae), Evolution 33: 104-116.

Walker, E.M., 1958, The Odonata of Canada and Alaska. Vol. II. Part III. The Anisoptera of Canada and Alaska, Univ. Toronto Press, Toronto, xi +318 pp.

Watson, J. A. L, 1991, The Australian Gomphidae (Odonata), Invertebr. Taxon. 5: 289-441.

Williamson, E.B, 1906, Copulation of Odonata -- I, Ent. News 17: 143-148.

VOLUME 4

VOLUME 5

BULLETIN OF AMERICAN ODONATOLOGY

VOLUME 1

VOLUME 2

VOLUME 3

continued on inside cover