INVERTEBRATES, AQUATIC PLANTS, AND WATERFOWL BROODS ON FOUR SELECTED WETLANDS IN ST. CROIX COUNTY, WISCONSIN

by

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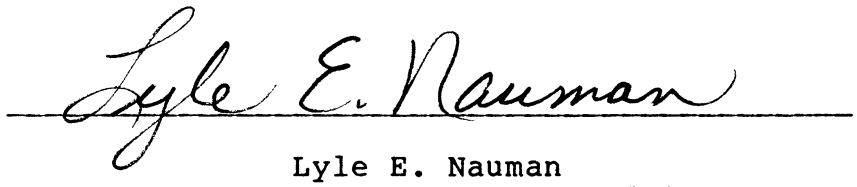

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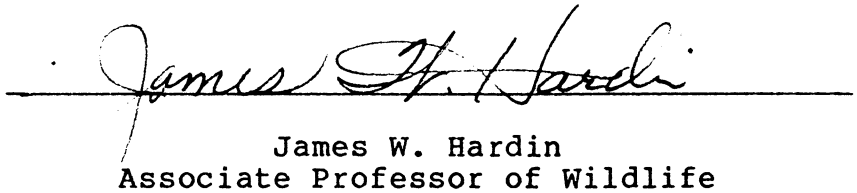

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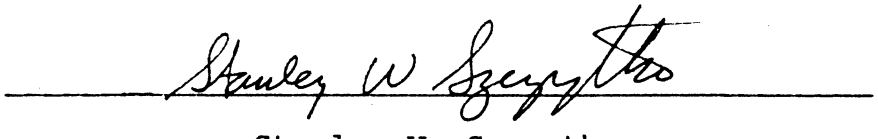

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Preface

The thesis is divided into 3 parts, 2 technical papers and appendices. The 2 papers are titled; "Factors influencing invertebrate abundance during the waterfowl brood rearing period", and "An analysis of invertebrate populations on four Waterfowl Production Areas in northwest Wisconsin". This project could never have been accomplished by one individual. I would like to thank my major advisor, Dr. Lyle E. Nauman, for his guidance and review of the thesis. Dr. James Hardin provided editorial assistance and Dr. Stanley Szczytko verfied aquatic insects and provided helpful suggestions and editorial comments. Dr. Robert Freckman verified aquatic plant samples and Dr. Fred Hilpert assisted organizing and analysing the data. Dick Lillie provided many suggestions and editorial assistance and Jim Evrard initiated the study and provided background information and data on brood movements. Tim Gruenwald and Bill and Genny Fannucchi provided moral support and suggestions during the field seasons.

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TABLE OF CONTENTS

Preface iii

List of tables vi

List of appendices viii

FACTORS INFLUENCING INVERTEBRATE ABUNDANCE DURING THE WATERFOWL BROOD REARING PERIOD 1

Abstract 1

Introduction 2

Study Area 3

Materials and Methods 4

Results and Discussion 7

Conclusion 20

Literature Cited 22

AN ANALYSIS OF AQUATIC INVERTEBRATE POPULATIONS ON FOUR WATERFOWL PRODUCTION AREAS IN NORTH WEST WISCONSIN ... 27

Abstract 27

Introduction 28

Study Area 29

Material and Methods 30

Results and Discussion 32

Conclusion 43

Literature Cited 44

Appendices 49

LIST OF TABLES

FACTORS INFLUENCING INVERTEBRATE ABUNDANCE DURING THE WATERFOWL BROOD REARING PERIOD.

Table 1. Dominant vegetative associations on Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, 1983-1984 8

Table 2. Variables entered in stepwise multiple regression for Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, 1983-1984 9

Table 3. Stepwise regression for factors influencing invertebrate abundance on Erickson Waterfowl Production Area, 1983-1984 10

Table 4. Stepwise regression for factors influencing invertebrate abundance on Amschler Waterfowl Production Area, 1983-1984 11

Table 5. Stepwise regression for factors influencing invertebrate abundance on Flaters Waterfowl Production Area, 1983-1984 12

Table 6. Water quality data from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, 1983 14

AN ANALYSIS OF AQUATIC INVERTEBRTATE POPULATIONS ON FOUR WATERFOWL PRODUCTION AREAS IN NORTHWEST WISCONSIN

Table 1. Dominant vegetative associations on Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, 1983-1984 33

Table 2. Invertebrate taxa found on Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, 1983-1984 . 34

Table 3. Mean invertebrate numbers and biomas/M^2 from benthic samples for Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, 1983-1984 . 35

Table 4. Mean invertebrate numbers and biomass/M^2 from water column samples for Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, 1983-1984 38

Table 5. Brood observations/survey/kilometer of shoreline for Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, 1983-1984 40

LIST OF APPENDICES

Appendix A.

Table 1. Brood survey results from Erickson Waterfowl Production Area, 1983 50

Table 2. Brood survey results from Erickson Waterfowl Production Area, 1984 51

Table 3. Brood survey results from Amschler Waterfowl Production Area, 1983 52

Table 4. Brood survey results from Amschler Waterfowl Production Area, 1984 53

Table 5. Brood survey results from Kruizenga Waterfowl Production Area, 1983 54

Table 6. Brood survey results from Kruizenga Waterfowl Production Area, 1984 55

Table 7. Brood survey results from Flaters Waterfowl Production Area, 1983 56

Table 8. Brood survey results from Flaters Waterfowl Production Area, 1984 57

Appendix B.

Table 1. Mean invertebrate numbers and biomass/M^2 from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, benthic samples 1983 .. 58

Table 2. Mean Chironomidae numbers and biomass/M^2 from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, benthic samples 1983 .. 59

Table 3. Mean Amphipoda numbers and biomass/M^2 from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, benthic samples 1983 60

Table 4. Mean invertebrate numbers and biomass/M^2 from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, benthic samples 1984 .. 61

Table 5. Mean Chironomidae numbers and biomass/M^2 from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, benthic samples 1984 .. 62

Table 6. Mean Amphipoda numbers and biomass/M^2 from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, benthic samples 1984 63

Table 7. Mean invertebrate numbers and biomass/M^3 from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, water column samples 1983 64

Table 8. Mean Chironomidae numbers and biomass/M3 from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, water column samples 1983 65

Table 9. Mean Amphipoda numbers and biomass/M^3 from Erickson, Amschler, Kruizenga and Flaters Waterfowl Production Areas, water column samples 1983 66

Table 10. Mean Cladocera numbers/M3 from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, water column samples 1983 67

Table 11. Mean Gastropoda numbers and biomass/M^3 from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, water column samples 1983 68

Table 12. Mean Zygoptera numbers and biomass/M^3 from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, water column samples 1983 69

Table 13. Mean Corixidae numbers and biomass/M^3 from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, water column samples 1983 70

Table 14. Mean Ephemeroptera numbers and biomass/M3 from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, water column samples 1983 71

Table 15. Mean invertebrate numbers and biomass/M3 from Erickson, Amschler, Kruizenge, and Flaters Waterfowl Production Areas, water column samples 1984 72

Table 16. Mean Chironomidae numbers and biomass/M^3 Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, water column samples 1984 73

Table 17. Mean Amphipoda numbers and biomass/M^3 from Erickson, Amschler, Kruizenga,and Flaters Waterfowl Production Areas, water column samples 1984 74

Table 18. Mean Cladocera numbers and biomass/M3 form Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, water column samples 1984 75

Table 19. Mean Gastropoda numbers and biomass/M3 from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, water column samples 1984 76

Table 20. Mean Zygoptera numbers and biomass/M3 from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, water column samples 1984 77

Table 21. Mean Corixidae numbers and biomass/M3 from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, water column samples 1984 78

Table 22. Mean Ephemeroptera numbers and biomass/M3 from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, water column samples 1984 79

Appendix C.

Aquatic plant species found in samples from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, 1983-1984 80

Appendix D.

Table 1. Significant differences (P<0.05) in invertebrate numbers and biomass between Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas from benthic samples, 1983-1984 81

Table 2. Significant differences (P<0.05) between Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas from water column samples, 1983-1984 ... 82

Appendix E.

Figure 1. Dominant plant associations on Erickson Waterfowl Production Area, 1983-1984 ... 83

Figure 2. Dominant plant associations on Amschler Waterfowl Production Area, 1983-1984 ... 84

Figure 3. Dominant plant associations on Kruizenga Waterfowl Production Area, 1983-1984 85

Figure 4. Dominant plant associations on Flaters Waterfowl Production Area, 1983-1984 ... 86

FACTORS INFLUENCING INVERTEBRATE ABUNDANCE DURING THE WATERFOWL BROOD REARING PERIOD

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Abstract: Two hundred forty water column invertebrate-aquatic plant samples were taken during the summers of 1983 and 1984 on 4 Waterfowl Production Areas (WPAs) in St. Croix and Polk counties, Wisconsin. Stepwise regression procedures were conducted to determine which factors were the best predictors of total invertebrate numbers and biomass. Predictors were also determined for the more common invertebrate taxa present on the study area. Detritus and duckweed (Lemna spp.) were the best predictors of total invertebrate biomass (R^2=0.293) and numbers (R^2=0.209), respectively, on Erickson WPA. On Amschler WPA, cattail (Typha spp.) and the water level were the best predictors of total invertebrate biomass (R^2=0.274) and numbers (R^2=0.181), respectively. On Flaters WPA, total invertebrate numbers were best predicted by Fries pondweed (Potamogeton friesii) (R^2=0.162). No significant (R^2>0.15) and (P<0.05) predictors of invertebrate numbers or biomass were found on Kruizenga WPA. No single predictor of total invertebrate numbers or biomass was found. In addition, predictors were different for individual invertebrate taxa, indicating a variety of aquatic plant species and growth forms are necessary to provide a variety of invertebrate food items required by ducklings.

The U.S. Fish and Wildlife Service and many state wildlife agencies are activity involved in the preservation of waterfowl production areas. With land values increasing and acquisition of property becoming more difficult, it is vital that acquired habitat have maximum management potential. Equally important is proper management of existing areas. Both of these objectives can only be met through a better understanding of waterfowl and wetland ecology.

Researchers have only begun to understand the importance of invertebrates in the diets of both breeding ducks and ducklings (Chura 1961, Sugden 1973, Bengtson 1975, Krapu and Swanson 1977). Prior to 1965, 95% of 125 food habit studies of waterfowl were based at least partially on foods taken from the gizzard (Bartonek 1968). Differences in digestibility have caused these past studies to overestimate the percentages of hard seeds in the diet and underestimate the quantities of invertebrates (Swanson and Bartonek 1970). Thus, past management of wetlands for waterfowl has emphasized seed production over invertebrate production.

Invertebrates are an essential component in the duckling diet. Sugden (1973) determined that no plant foods were high enough in protein nor had a wide enough array of amino acids to support growing ducklings. He also felt that only the wide variety of invertebrate foods consumed by ducklings would satisfy both these needs. Street (1978) in a laboratory study found that growing ducklings could

not survive on plant foods alone but needed the supplemental protein provided by insects. In a wet gravel quarry area of England, Street (1977) speculated that low duckling survival was due to the low productivity of invertebrates.

Several authors have shown that broods tend to concentrate or move to wetlands having high invertebrate numbers (Collias and Collias 1963, Godin and Joyner 1981, Talent et al. 1982, Longcore and Ringleman 1982). Thus with the importance of invertebrates to ducklings well documented, further understanding of the factors that influence invertebrate abundance is needed. The present study examined some of the factors influencing invertebrate production during the waterfowl brood rearing period.

Sincere appreciation is extended to all who assisted with the project. I thank J. Evrard, D. Lillie, L. Nauman, and J. Hardin for their support and editorial suggestions and S. Szczytko for editorial comments and verification of invertebrate taxa. F. Hilpert assisted with analysis and organization of data and R. Freckman verified aquatic plants. A special thanks is extended to those that sorted invertebrate samples. Partial funding for the project was supplied through the Wisconsin Department of Natural Resources and the Federal Aid to Wildlife Restoration Act under Pittman-Robertson project W-141-R.

STUDY AREA

The study area is located in northern St. Croix and southern Polk counties east of Star Prairie, Wisconsin.

Four waterfowl production areas (WPAs), Erickson (26 ha), Amschler (14 ha), Kruizenga (2 ha), and Flaters (1 ha), were monitored for invertebrates and aquatic plants during the summers of 1983 and 1984. All 4 areas have a history of brood use and thus can be considered brood habitat. Wetland classifications were as follows; Erickson, system lacustrine, subsystem littoral, class unconsolidated bottom, and dominance type mud; Amschler, system lacustrine, subsystem littoral, class aquatic bed, subclass rooted vascular, and dominance type Myriophyllum spicatum; Kruizenga, system palustrine, class emergent, subclass persistent, and dominance type Typha spp.-Carex spp.; Flaters, system palustrine, class aquatic bed, subclass rooted vascular, and dominance type Potamogeton friesii. All 4 areas had permanently flooded water regimes and an alkaline water chemistry (Cowardin et al. 1979).

MATERIALS AND METHODS

Each area was sampled at 2 week intervals from 15 May to 8 August 1983 and 1984, allowing 6 sample periods for each wetland each year. Sampling was concluded the first week in August when most of the ducklings had exceeded age class IIb (Gollop and Marshall 1954). At this age, their diet is predominantly plant material (Chura 1961, Sugden 1973). Samples were taken near wetland perimeters using a random numbers table to determine distances between sample

sites. Sample sites were in water less than 61 cm as this is the depth used by feeding puddle ducks (Swanson and Meyer 1977).

Two hundred forty water column samples were taken during the 2 years of the study. There were 72, 72, 60, and 36 taken, respectively, from Erickson, Amschler, Kruizenga, and Flaters WPAs. Variations in sample number were based subjectively on differences in wetland size and habitat diversity. Larger wetlands with greater habitat diversity were sampled more than smaller less diverse wetlands.

A modified Gerking sampler (Gerking 1957) was used to sample the water column for invertebrates and aquatic plants. The sampler was constructed of 0.64 cm (0.25 in) plexiglas with dimensions of 50 x 50.5 x 77 cm high. The large size of this sampler permitted the capture of the faster invertebrates such as water boatman (Corixidae) and backswimmers (Notonectidae) and worked well on the larger emergents such as cattail. In addition, the edge effect inherent to many smaller samples was minimized (Korinkova 1971). A total of 6, 6, 5, and 3 water column samples were taken during each sample period from Erickson, Amschler, Kruizenga, and Flaters WPAs, respectively.

At each sample site, data on water depth, water temperature, date, time, and location were recorded. Each sample was passed through a #30 U.S. standard sieve to remove small particulate matter.

Aquatic plants, removed from the Gerking sampler, were separated to species using Fassett (1957) and air dried

weights determined. Detritus was considered any plant material not of that season's growth.

Invertebrate samples were preserved in 95% ethyl alcohol and prior to sorting were stained with a combination of Biebrich Scarlet and Eosin B (Williams and Williams 1973). This combination proved especially effective on the softer bodied invertebrates such as Chironomidae (midges) and Oligocheates (aquatic earthworms). Samples were sorted in a porcelain pan to family for Coleoptera, Diptera, and Hemiptera and to order for other invertebrates using Hilsenhoff (1975) for aquatic insects and Pennak (1978) for other aquatic invertebrates.

A 50% subsampling technique was used to reduce time required to sort samples. A porcelain pan was divided in half. A portion of the total sample was then placed in the pan, mixed with water and evenly distributed. A coin toss determined which side was to be sorted. All numbers and weights were doubled before recording on data sheets. Air dried weights were determined, to the nearest 0.0001 g, for each taxonomic group of invertebrates from each sample using a Mettler H51 analytic balance. Approximately 500 copepods and cladocerans were taken from each of 15 samples and weighed to determine the mean weight of individuals. Later these two groups were counted and the weight conversions applied.

An SPSS program (Statistical Package for the Social Sciences) on a Burroughs 6900 mainframe computer was used for statistical analysis. Stepwise multiple regression

procedures were used to determine the best predictors of total invertebrate numbers and weights for each area. In addition, predictors were determined for those invertebrate taxa important in the diet of ducklings (Chura 1961, Collias and Collias 1963, and Perret 1962). On Erickson WPA, Pleidae (Hemiptera) was entered in the analysis because of the large numbers present. Samples from 1983 and 1984 were pooled for analysis.

RESULTS AND DISCUSSION

Dominant vegetative associations on the 4 WPA's are given in Table 1. Most previous studies of invertebrate-aquatic plant associations were conducted in monotypic stands of aquatic plants. While this approach is useful for determining quanitative associations with different aquatic plants, it may not represent a natural aquatic ecosystem with a diversity of plant species and varying structural composition. In addition, past studies usually sampled only one wetland which does not give an indication of invertebrate predictors over a wider geographical area or from differing wetland basins. Stepwise multiple regression procedures were used in the present study because it analyses a large numbers of variables (Table 2) and reduces them to a smaller set of predictor variables (Tables 3-5). Results are expressed as R^2 values. These R^2 values represent the proportion of the variation in the dependent variable that is explained by the independent variable.

Table 1. Dominant vegetative associations on Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, 1983-1984.

Area	Percent occurance
Erickson	
Open water	75.6
Arrowhead-Burreed-Cattail	9.7
Reed cannary grass	4.5
Coontail-Elodea	3.7
Cattail	3.5
Willow	3.2
Amschler	
Open water	37.1
Milfoil	34.0
Reed canary grass	12.1
Milfoil-Smartweed	7.8
Smartweed	5.7
Arrowhead-sedge	1.9
Cattail	1.4
Kruizenga	
Cattail-Duckweed	40.1
Open water	35.1
Sedge	13.8
Floating pondweed	4.9
Duckweed	3.3
Duckweed-Rushes	2.8
Flaters	
Fries pondweed	63.3
Reed canary grass	20.9
Duckweed	15.8

Table 2. Variables entered in stepwise multiple regression for Erickson (1), Amschler (2), Kruizenga (3), and Flaters (4) Waterfowl Production Areas, 1983-1984.

Dependent variables	Independent variables
Total invertebrate numbers (1,2,3,4)	*Sparganium eurycarpum* (1,3)
Total invertebrate biomass (1,2,3,4)	*Typha* spp. (1,2,3)
Gastropoda numbers (1,2,3,4)	*Carex* spp. (1,2,3,4)
Gastropoda biomass (1,2,3,4)	*Elodea canadensis* (1)
Ephemeroptera numbers (1,2)	*Ceratophyllum demersum* (1,2,3,4)
Ephemeroptera biomass (1,2)	*Polygonum* spp. (1,2,3,4)
Cladocera numbers (1,2,3,4)	*Lemna minor* (1,2,3,4)
Chironomidae numbers (1,2,3,4)	*Potamogeton zosteriformis* (1,2,3)
Chironmoidae biomass (1,2,3,4)	Green algae (1,2,3,4)
Amphipoda numbers (1,2,3,4)	*Eleocharis* (1,2)
Amphipoda biomass (1,2,3,4)	Detritus (1,2,3,4)
Corixidae numbers (1,3,4)	*Phalaris arundinacea* (1,2,3,4)
Corixidae biomass (1,3,4)	*Sagittaria latifolia* (1,2,3)
Pleidae numbers (1)	*Scirpus validus* (1,2)
Pleidae biomass (1)	Date (1,2,3,4)
Zygoptera biomass (1,2)	Water temperature (1,2,3,4)
Zygoptera numbers (1,2)	Pond level (1,2,3,4)
	Sample volume (1,2,3,4)
	P. natans (2,3)
	Myriophyllum spicatum (2)
	P. pusillus (2)
	P. gramineus (2)
	P. friesii (4)
	Utricularia vulgaris (3)

Table 3. Stepwise regression for factors influencing invertebrate abundance on Erickson Waterfowl Production Area, 1983-1984. (only R^2 values greater than 0.15 are listed, ($P < 0.05$).

Dependent variables	Independent variables	R^2 improvement
Total invertebrate numbers	*Lemna minor*	0.209
	Ceratopyllum demersum	0.402
	Detritus	0.466
Total invertebrate weight	Detritus	0.293
	Phalaris arundinacea	0.533
	L. minor	0.616
Amphipod weight	*L. minor*	0.308
	C. demersum	0.493
	Detritus	0.569
Amphipod numbers	*L. minor*	0.325
	C. demersum	0.474
	P. arundinacea	0.527
Pleidae numbers	*C. demersum*	0.268
	L. minor	0.415
Zygopteran numbers	*C. demersum*	0.473
Gastropoda weight	Detritus	0.409
Gatropoda numbers	Detritus	0.439
	Date	0.483

Table 4. Stepwise regression for factors influencing invertebrate abundance on Amschler Waterfowl Production Area, 1983-1984. (only those R^2 values greater than 0.15 are listed,($P<0.05$)

Depenent variable	Independent variable	R^2 improvement
Total invertebrate numbers	Pond level	0.181
	Potamogeton zosteriformis	0.293
	Phalaris arundinacea	0.327
Total invertebrate weight	*Typha* spp.	0.274
	P. arundinacea	0.336
	Potamogeton gramineus	0.379
Chironomidae numbers	Detritus	0.198
	Date	0.278
	Water temperature	0.353
Chironomidae weight	Green algae	0.785
	Date	0.802
Amphipod weight	*Typha* spp.	0.526
	Green algae	0.651
	P. arundinacea	0.681
Zygoptera numbers	*Typha* spp.	0.224
	Myriophyllum spicatum	0.290
	P. arundinacea	0.357
Cladocera numbers	*P. zosteriformis*	0.196
	P. arundinacea	0.289
	M. spicatum	0.357
Ephemeroptera weight	Green algae	0.312
	Typha spp.	0.434
	Water temperature	0.506
Ephemeroptera numbers	*Typha* spp.	0.278
	Carex spp.	0.399

Table 5. Stepwise regression of factors influencing invertebrate abundance on Flaters Waterfowl Production Area, 1983-1984. (only those R^2 values greater than 0.15 are listed, ($P<0.05$)

Dependent variable	Independent variable	R^2 improvement
Total invertebrate numbers	*Potamogeton friesii*	0.162
	Date	0.251
Amphipod numbers	*P. friesii*	0.317
	Sample volume	0.460
Amphipod weight	*P. friesii*	0.185
	Sample volume	0.331
Chironomidae numbers	Water temperature	0.176
Gastropoda weight	*Phalaris arundinacea*	0.193
	Water temperature	0.332

For example, in Table 3, the dry weight of duckweed explained 20.9% of the variation in total invertebrate numbers on Erickson WPA. With the addition of coontail, 19.3% or a total of 40.2% of the variation in total invertebrate numbers is explained. Thus duckweed is a predictor and the combination is a better predictor of total invertebrate numbers for this wetland.

Comparison with other studies are difficult because of differences in geographical areas, chemical, physical, and climatic conditions, and different aquatic plants and invertebrate species. In addition, varying methodology is often employed, such as different invertebrate sorting procedures, sampling techniques, sieve or mesh sizes, and expression of results.

Generally, each wetland had a different set of predictors for each invertebrate group (Tables 3-5). These differences probably result from different aquatic plants and limnological conditions among wetlands (Table 6). The different physical and chemical conditions result in different species on each wetland, each species with its own habitat requirements. In particular, nitrogen and phosphorus values differed among wetlands. In fresh water ecosystems, productivity is most often limited by these 2 nutrients (Wetzel 1983). Another explanation for these differences may be the presence of fish in each of the 4 areas. Fish reduce invertebrate size, numbers, and biomass and compete with both ducklings and breeding adults for invertebrates (Pehrsson 1984).

Table 6. Water quality data from Erickson (23 Aug), Amschler (22 Aug), Kruizenga (13 June), and Flaters (13 June) Waterfowl Production Areas, 1983.

	Erickson	Amschler	Kruizenga	Flaters
Total Phosphorus (mg/l)	0.37	0.038	0.2	0.54
Total Kjel N (mg/l)	5.1	1.1	1.53	3.1
NH3-N (mg/l)	0.03	0.05	0.02	0.04
NO2 and NO3-N (mg/l)	<0.02	<0.02	<0.02	0.02
Total Calcium (mg/l)	27.0	22.0	26.5	8.0
Total Magnesium (mg/l)	15.0	17.0	10.0	4.0
Total Sulfates (mg/l)	5.0	2.1	2.0	1.0
pH	8.2	8.7	7.8	7.6
Total Alkalinity -CaCO3 (mg/l)	128.0	117.0	105.0	40.0
Chloride (mg/l)	5.1	5.2	___	2.4

Analysis conducted by the State Laboratory of Hygiene, Madison, Wisconsin.

Total Invertebrates

On Erickson WPA, total invertebrate numbers were best predicted using duckweed with coontail (Ceratophyllum demersum) second (Table 3). Krull (1970) found coontail harbored the most invertebrates. Detritus was the best predictor of total invertebrate biomass. Different predictors of invertebrate numbers and biomass probably result from differences in sizes between different taxa or sizes of individuals within the same taxa from each wetland.

On Amschler WPA, pond level was the best predictor of total invertebrate numbers (Table 4). The water level on this wetland rose during 1984 creating newly flooded habitat. McKnight (1969) in a Utah study found that newly flooded areas produced large quantities of invertebrates, especially if those areas contained organic matter as a food base. The rising water level on Amschler flooded the upland grass surrounding the wetland. These grasses provide food and habitat for a variety of invertebrates. Swanson and Meyer (1974) found that annual reflooding of temporary prairie wetlands resulted in ideal conditions for aquatic invertebrates. Periodic drawndowns and reflooding are a common management tool to increase the productivity of marshes (Fredrickson and Taylor 1982).

Cattail was the best predictor of invertebrate biomass on Amschler. Since cattail also was the best predictor of Zygoptera numbers (Table 4), the results could have been strongly influenced by the biomass of this group.

On Flaters WPA, Fries pondweed was the best predictor of total invertebrate numbers (Table 5). This plant is thread-like and has a large surface area for colonization by invertebrates. Many invertebrate groups eat the periphyton attached to plants (Pennak 1978) and thus the larger surface area probably results in a larger food base. Krecker (1939) and Andrews and Hasler (1943) indicated plants with many leaf dissections and a large surface area tended to have a greater abundance of invertebrates. No predictors of total invertebrate biomass were found on Flaters WPA and no predictors of either invertebrate biomass or numbers were found on Kruizenga WPA.

Amphipoda

Fries pondweed was the best predictor of Amphipoda weight on Flaters WPA. Voights (1976) found the largest biomass of Amphipoda in dense stands of submergents. A factor influencing Amphipod numbers may be the shading afforded by this plant. Amphipods react negatively to light (Pennak 1978) and may enter the pondweed to escape the daylight. This also may explain why sample volume (a function of depth) ranks second (Table 5) to Fries pondweed, with less light at greater depth. On Erickson WPA, duckweed was the best predictor of both Amphipoda numbers and weight. The thick blanket of this plant on the water surface may provide the shading attractive to Amphipoda. On Amschler WPA, Amphipoda biomass was best predicted by cattail (Table 4), another shade providing plant. Sampling at night when

many duck broods feed (Swanson and Sargent 1972) may have resulted in a different predictor of Amphipoda abundance. No predictors (R^2>0.15) were found for Amphipoda numbers or biomass for Kruizenga WPA.

Chiromonidae

Chironomidae numbers and biomass were best predicted by detritus and green algae, respectively, on Amschler WPA. Pennak (1978) states that most Chironomidae feed on algae, higher aquatic plants and organic detritus, so these results are expected. No predictors (R^2>0.15) of Chironomidae abundance were found on Kruizenga, Flaters or Erickson WPAs.

Ephemeroptera

The only significant associations between Ephemeroptera and the variables measured on Amschler WPA (Table 3) were with green algae for weight and cattail for numbers. The majority of the Ephemeroptera on Amschler were Caenidae, which are classified as sprawlers and collectors-gatherers (Merrit and Cummins 1978). They describe sprawlers as inhabiting the surface of floating leaves of vascular hydrophytes or fine sediments and collectors-gatherers as eating fine particulate organic matter. Why cattail and green algae are predictors of Ephemeroptera abundance is unknown. No significant (R^2>0.15 and $P<0.05$) associations were noted on Flaters, Kruizenga or Erickson WPAs.

Gastropoda

The best predictor of Gastropoda numbers and biomass

was detritus for Erickson WPA. Pennak (1978) states that chief foods of Gastropoda are algae that covers plants, but dead plant material is frequently ingested. On Flaters WPA, reed canary grass (Phalaris arundinacea) was the best predictor of Gastropoda weight (Table 5). With the exception of Voights (1976), most previous studies point to Gastropods being most closely associated with fine leaved submergents (Gerking 1957, Collias and Collias 1963, and McCrady 1982). Why reed canary grass on Flaters WPA was the best predictor of Gastropoda weight is unknown, especially considering that Fries pondweed, a fine leaved submergent, was readily available. With the vast number of variables at work in a fresh water ecosystem, unexplained variability is expected. Significant predictors (R^2>0.15) of Gastropoda abundance were not found on Amschler or Kruizenga WPA.

Cladocera

Collias and Collias (1963) found in a laboratory experiment that Cladocera were readily eaten by 10 species of incubator hatched ducklings, indicating they are a potential food item of wild ducklings. The only R^2 value > 0.15 for Cladocera numbers was from Amschler WPA where flatstem pondweed (P. zosteriformis) was the best predictor. No other predictors were found for Cladocera, which are generally found in open water (Pennak 1978, Voights 1976).

Pleidae

Pleidae were also entered in analysis as a dependent variable for Erickson WPA because of the large numbers

present. Because ducklings tend to be opportunistic in their feeding (Perret 1962), it was felt that this group of invertebrates could potentially be an important food item. Pleidae numbers were best predicted by coontail. The coontail on Erickson grows in dense tangled stands, typical Pleidae habitat (Pennak 1978).

Zygoptera

On Erickson WPA, the best predictor of Zygoptera abundance was coontail, Gerking (1957) found Najas flexilis supported the most Odonata, including suborder Zygoptera. On Amschler WPA, the best predictor of Zygoptera numbers was cattail. Voights (1976) found most emerging Odonata in dense stands of emergents, this could explain the increased numbers in this habitat. No predictors of Zygoptera numbers or weights were found on Flaters or Kruizenga WPA.

There are 2 theories regarding invertebrate aquatic plant associations: (1) increasing numbers of invertebrates are found on plants with greater leaf dissection and surface area (Krecker 1939, Andrews and Hasler 1943, Gerrish and Bristow 1979); (2) invertebrates may be more abundant on certain aquatic plant species irrespective of large surface area or increasing leaf dissection (Rosine 1955).

This study seems to support a combination of these 2 theories. In general, most invertebrate groups were associated with aquatic plants having large surface areas but this did not always prove true. In several instances

cattail was found as a good predictor even though this plant has a reduced surface area relative to the other plants present. On the other hand, some fine leaved submergents were not good predictors of any invertebrate groups. Krecker (1939) found that M. spicatum harbored the most total invertebrates, but in the present study, this plant was not a good predictor of any invertebrate groups. This plant was common on Amschler WPA and has many fine leaf dissections.

Which invertebrates colonize specific plant types depends on a wide variety of factors such as life cycle stage, invertebrate species, food habits, habitat preferences, trophic structure of the wetland, and what aquatic plants are available. Aquatic plant availability depends on a variety of physical, chemical, and biological factors (Davis and Brinson 1980).

CONCLUSION

The results of this study show the wide variety of indicators of aquatic invertebrate abundance even within a small geographic area. Differences in flora, fauna and physical and chemical conditions among wetlands result in different predictors of abundance. Of particular importance are the variety of predictors of the different invertebrate taxa. Thus to maintain a diversity of aquatic invertebrates a diversity of habitat must be present, especially considering the range of animal foods consumed by ducklings. On many managed wetlands, monotypic stands of seed producing

plants are grown to maximize food production. The results from this study indicate that this practice may severely limit the diversity of invertebrates. This practice must be re-evaluated if an objective of these areas is waterfowl production. A variety of wetland management techniques exist to alter wetland plant composition ultimately affecting invertebrate communities.

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AN ANALYSIS OF INVERTEBRATE POPULATIONS ON FOUR WATERFOWL PRODUCTION AREAS IN NORTHWEST WISCONSIN

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Abstract: Four Waterfowl Production Areas (WPA's) in St. Croix and Polk counties Wisconsin were studied during the summers of 1983 and 1984 and 240 water column and 240 benthic invertebrate samples were collected. The purpose of the study was to determine if aquatic invertebrates were limiting duckling production. Mean water column invertebrate densities ranged from 2,267 to 10,317/M^3 on Amschler and Flaters, respectively. Mean benthic invertebrate densities ranged from 15,453 on Kruizenga to 38,085/M^2 on Amschler. Mean water column invertebrate biomass (grams dry weight) ranged from 1.77 to 8.80/M^3 from Amschler and Flaters, respectively. Mean benthic invertebrate biomass ranged from 3.05/M^2 on Amschler to 16.06/M^2 on Flaters. All values, except Amschler's water column invertebrate densities, were comparable to good waterfowl producing areas, thus aquatic invertebrate populations are probably not limiting duckling production. Analysis of duckling survival and movements supports this conclusion.

The importance of aquatic invertebrates to juvenile waterfowl has been well documented (Chura 1961, Collias and Collias 1963, Sugden 1973, Bengtson 1975, Krapu and Swanson 1977). Several authors also have demonstrated the necessity of this high protien food source to the growth and development of a brood (Sugden 1973, Street 1978). Other studies have demonstrated that broods tend to move to wetlands high in invertebrate numbers (Talent et al. 1982). In some areas researchers have speculated that a lack of available invertebrates may severely limit duckling survival (Street 1977) and production (Baldassarre and Nauman 1981, Peterson and Low 1977).

Within Wisconsin, there are 2 noted waterfowl production areas, the southeast and the northwest (St. Croix, Polk, Dunn, and Barron counties) (Wheeler and March 1979). Recently, the Wisconsin Department of Natural Resources has expressed concern that aquatic invertebrates may be limiting duckling production in these northwest counties. The purpose of this study was to monitor invertebrate populations and brood use on 4 selected wetlands in St. Croix and Polk counties of Wisconsin, and determine if invertebrate numbers or biomass is limiting duckling production.

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plants. A special thanks is extended to those that sorted invertebrate samples. Partial funding for the project was supplied through the Wisconsin DNR and the Federal Aid to Wildlife Restoration Act under Pittman-Robertson project W-141-R.

STUDY AREA

The study areas are located in northern St. Croix and southern Polk counties immediately east of Star Prairie, Wisconsin. The major land use is dairy farming and corn and alfalfa production. Four Waterfowl Production Areas (WPA's) were monitored for brood use and invertebrates from 15 May to 8 August 1983 and 1984. Study areas were selected based on past brood observation records from the Wisconsin DNR. Erickson WPA (26 ha) and Kruizenga WPA (2 ha) received relatively good brood use in 1982, while Amschler WPA (14 ha) and Flaters (1 ha) received relatively poor use (J. Evrard pers. comm.). These 4 wetlands represent a cross section of available brood rearing habitat. Wetland classifications were as follows; Erickson, system lacustrine, subsystem littoral, class unconsolidated bottom, and dominance type mud; Amschler, system lacustrine, subsystem littoral, class aquatic bed, subclass rooted vascular, and dominance type Myriophyllum spicatum; Kruizenga, system palustrine, class emergent, subclass persistent, and dominance type Typha spp.-Carex spp.; Flaters, system palustrine, class aquatic

bed, subclass rooted vascular, and dominance type Potamogeton friesii. All 4 areas had permanently flooded water regimes and an alkaline water chemistry (Cowardin et al. 1979).

MATERIALS AND METHODS

Each area was sampled at 2-week intervals from 15 May to 8 August 1983 and 1984, allowing 6 sample periods for each wetland. Sampling was concluded the first week in August when most ducklings had exceeded age class IIb (Gollop and Marshall 1954). At this age their diet is predominantly plant material (Chura 1961, Sugden 1973). Samples were taken near wetland perimeters using a random numbers table to determine distances between sample sites. Sample sites were in water less than 61 cm as this is the depth used by feeding puddle ducks (Swanson and Meyer 1977).

A modified Gerking sampler (Gerking 1957) was used to sample the water column for invertebrates. The sampler was made of 0.635 cm (0.025 in) plexiglass with dimensions of 50 x 50.5 x 77 cm. The large size of this sampler permitted capture of the faster invertebrates such as water boatman (Corixidae) and backswimmers (Notonectidae), and reduced bias caused by edge effect, often a problem in small samplers (Korinkova 1971). A 7.7 cm diameter core sampler (Swanson 1978) made of PVC pipe was used to sample the benthos.

Six water column and 6 benthic samples were taken on Erickson and Amschler WPAs during each of the sample

periods. Five water column and 5 benthic samples were taken from Kruizenga WPA and 3 water column and 3 benthic samples from Flaters WPA. Variation in sample number resulted from differences in wetland size and habitat diversity. Larger wetlands with greater habitat diversity were sampled more intensively than smaller less diverse wetlands.

At each sample site, both a water column and a benthic sample were taken and date, time, location, and water temperature was recorded. Each sample was passed through a #30 U.S. standard sieve to remove small particulate matter.

A 50% subsampling technique was used to reduce time required to sort whole samples. The porcelain pan was divided in half, a portion of the total sample was placed in the pan, mixed with water and evenly distributed. A coin toss determined which side was to be sorted. All numbers and weights were doubled before recording on data sheets. Air dried weights were determined, to the nearest 0.0001 g, for each taxanomic group of invertebrates from each sample using a Mettler H51 balance. Approximately 500 copepods and cladocerans were taken from each of 15 samples and weighted determine the mean weight of individuals. Later these two groups were counted and the weight conversions applied.

Samples were preserved in 95% ethyl alcohol and prior to sorting, were stained with a combination of Biebrich scarlet and Eosin B (Williams and Williams 1973). Samples were sorted in a porcelain pan to family for Coleoptera, Diptera, and Hemiptera, and to order for other invertebrates

using using Hilsenhoff (1975) for aquatic insects and Pennak (1978) for other aquatic invertebrates.

Brood observations were conducted once per week on each of the 4 areas. Vantage points allowing for complete coverage of the wetland was used for Kruizenga and Flaters WPAs. A combination of flush counts and vantage point observations were used on Erickson and Amschler WPAs as these 2 areas were too large to be covered from 1 point. Both point observations and flush counts generally yield similar results (Rumble and Flake 1982).

Data from each area for both 1983 and 1984 were pooled for analysis using an SPSS (Statistical Package for the Social Sciences) program on a Burroughs 6900 mainframe computer. One way ANOVA procedures were run to compare mean invertebrate numbers and biomass among the 4 areas for both water column and benthic samples. Scheffes procedure (Scheffe 1959) was run to determine significant ($P<0.05$) differences among areas.

RESULTS AND DISCUSSION

Benthic Samples

Dominant vegetative associations on the 4 WPA's are given in Table 1. A variety of invertebrate taxa were present on each of the study areas (Table 2). Mean total invertebrate numbers ranged from 15,453/M^2 on Kruizenga WPA to 38,085 /M^2 on Erickson WPA (Table 3). Wheeler and March (1979) found densities ranging from 3,960 to 50,260/M^2 on

Table 1. Dominant vegetative associations on Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, 1983-1984.

Area	Percent occurance
Erickson	
Open water	75.6
Arrowhead-Burreed-Cattail	9.7
Reed cannary grass	4.5
Coontail-Elodea	3.7
Cattail	3.5
Willow	3.2
Amschler	
Open water	37.1
Milfoil	34.0
Reed canary grass	12.1
Milfoil-Smartweed	7.8
Smartweed	5.7
Arrowhead-sedge	1.9
Cattail	1.4
Kruizenga	
Cattail-Duckweed	40.1
Open water	35.1
Sedge	13.8
Floating pondweed	4.9
Duckweed	3.3
Duckweed-Rushes	2.8
Flaters	
Fries pondweed	63.3
Reed canary grass	20.9
Duckweed	15.8

Table 2. Invertebrate taxa present on Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, 1983-1984.

Erickson	Amschler	Kruizenga	Flaters
Ephemeroptera	Oligocheate	Amphipoda	Collembola
Hydracarina	Cladocera	Copepoda	Hirundinea
Gastropoda	Copepoda	Cladocera	Gastropoda
Oligoceate	Gastropoda	Ephemeroptera	Copepoda
Cladocera	Hirudinea	Hirundinea	Amphipoda
Copepoda	Collembola	Gastropoda	Oligocheate
Hirudinea	Hydracarina	Oligocheate	Tricoptera
Amphipoda	Ephemeroptera	Collembola	Cladocera
Collembola	Amphipoda	Hydracarina	Hydracarina
Decapoda	Tricoptera	Tricoptera	Ephemeroptera
Tricoptera	Diptera	Diptera	Diptera
Diptera	Chironomidae	Chironomidae	Chironomidae
Chironomidae	Ceratopogonidae	Tipulidae	Tipulidae
Ceratopogonidae	Stratiomyidae	Stratiomyidae	Stratiomyidae
Syrphidae	Hemiptera	Ceratopogonidae	Ceratopogonidae
Stratiomyidae	Veliidae	Sciomyzidae	Sciomyzidae
Tipulidae	Pleidae	Syrphidae	Tabanidae
Hemiptera	Corixidae	Culicidae	Hemiptera
Corixidae	Hydrometridae	Hemiptera	Corixidae
Pleidae	Coleoptera	Corixidae	Pleidae
Notonectidae	Dytiscidae	Pleidae	Mesoveliidae
Veliidae	Gyrinidae	Mesoveliidae	Notonectidae
Mesoveliidae	Haliplidae	Notonectidae	Coleoptera
Nepidae	Hydrophilidae	Gerridae	Helodidae
Coleoptera	Circulionidae	Veliidae	Dytiscidae
Haliplidae	Odonata	Belostomatidae	Hydrophilidae
Dytiscidae	Anisoptera	Coleoptera	Gyrinidae
Helodidae	Zygoptera	Dytiscidae	Odonata
Hydrophilidae		Helodidae	Anisoptera
Circulionidae		Circulionidae	Zygoptera
Odonata		Hydrophilidae	
Anisoptera		Odonata	
Zygoptera		Anisoptera	
		Zygoptera	

Table 3. Mean invertebrate numbers and biomass/M^2 from benthic samples for Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, 1983-1984. Biomass is in grams dry weight, (95% confidence intervals).

	Erickson (N=72)	Amschler (N=72)	Kruizenga (N=60)	Flaters (N=36)
Total invertebrate numbers	38085 (31193-44977)	19595 (16806-22384)	15453 (11691-19214)	20180 (14806-25553)
Total invertebrate biomass	5.85 (3.74-7.96)	3.05 (1.96-4.14)	5.10 (2.20-8.00)	16.06 (6.32-25.80)
Chironomidae numbers	4373 (3161-5585)	6300 (4820-7781)	5220 (2734-7706)	6628 (3986-9271)
Chironomidae biomass	0.41 (0.28-0.53)	0.50 (0.33-0.67)	1.12 (0.24-2.08)	2.02 (0.41-3.62)

wetlands in southeast Wisconsin using an Ekman dredge and felt this invertebrate population was not limiting duck production. Southeast Wisconsin is considered one of the most productive areas in Wisconsin for waterfowl (Jahn and Hunt 1964).

In two central Wisconsin studies, Nelson (1978) and Baldassarre (1978) found mean total invertebrate densities of 2,372 and 3,747/M^2, respectively. Both authors reported production of near flight aged young was less than 33 percent of that reported from southeast Wisconsin and believed this was a result of poor water and soil fertility ultimately resulting in depressed invertebrate populations.

Chironomidae is an extremely important taxa in the diets of juvenile waterfowl (Chura 1961, Sugden 1973). Chironomidae populations ranged from 4,373 to 6,628/M^2 on Erickson and Flaters WPAs, respectively (Table 3). In a North Dakota study, Talent et al. (1982) suggested that broods moved from wetlands low in Chironomidae numbers to wetlands with high populations. He found Chironomidae densities of 1,950 and 7,047/M^2 on areas used as final brood rearing habitat and densities of 648 to 10,092/M^2 on wetlands used by sedentary broods. On areas unused by broods, densities were 68 and 205/M^2. Since a core sampler of similar design was used, the results are comparable. North Dakota, as part of the prairie pothole region, produces approximately 5 million ducks annually (Bellrose 1976) and thus is considered one of the optimum production areas in North America.

Street (1977), in an Oxford, England study felt that excessive duckling mortality was due to a lack of available invertebrate food items, especially Chironomidae. He measured Chironomidae densities with an Ekman dredge and determined densities of 422 and 822/M^2. McKnight (1969) found Chironomidae densities of 6,960 and 10,800/M^2 on 2 newly flooded spring fed marshes at Fish Springs NWR, Utah. He attributed the high duckling production on these marshes to the high Chironomidae populations. Managed waterfowl areas in the west are known to have some of the highest waterfowl production in North America (Jensen and Chattin 1964).

Water Column Invertebrates

Total invertebrate numbers/M^3 from water column samples ranged from 2,267 on Amschler WPA to 10,317 on Flaters WPA (Table 4). Kaminski and Prince (1981), at Delta Marsh, Manitoba, found densities of 6,993 and 18,906/M^3 on 2 areas used as controls for wetland treatment studies. Wheeler and March (1979) found that wetlands in southeastern Wisconsin ranged from 4,500 to 27,000 invertebrates/M^3 in water less than 15 cm deep. They also felt that this invertebrate population was not a limiting factor to waterfowl production. These 3 areas are all considered good waterfowl production areas, and the results from this study compare favorably.

In a central Wisconsin study, Baldassarre (1978) found mean invertebrate densities of 3 impoundments to be 3,067/M^3 (N=21). He felt a lack of invertebrates in this area was

Table 4. Mean invertebrate numbers and biomass/M^3 from water column samples for Erickson, Amschler, Kruizenga, Flaters Waterfowl Production Areas, 1983-1984. Biomass is in grams dry weight, (95% confidence intervals).

	Erickson (N=72)	Amschler (N=72)	Kriuzenga (N=60)	Flaters (N=36)
Total Invertebrate Numbers	9688 (7109-12267)	2267 (1623-2911)	6835 (5189-8481)	10317 (7079-13554)
Biomass	2.64 (1.67-3.60)	1.77 (0.99-2.55)	3.06 (1.86-4.27)	8.80 (4.31-13.29)
Chironomidae numbers	2040 (1330-2750)	471 (267-675)	1270 (720-1820)	1405 (539-2271)
Biomass	0.14 (0.09-0.20)	0.024 (0.01-0.04)	0.14 (0.06-0.22)	0.11 (0.07-0.15)
Amphipoda numbers	131 (74-189)	14 (4-25)	947 (627-1267)	3680 (2010-5350)
Biomass	0.27 (0.16-0.38)	0.02 (0.01-0.03)	0.31 (0.20-0.42)	2.74 (0.93-4.55)
Cladocera numbers	1238 (299-2176)	940 (520-1360)	1315 (742-1888)	687 (0-1538)
Gastropoda numbers	144 (80-208)	22 (10-34)	298 (106-490)	285 (42-529)
Biomass	0.54 (0.27-0.81)	0.26 (-0.10-0.62)	1.32 (0.24-2.39)	2.32 (0.53-4.11)
Corixidae numbers	75 (1-149)	6 (2-11)	74 (38-110)	697 (349-1045)
Biomass	0.03 (-0.02-0.08)	0.004 (0.001-0.007)	0.07 (0.01-0.12)	0.39 (0.20-0.59)

depressing duck production. Amschler WPA (2,267/M^3), had significantly ($P<0.05$) fewer water column invertebrates than the other 3 study areas and also had the lowest brood use (Table 5). Amschler WPA has a large pumkinseed (Lepomis gibbosus) population (H. Bolton pers. comm.) which may be impacting populations of invertebrates. In Sweden, fish and ducks compete directly for invertebrate food items (Pehrsson 1984). Thus Amschler WPA may be lacking water column invertebarates but appears to have adequate benthic invertebrates (Table 3). Whether the benthic invertebrates are available to ducklings is unknown.

Invertebrate biomass/M^3 ranged from 1.77 g on Amschler WPA to 8.8 g on Flaters WPA (Table 4). Kaminski and Prince (1981), found 2.84 and 11.16 g/M^3 in a Delta Marsh, Manitoba study.

Brood Use, Mobility, and Survival

Two species were recorded during brood observations, blue-winged teal (Anas discors), and mallard (Anas platyrhynchos). Both species were combined when determining brood use/km of shoreline (Table 5).

On the 4 study areas, age class III mallard broods averaged 6.7 (N=9). Talent et al. (1982), in a study with radio marked broods, found that mallards fledged an average of 5.0 young per brood (N=4). He believed this was typical of prairie wetlands. Bellrose (1976), in a summary of waterfowl brood studies, determined class III mallard broods averaged 5.9 (N=1169). Street (1977) in England, found that

Table 5. Duck brood observations/survey/kilometer of shoreline for Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas (21 total surveys per wetland), 1983-1984.

Area	Sightings/survey/km
Erickson	0.35
Amschler	0.18
Kruizenga	0.78
Flaters	1.28

class III broods averaged 3.3 ± 0.5 ducklings. He attributed this low number to excessive losses early in brood rearing due to a lack of invertebrate foods. Thus, survival of ducklings appears comparable with an area of North Dakota and from studies of mallard broods from a variety of locations.

Blue-winged teal averaged 6.0 duckling at age class III (N=6). Bellrose (1976) in a summary of brood observations reports that the average class III brood is 7.51 (N=2924). Although this study figure is lower than reported by Bellrose (1976) brood attrition during the early life stage (I and II) was Class I = 9.47 (N=13) and class II = 9.38 (N=8). Bellrose (1976) determined average class I broods of 8.4 (N=3039) and class II broods of 7.9 (N=3061). Invertebrates make up the most important component of the early life stage diet (Chura 1961, Sugden 1973) thus if invertebrates were limiting, mortality during these early age classes would be greater. Street (1977) found in an area deficient in invertebrates that nearly all of the brood mortality (mallards) occurred in the first 12 days of life and that 60% of the class Ia broods were lost completely (mammalian predators were controlled in this study). While the present study did not determine the degree of total brood loss, the large size of class I and II blue-winged teal and class III mallard broods would indicate that invertebrates are not impacting duckling survival.

The mobility of duck broods has been well documented (Evans and Black 1956, Berg 1956, Talent et al. 1982,

Ringleman and Longcore 1982). Many researchers have shown that brood habitat selection and movements are related to invertebrate abundance (Collias and Collias 1963, Bengtson 1975, Talent et al. 1982).

The Wisconsin DNR has been nasal marking (Doty and Greenwood 1974) hens with broods on and near the study areas. Of 14 subsequent observations of blue-wing teal broods, 9 were on the wetland nearest the nest and of 2 subsequent mallard brood observations, both were on their natal wetland (J. Evrard pers. comm.). Although this data is limited it would indicate that invertebrates are adaquate for at least the sedentary broods. On Flaters and Kruizenga WPAs, several broods stayed on the wetland from class 1 through class III, again indicating invertebrate production was adaquate for growth and development.

No attempt was made to correlate brood use with invertebrate abundance because of the multitude of factors ultimately affecting use such as brood predation, number of nesting pairs, nest success, proximity of nesting, and wetland cover. In addition, the differing visibility of broods on each of the areas made an absolute determination of brood use impossible.

Although quanitative invertebrate data was gathered during the study, the availability of this food source can only be assumed. The availablity of invertebrates to ducklings is dependent on the physical ability of the bird to catch and consume the particular food item (Collias and

Collias 1963). Another important consideration is the availability of terrestrial invertebrates to ducklings in this area. On several occasions ducklings were observed picking spiders or insects from terrestrial vegetation. If aquatic invertebrates were lacking in the area, ducklings could possibly supplement their diet with terrestrial food items. Chura (1961) documented the importance of terrestrial invertebrates to juvenile waterfowl.

Further research is needed in this area to determine invertebrate populations present during the spring migration. If invertebrate populations are insufficent at this time of year, pairs may leave for more favorable food resources. The ultimate determinant of duckling density may be more related to numbers of nesting pairs and predation.

CONCLUSION

In summary, invertebrate densities were comparable to those found in good production areas; North Dakota wetlands, Delta Marsh, Manitoba, newly impounded marshes at the Fish Springs NWR, Utah, and southeast Wisconsin. In addition, broods in this area generally remain on their natal wetland even though other wetlands are available, and duckling survival is comparable to good waterfowl production areas, thus invertebrate populations are probably not limiting duckling production in this area of Wisconsin.

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APPENDICES

Appendix A. Table 1. Brood survey results from Erickson Waterfowl Production Area, 1983. Number of ducklings in parentheses.

	Age Class						
Date	Ia	Ib	Ic	IIa	IIb	IIc	III
1 June							
5 June							
9 June		1(8)M					
17 June			1(3)W				
24 June				1(3)W			
1 July		1(9)B		1(8)M			
6 July		1(?)B 1(10)B	1(10)B		1(?)M		
15 July			1(?)B	1(?)M	1(9)B		
22 July						1(7)B	1(8)B

(?) incomplete count

B Blue winged teal (Anas discors)

M Mallard (Anas platyrhynchos)

W Wood duck (Aix sponsa)

Appendix A. Table 2. Brood survey results from Erickson Waterfowl Production Area, 1984. Number of ducklings in parentheses.

	Age Class						
Date	Ia	Ib	Ic	IIa	IIb	IIC	III
26 May							
2 June	1(6)B						
8 June	1(?)B 1(?)W 1(9)M						
15 June			1(?)W 1(8)M				
23 June							
27 June		1(4)G					
5 July				1(13)B			
11 July		1(4)B	1(7)B 1(7)B	1(?)B	1(?)B 1(11)B		
18 July			1(4)B			1(8)B 1(7)B 1(4)B	1(4)B

(?) incomplete count

G Green winged teal (*Anas crecca*)

M Mallard (*Anas platyrhynchos*)

B Blue winged teal (*Anas discors*)

W Wood duck (*Aix sponsa*)

Appendix A. Table 3. Brood survey results from Amschler Waterfowl Production Area, 1983. Number of ducklings in parentheses.

	Age Class						
Date	Ia	Ib	Ic	IIa	IIb	IIc	III
26 May							
4 June							
8 June	1(10)M						
13 June							
23 June			1(7)M				
30 June							
6 July							
13 July				1(?)W			
22 July							1(7)M 1(3)M
28 July					1(8)B		

(?) incomplete count

W Wood duck (*Aix sponsa*)

M Mallard (*Anas platyrhynchos*)

B Blue winged teal (*Anas discors*)

Appendix A. Table 4. Brood survey results from Amschler Waterfowl Production Area, 1984. Number of ducklings in parentheses.

	Age Class						
Date	Ia	Ib	Ic	IIa	IIb	IIc	III
24 May							
1 June							
10 June							
14 June							
20 June							
28 June				1(?)M			
4 July			1(14)B 1(12)B	1(10)B			
12 July			1(?)B				
18 July	1(4)B		1(?)B 1(10)W				
28 July							
1 Aug						1(?)W	

(?) incomplete count

M Mallard (Anas platyrhynchos)

B Blue winged teal (Anas discors)

W Wood duck (Aix sponsa)

Appendix A. Table 5. Brood survey results from Kruizenga Waterfowl Production Area, 1983. Number of ducklings in parentheses.

	Age Class						
Date	Ia	Ib	Ic	IIa	IIb	IIc	III
24 May							
31 May	1(7)M						
6 June		1(7)M					
11 June		1(?)M					
17 June	1(9)R 1(?)M		1(?)M				
25 June					1(?)M		
6 July						1(5)M	
12 July		1(9)B					1(6)M
21 July							1(7)M 1(6)M
26 July						1(6)B	1(7)M 1(4)M
1 Aug							1(7)M 1(6)B

(?) incomplete count

R Ringneck duck (Aythya collaris)

M Mallard (Anas platyrhynchos)

B Blue winged teal (Anas discors)

Appendix A. Table 6. Brood survey results from Kruizenga Waterfowl Production Area, 1984. Number of ducklings in parentheses.

	Age Class						
Date	Ia	Ib	Ic	IIa	IIb	IIc	III
22 May							
5 June							
12 June							
18 June							
25 June		1(13)B					
3 July							
9 July			1(?)B		1(13)B		
16 July						1(?)B	
23 July							
30 July							

(?) incomplete count

B Blue winged teal (Anas discors)

Appendix A. Table 7. Brood survey results from Flaters Waterfowl Production Area, 1983. Number of ducklings in parentheses.

	Age class						
Date	Ia	Ib	Ic	IIa	IIb	IIc	III
24 May							
2 June							
6 June							
13 June	1(8)M						
22 June			1(8)M				
25 June				1(?)M			
5 July	1(4)M						
12 July		1(4)M					
20 July							
26 July							
4 Aug							

(?) incomplete count

M Mallard (*Anas platyrhynchos*)

Appendix A. Table 8. Brood survey results from Flaters Waterfowl Production Area, 1984. Number of ducklings in parentheses.

	Age Class						
Date	Ia	Ib	Ic	IIa	IIb	IIc	III
23 May							
30 May							
6 June							
13 June							
19 June							
28 June							
4 July		1(9)M					
10 July			1(9)M				
16 July	1(7)M				1(5)B		
24 July					1(6)M		

(?) incomplete count

M Mallard (Anas platyrhynchos)

B Blue winged teal (Anas discors)

Appendix B. Table 1. Mean invertebrate numbers and biomass (grams dry weight)/M^2 from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, benthic samples 1983.

Total invertebrates

Date	Erickson	SD	N	Amschler	SD	N	Date	Kruizenga	SD	N	Flaters	SD	N
21 May	21879	14878	6	6418	3674	6	16 May	6340	4138	5	6809	1702	3
	(3.711)	(5.172)		(7.182)	(12.802)			(0.712)	(0.400)		(0.751)	(0.348)	
4 June	35283	17666	6	15213	11515	6	29 May	21702	15548	5	34752	24050	3
	(6.049)	(7.522)		(2.282)	(2.516)			(1.848)	(1.001)		(7.238)	(2.406)	
18 June	31986	2440	6	11276	6112	6	11 June	27234	16650	5	49645	19733	3
	(1.656)	(0.745)		(1.285)	(1.281)			(1.246)	(1.173)		(18.709)	(13.768)	
2 July	51418	22826	6	30638	10080	6	25 June	30128	20710	5	23262	10641	3
	(4.218)	(2.736)		(2.133)	(1.736)			(1.801)	(0.942)		(40.347)	(62.638)	
17 July	61666	30177	6	19858	9953	6	9 July	13277	9503	5	9929	5388	3
	(5.489)	(3.141)		(0.746)	(0.429)			(14.075)	(25.859)		(7.521)	(5.924)	
1 Aug	85886	45055	6	14681	6986	6	25 July	11489	4223	5	11773	11516	3
	(18.779)	(23.004)		(0.871)	(0.585)			(15.185)	(28.973)		(7.200)	(7.183)	
							6 Aug	6894	4019	5	7518	2600	3
								(5.267)	(3.313)		(29.335)	(44.987)	
Mean	48020	33538	36	16347	10999	36	Mean	16723	14502	35	20527	19127	21
	(6.651)	(11.061)		(2.417)	(5.456)			(5.733)	(14.618)		(15.871)	(28.433)	

Appendix B. Table 2. Mean Chironomidae numbers and biomass (grams dry weight)/M^2 from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, benthic samples 1983.

	Chironomidae											
Date	Erickson	SD	N	Amschler	SD	N	Date	Kruizenga	SD	N	Flaters	SD	N
21 May	6028 (0.531)	4349 (0.486)	6	1596 (0.050)	1057 (0.046)	6	16 May	979 0.022)	731 (0.026)	5	851 (0.266)	426 (0.437)	3
4 June	3262 (0.226)	3038 (0.253)	6	8617 (0.329)	10972 (0.249)	6	29 May	4596 (0.077)	4704 (0.031)	5	14326 (0.749)	6171 (0.347)	3
18 June	2837 (0.095)	2944 (0.133)	6	3830 (0.328)	2067 (0.277)	6	11 June	12426 (0.452)	19136 (0.778)	5	26383 (12.461)	8218 (14.504)	3
2 July	4468 (0.259)	4605 (0.296)	6	14893 (0.843)	11405 (0.847)	6	25 June	7660 (0.671)	8006 (1.158)	5	13900 (1.206)	5405 (0.194)	3
17 July	10000 (0.656)	8599 (0.720)	6	6312 (0.321)	4555 (0.313)	6	9 July	6723 (5.123)	12671 (11.338)	5	4255 (1.314)	4833 (1.925)	3
1 Aug	5816 (0.493)	4736 (0.399)	6	7376 (0.367)	7563 (0.421)	6	25 July	4085 (2.565)	5454 (3.768)	5	3546 (0.398)	4745 (0.394)	3
							6 Aug	1277 (1.749)	2407 (3.657)	5	4539 (1.072)	886 (0.583)	3
Mean	5402 (0.376)	5276 (0.441)	36	7104 (0.373)	8102 (0.468)	36	Mean	5392 (1.522)	9505 (4.646)	35	9686 (2.495)	9573 (6.246)	21

Appendix B. Table 3. Mean Amphipoda numbers and biomass (grams dry weight)/M^2 from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, benthic samples 1983.

	Amphipoda											
Date	Erickson	SD	N	Amschler	SD	N	Date	Kruizenga	SD	N	Flaters	SD	N
21 May	319 (0.153)	499 (0.292)	6	36 (0.003)	87 (0.006)	6	16 May	170 (0.083)	233 (0.182)	5	1560 (0.170)	2344 (0.172)	3
4 June	1134 (0.247)	1972 (0.372)	6	177 (0.032)	341 (0.076)	6	29 May	2128 (0.237)	3818 (0.341)	5	6950 (3.999)	3019 (3.238)	3
18 June	142 (0.001)	347 (0.001)	6	355 (0.033)	682 (0.063)	6	11 June	1447 (0.166)	1665 (0.193)	5	10071 (3.315)	8557 (2.870)	3
2 July	1418 (0.263)	1607 (0.324)	6	2837 (0.121)	3774 (0.141)	6	25 June	1617 (0.497)	819 (0.404)	5	5248 (1.190)	4668 (1.502)	3
17 July	2128 (0.442)	1845 (0.402)	6	496 (0.055)	682 (0.069)	6	9 July	2894 (0.439)	2115 (0.424)	5	3830 (0.488)	1950 (0.325)	3
1 Aug	3049 (0.433)	3280 (0.675)	6	142 (0.010)	220 (0.022)	6	25 July	596 (0.135)	1332 (0.301)	5	851 (0.308)	851 (0.281)	3
							6 Aug	681 (0.101)	1068 (0.131)	5	1135 (0.980)	1965 (1.698)	3
Mean	1365 (0.256)	2012 (0.400)	36	674 (0.042)	1783 (0.081)	36	Mean	1362 (0.237)	1950 (0.315)	35	4235 (1.493)	4736 (2.127)	21

Appendix B. Table 4. Mean invertebrate numbers and biomass (grams dry weight)/M^2 from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, benthic samples 1984.

Total invertebrates

Date	Erickson	SD	N	Amschler	SD	N	Date	Kruizenga	SD	N	Flaters	SD	N
26 May	20816 (1.984)	15334 (1.962)	6	22624 (5.023)	14442 (3.659)	6	19 May	8851 (5.273)	3060 (5.273)	5	19433 (9.915)	5978 (3.527)	3
8 June	38227 (3.161)	30243 (2.197)	6	18653 (1.272)	7417 (0.699)	6	1 June	17702 (0.605)	18393 (0.673)	5	35815 (5.394)	12282 (5.894)	3
22 June	18369 (3.401)	12970 (2.064)	6	25531 (2.687)	10506 (3.523)	6	15 June	18979 (2.281)	19289 (1.785)	5	31773 (5.422)	4550 (0.887)	3
6 July	26383 (3.904)	15148 (3.782)	6	37127 (4.850)	12629 (4.711)	6	29 June	21021 (11.313)	23789 (10.248)	5	10638 (4.006)	3829 (2.826)	3
20 July	25673 (10.548)	22998 (14.243)	6	18798 (3.670)	8899 (1.789)	6	12 July	4851 (2.898)	4262 (2.615)	5	6667 (66.907)	2099 (60.176)	3
3 Aug	39432 (7.322)	25099 (3.629)	6	14326 (4.552)	6980 (5.665)	6	26 July	12426 (3.803)	10210 (4.538)	5	14326 (6.044)	9030 (5.101)	3
Mean	28150 (5.055)	21285 (6.613)	36	22842 (3.680)	12205 (3.716)	36	Mean	13972 (4.362)	15126 (5.889)	30	19775 (16.281)	12544 (31.336)	18

Appendix B. Table 5. Mean Chironomidae numbers and biomass (grams dry weight)/M^2 from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, benthic samples 1984.

	Chironomidae											
Date	Erickson	SD	N	Amschler	SD	N	Date	Kruizenga	SD	N	Flaters	SD	N
26 May	1489 (0.203)	699 (0.203)	6	3546 (1.358)	1878 (1.704)	6	19 May	1532 (0.405)	979 (0.766)	5	4681 (2.810)	2790 (1.136)	3
8 June	8298 (0.495)	10325 (0.821)	6	4610 (0.269)	3398 (0.172)	6	1 June	8511 (0.087)	17842 (0.080)	5	6028 (4.149)	4310 (5.098)	3
22 June	3759 (0.216)	4734 (0.368)	6	6808 (0.334)	3611 (0.406)	6	15 June	2979 (0.280)	3255 (0.192)	5	2128 (0.268)	426 (0.193)	3
6 July	1915 (0.314)	1800 (0.480)	6	8298 (0.500)	6775 (0.654)	6	29 June	10383 (2.331)	17023 (3.576)	5	426 (0.228)	426 (0.218)	3
20 July	2482 (0.650)	1509 (0.563)	6	5957 (0.766)	1346 (1.040)	6	12 July	1447 (0.520)	3235 (1.163)	5	851 (0.953)	737 (1.342)	3
3 Aug	2128 (0.722)	1262 (1.149)	6	3759 (0.504)	3132 (0.647)	6	26 July	5277 (0.761)	5650 (1.497)	5	4255 (0.326)	3782 (0.382)	3
Mean	3345 (0.433)	5007 (0.656)	36	5497 (0.622)	3901 (0.925)	36	Mean	5021 (0.731)	10169 (1.709)	30	3061 (1.456)	3066 (2.416)	18

Appendix B. Table 6. Mean Amphipoda numbers and biomass (grams dry weight)/M^2 from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, benthic samples 1984.

	Amphipoda											
Date	Erickson	SD	N	Amschler	SD	N	Date	Kruizenga	SD	N	Flaters	SD	N
26 May	213 (0.162)	521 (0.398)	6	0 (0.0)	0 (0.0)	6	19 May	0 (0.0)	0 (0.0)	5	1135 (2.867)	246 (1.654)	3
8 June	1134 (0.205)	1193 (0.295)	6	213 (0.016)	521 (0.040)	6	1 June	85 (0.015)	190 (0.034)	5	2270 (.00)	1494 (0.097)	3
22 June	425 (0.089)	538 (0.151)	6	284 (0.050)	515 (0.102)	6	15 June	170 (0.011)	381 (0.025)	5	6809 (1.820)	4443 (0.875)	3
6 July	2199 (0.648)	3355 (0.840)	6	3546 (0.712)	6875 (1.376)	6	29 June	85 (0.015)	190 (0.032)	5	3972 (2.054)	1368 (0.775)	3
20 July	213 (0.126)	356 (0.251)	6	567 (0.269)	581 (0.247)	6	12 July	0 (0.0)	0 (0.0)	5	3829 (2.905)	2553 (2.342)	3
3 Aug	4043 (0.623)	3823 (0.508)	6	1277 (0.172)	2525 (0.235)	6	26 July	85 (0.001)	190 (0.001)	5	4823 (2.817)	886 (1.501)	3
Mean	1371 (0.309)	2442 (0.491)	36	981 (0.622)	3051 (0.925)	36	Mean	71 (0.007)	196 (0.021)	30	3806 (2.094)	2669 (1.557)	18

Appendix B. Table 7. Mean invertebrate numbers and biomass (grams dry weight)/M^3 from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, water column samples 1983.

Total invertebrates

Date	Erickson	SD	N	Amschler	SD	N	Date	Kruizenga	SD	N	Flaters	SD	N
21 May	8464 (1.110)	5717 (0.550)	6	4324 (3.870)	3219 (5.890)	6	16 May	3667 (3.052)	2293 (2.004)	5	14048 (24.783)	1553 (17.267)	3
4 June	6112 (1.110)	5186 (1.050)	6	1028 (0.460)	925 (0.410)	6	29 May	15410 (2.111)	10765 (1.121)	5	16902 (5.605)	5858 (1.912)	3
18 June	1941 (0.310)	1000 (0.190)	6	735 (1.460)	594 (3.450)	6	11 June	14935 (2.687)	8744 (1.650)	5	10704 (4.812)	6807 (4.382)	3
2 July	5116 (1.170)	2463 (0.720)	6	746 (0.100)	563 (0.130)	6	25 June	10785 (2.203)	6380 (1.093)	5	9820 (3.136)	12064 (4.395)	3
17 July	16857 (2.780)	8635 (1.990)	6	1854 (1.170)	3383 (1.790)	6	9 July	4432 (4.136)	2787 (2.949)	5	15106 (28.040)	17070 (35.734)	3
1 Aug	10763 (1.950)	10282 (1.940)	6	2.980 (0.020)	3.470 (0.020)	6	25 July	1342 (0.263)	1538 (0.229)	5	1484 (1.221)	641 (0.828)	3
							6 Aug	4357 (0.478)	4089 (0.317)	5	3228 (1.477)	4820 (1.739)	3
Mean	8209 (1.410)	7639 (1.420)	36	1498 (1.180)	2285 (2.980)	36	Mean	7847 (2.133)	7782 (1.949)	35	10185 (9.869)	9256 (16.738)	21

Appendix B. Table 8. Mean Chironomidae numbers and biomass (grams dry weight)/M^3 from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, water column samples 1983.

	Chironomidae											
Date	Erickson	SD	N	Amschler	SD	N	Date	Kruizenga	SD	N	Flaters	SD	N
21 May	6550 (0.651)	5807 (0.489)	6	1358 (0.086)	1014 (0.116)	6	16 May	303.4 (0.024)	259.4 (0.027)	5	421.4 (0.026)	407.4 (0.033)	3
4 June	2048 (0.123)	1774 (0.104)	6	467 (0.026)	316 (0.023)	6	29 May	2753.1 (0.055)	2232.5 (0.037)	5	8042.9 (0.310)	5701.0 (0.218)	3
18 June	228 (0.025)	186 (0.038)	6	106 (0.009)	155 (0.010)	6	11 June	4655.7 (0.348)	5387.1 (0.684)	5	2898.2 (0.321)	421.6 (0.071)	3
2 July	1638 (0.090)	1282 (0.080)	6	149 (0.004)	116 (0.004)	6	25 June	1548.2 (0.315)	2178.4 (0.583)	5	962.6 (0.102)	243.6 (0.033)	3
17 July	1375 (0.073)	1049 (0.048)	6	50 (0.002)	59 (0.003)	6	9 July	458.9 (0.199)	813.7 (0.399)	5	329.4 (0.033)	72.1 (0.016)	3
1 Aug	592 (0.040)	369 (0.035)	6	36 (0.001)	38 (0.001)	6	25 July	53.3 (0.012)	69.7 (0.016)	5	386.8 (0.036)	353.1 (0.047)	3
							6 Aug	106.1 (0.012)	109.6 (0.015)	5	865.2 (0.142)	1328.5 (0.231)	3
Mean	2072 (0.167)	3193 (0.294)	36	361 (0.020)	627 (0.055)	36	Mean	1411.2 (0.138)	2701.4 (0.365)	35	1986.6 (0.139)	3258.2 (0.160)	21

Appendix B. Table 9. Mean Amphipoda numbers and biomass (grams dry weight)/M^3 from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, water column samples 1983.

	Amphipoda											
Date	Erickson	SD	N	Amschler	SD	N	Date	Kruizenga	SD	N	Flaters	SD	N
21 May	39.1 (0.027)	26.4 (0.024)	6	780.7 (0.060)	1123.5 (0.089)	6	16 May	569.9 (0.626)	281.6 (0.427)	5	7204.4 (8.520)	3084.3 (4.400)	3
4 June	526.8 (0.106)	601.4 (0.095)	6	448.7 (0.024)	487.8 (0.028)	6	29 May	2018.4 (0.931)	1821.7 (0.544)	5	6210.9 (3.014)	1953.0 (1.715)	3
18 June	98.6 (0.010)	191.9 (0.014)	6	23.3 (0.002)	45.2 (0.004)	6	11 June	2228.8 (0.486)	1020.5 (0.330)	5	4581.1 (2.118)	5131.9 (2.818)	3
2 July	554.9 (0.123)	364.2 (0.081)	6	8.4 (0.001)	13.1 (0.002)	6	25 June	2069.0 (0.678)	1981.5 (0.565)	5	6006.7 (2.100)	9340.4 (3.391)	3
17 July	2136.7 (0.345)	2199.3 (0.287)	6	11.5 (0.004)	20.7 (0.006)	6	9 July	1498.3 (0.607)	1242.4 (0.669)	5	9030.1 (10.965)	12925.5 (17.826)	3
1 Aug	3224.2 (0.311)	5326.1 (0.381)	6	0.0 (0.0)	0.0 (0.0)	6	25 July	425.9 (0.043)	574.6 (0.043)	5	171.9 (0.076)	259.7 (0.119)	3
							6 Aug	1824.9 (0.114)	1676.2 (0.107)	5	283.0 (0.130)	490.2 (0.225)	3
Mean	1096.7 (0.154)	2500.0 (0.228)	36	212.1 (0.015)	554.6 (0.042)	36	Mean	1519.3 (0.498)	1418.6 (0.499)	35	4784.0 (3.846)	6306.9 (7.214)	21

Appendix B. Table 10. Mean Cladoceran numbers/M^3 from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, water column samples 1983.

	Cladocera											
Date	Erickson	SD	N	Amschler	SD	N	Date	Kruizenga	SD	N	Flaters	SD	N
21 May	541	581	6	1848	2241	6	16 May	0.0	0.0	5	13.9	24.1	3
4 June	750	1121	6	74	97	6	29 May	1580.8	1241.5	5	186.9	240.5	3
18 June	139	93	6	386	400	6	11 June	2984.8	2633.2	5	275.5	341.1	3
2 July	562	283	6	356	370	6	25 June	4291.6	4891.4	5	97.2	168.4	3
17 July	1560	3650	6	1587	3013	6	9 July	553.1	569.2	5	422.4	668.4	3
1 Aug	521	416	6	43	75	6	25 July	283.6	324.0	5	49.5	72.0	3
							6 Aug	542.6	635.4	5	167.7	263.2	3
Mean	679	1209	36	716	1612	36	Mean	1462.4	2488.9	35	173.3	300.5	21

Appendix B. Table 11. Mean Gastropoda numbers and biomass (grams dry weight)/M^3 from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, water column samples 1983.

Gastropoda													
Date	Erickson	SD	N	Amschler	SD	N	Date	Kruizenga	SD	N	Flaters	SD	N
21 May	11.2 (0.067)	11.2 (0.079)	6	68.9 (2.240)	80.3 (5.170)	6	16 May	8.0 (0.001)	17.9 (0.003)	5	300.3 (1.761)	168.6 (0.904)	3
4 June	40.2 (0.043)	77.3 (0.085)	6	5.5 (0.123)	13.4 (0.310)	6	29 May	118.2 (0.064)	138.0 (0.054)	5	176.4 (0.131)	104.7 (0.140)	3
18 June	4.9 (0.005)	7.6 (0.011)	6	6.2 (0.001)	9.7 (0.002)	6	11 June	109.4 (0.057)	120.4 (0.063)	5	37.5 (0.367)	26.2 (0.023)	3
2 July	116.9 (0.273)	156.6 (0.406)	6	0.0 (0.0)	0.0 (0.0)	6	25 June	30.4 (0.030)	45.6 (0.041)	5	159.3 (0.220)	156.3 (0.298)	3
17 July	130.9 (0.293)	71.6 (0.262)	6	0.0 (0.0)	0.0 (0.0)	6	9 July	0.0 (0.0)	0.0 (0.0)	5	270.8 (4.616)	22.6 (4.046)	3
1 Aug	96.4 (0.152)	78.7 (0.141)	6	0.0 (0.0)	0.0 (0.0)	6	25 July	0.0 (0.0)	0.0 (0.0)	5	101.5 (0.598)	59.2 (0.331)	3
							6 Aug	19.1 (0.024)	29.9 (0.049)	5	31.4 (0.475)	54.5 (0.823)	3
Mean	66.8 (0.139)	92.7 (0.226)	36	13.4 (0.390)	40.0 (2.130)	36	Mean	40.7 (0.025)	81.5 (0.044)	35	153.9 (1.120)	131.1 (2.062)	21

Appendix B. Table 12. Mean Zygoptera numbers and biomass (grams dry weight)/M^3 from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, water column samples 1983.

	Zygoptera											
Date	Erickson	SD	N	Amschler	SD	N	Date	Kruizenga	SD	N	Flaters	SD	N
21 May	36.1 (0.041)	45.8 (0.055)	6	89.1 (0.052)	162.9 (0.084)	6	16 May	24.5 (0.035)	23.3 (0.069)	5	107.5 (0.416)	83.1 (0.259)	3
4 June	106.3 (0.230)	156.3 (0.327)	6	89.1 (0.123)	147.3 (0.206)	6	29 May	119.8 (0.116)	71.7 (0.158)	5	102.9 (0.440)	44.5 (0.273)	3
18 June	7.3 (0.003)	17.9 (0.008)	6	18.3 (0.031)	28.6 (0.050)	6	11 June	102.7 (0.190)	64.4 (0.139)	5	10.4 (0.039)	9.1 (0.066)	3
2 July	31.4 (0.036)	30.7 (0.087)	6	14.3 (0.032)	23.7 (0.069)	6	25 June	25.2 (0.052)	24.7 (0.569)	5	30.1 (0.070)	27.4 (0.040)	3
18 July	665.6 (0.056)	1006.9 (0.067)	6	16.3 (0.003)	30.8 (0.007)	6	9 July	0.0 (0.0)	0.0 (0.0)	5	111.6 (0.111)	63.6 (0.029)	3
1 Aug	341.1 (0.031)	505.5 (0.063)	6	68.2 (0.004)	167.0 (0.011)	6	25 July	3.4 (0.0)	7.7 (0.0)	5	99.0 (0.015)	74.4 (0.014)	3
							6 Aug	48.5 (0.004)	108.4 (0.009)	5	56.6 (0.011)	98.0 (0.020)	3
Mean	198.0 (0.067)	493.2 (0.154)	36	49.2 (0.041)	111.2 (0.098)	36	Mean	46.4 (0.057)	67.8 (0.104)	35	74.1 (0.157)	66.5 (0.021)	21

Appendix B. Table 13. Mean Corixidae numbers and biomass (grams dry weight)/M^3 from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, water column samples 1983.

	Corixidae											
Date	Erickson	SD	N	Amschler	SD	N	Date	Kruizenga	SD	N	Flaters	SD	N
21 May	65.2 (0.007)	141.3 (0.015)	6	0.0 (0.0)	0.0 (0.0)	6	16 May	14.3 (0.001)	31.9 (0.002)	5	0.0 (0.0)	0.0 (0.0)	3
4 June	22.7 (0.006)	20.0 (0.010)	6	8.9 (0.006)	14.3 (0.010)	6	29 May	221.5 (0.062)	57.2 (0.105)	5	448.9 (0.024)	371.5 (0.026)	3
18 June	3.7 (0.001)	9.0 (0.001)	6	7.7 (0.001)	12.8 (0.095)	6	11 June	217.4 (0.074)	292.9 (0.119)	5	428.4 (0.176)	323.0 (0.125)	3
2 July	13.1 (0.002)	26.2 (0.004)	6	0.0 (0.0)	0.0 (0.0)	6	25 June	20.4 (0.035)	28.0 (0.048)	5	272.9 (0.324)	181.4 (0.285)	3
18 July	117.3 (0.012)	146.6 (0.024)	6	11.2 (0.002)	18.1 (0.002)	6	9 July	108.5 (0.282)	242.7 (0.631)	5	204.5 (0.355)	12.0 (0.201)	3
1 Aug	45.4 (0.014)	73.2 (0.029)	6	14.7 (0.005)	21.9 (0.005)	6	25 July	23.1 (0.028)	30.3 (0.049)	5	485.9 (0.177)	414.6 (0.147)	3
							6 Aug	99.6 (0.166)	190.7 (0.370)	5	368.4 (0.093)	531.4 (0.107)	3
Mean	44.6 (0.008)	91.5 (0.017)	36	7.1 (0.003)	14.1 (0.006)	36	Mean	100.7 (0.093)	170.6 (0.274)	35	315.6 (0.164)	315.2 (0.185)	21

Appendix B. Table 14. Mean Ephemeroptera numbers and biomass (grams dry weight)/M^3 from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, water column samples 1983.

	Ephemeroptera											
Date	Erickson	SD	N	Amschler	SD	N	Date	Kruizenga	SD	N	Flaters	SD	N
21 May	247.2 (0.032)	263.6 (0.039)	6	211.6 (0.058)	259.3 (0.057)	6	16 May	7.1 (0.001)	16.0 (0.001)	5	0.0 (0.0)	0.0 (0.0)	3
4 June	454.9 (0.067)	469.0 (0.066)	6	188.7 (0.028)	311.6 (0.040)	6	29 May	9.0 (0.001)	12.5 (0.002)	5	0.0 (0.0)	0.0 (0.0)	3
18 June	77.7 (0.017)	83.8 (0.019)	6	58.9 (0.003)	94.0 (0.004)	6	11 June	6.9 (0.001)	15.4 (0.001)	5	5.5 (0.001)	9.5 (0.001)	3
2 July	191.8 (0.066)	147.1 (0.047)	6	41.5 (0.002)	88.1 (0.005)	6	25 June	0.0 (0.0)	0.0 (0.0)	5	25.7 (0.027)	24.8 (0.033)	3
18 July	1276.6 (0.066)	870.7 (0.046)	6	95.1 (0.009)	180.6 (0.019)	6	9 July	0.0 (0.0)	0.0 (0.0)	5	5.9 (0.007)	10.1 (0.012)	3
1 Aug	585.4 (0.165)	539.0 (0.176)	6	68.2 (0.005)	63.6 (0.005)	6	25 July	9.2 (0.001)	12.7 (0.001)	5	56.5 (0.024)	23.0 (0.010)	3
							6 Aug	4.2 (0.002)	9.3 (0.004)	5	17.7 (0.008)	19.0 (0.009)	3
Mean	472.3 (0.069)	597.7 (0.091)	36	110.7 (0.018)	188.4 (0.034)	36	Mean	5.2 (0.001)	10.9 (0.002)	35	15.9 (0.009)	23.2 (0.016)	21

Appendix B. Table 15. Mean invertebrate numbers and biomass (grams dry weight)/M^3 from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, water column samples 1984.

Total invertebrates

Date	Erickson	SD	N	Amschler	SD	N	Date	Kruizenga	SD	N	Flaters	SD	N
26 May	5880 (1.648)	6825 (1.425)	6	2188 (1.090)	1713 (1.143)	6	19 May	4137 (4.015)	3227 (5.399)	5	15874 (7.015)	16603 (5.042)	3
8 June	22439 (5.465)	22460 (5.862)	6	1703 (1.669)	1737 (3.604)	6	1 June	3395 (1.171)	972 (2.031)	5	11781 (3.805)	10215 (5.224)	3
22 June	7343 (5.067)	5244 (3.602)	6	4906 (2.596)	5146 (3.178)	6	15 June	11030 (2.444)	5078 (1.578)	5	19495 (4.970)	14830 (1.458)	3
6 July	5973 (2.200)	4162 (3.297)	6	4684 (0.373)	3187 (0.259)	6	29 June	8634 (7.139)	3701 (8.320)	5	4851 (8.845)	3357 (9.841)	3
20 July	3295 (1.365)	2692 (1.922)	6	2935 (2.403)	2660 (3.104)	6	12 July	3388 (7.948)	1903 (12.304)	5	3426 (12.614)	2601 (18.156)	3
3 Aug	22070 (7.439)	15832 (10.386)	6	1800 (6.023)	1265 (5.804)	6	26 July	3356 (2.180)	2778 (1.572)	5	7412 (8.071)	5943 (10.755)	3
Mean	11167 (3.864)	13663 (5.459)	36	3036 (2.359)	3013 (3.610)	36	Mean	5657 (4.150)	4262 (6.514)	30	10473 (7.554)	10614 (8.872)	18

Appendix B. Table 16. Mean Chironomidae numbers and biomass (grams dry weight)/M^3 from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, water column samples 1984.

	Chironomidae											
Date	Erickson	SD	N	Amschler	SD	N	Date	Kruizenga	SD	N	Flaters	SD	N
26 May	1008 (0.063)	1495 (0.096)	6	164 (0.086)	197 (0.197)	6	19 May	783.0 (0.397)	1059.8 (0.395)	5	914.1 (0.169)	574.4 (0.013)	3
8 June	5511 (0.160)	5184 (0.165)	6	380 (0.009)	458 (0.014)	6	1 June	566.9 (0.006)	721.8 (0.005)	5	2165.3 (0.121)	3340.8 (0.078)	3
22 June	1747 (0.262)	1703 (0.349)	6	1212 (0.021)	2429 (0.040)	6	15 June	1845.7 (0.072)	1388.7 (0.089)	5	309.0 (0.084)	81.0 (0.070)	3
6 July	785 (0.085)	892 (0.138)	6	716 (0.022)	629 (0.018)	6	29 June	1531.0 (0.159)	1851.3 (0.294)	5	191.3 (0.005)	177.4 (0.003)	3
20 July	464 (0.050)	742 (0.059)	6	520 (0.018)	321 (0.024)	6	12 July	387.7 (0.025)	323.3 (0.026)	5	192.1 (0.028)	113.1 (0.018)	3
3 Aug	2528 (0.107)	2561 (0.098)	6	491 (0.006)	760 (0.009)	6	26 July	1524.1 (0.205)	1628.0 (0.246)	5	589.2 (0.044)	461.4 (0.019)	3
Mean	2007 (0.121)	2950 (0.180)	36	581 (0.027)	1069 (0.082)	36	Mean	1106.4 (0.144)	1287.7 (0.248)	30	726.8 (0.075)	1374.6 (0.069)	18

Appendix B. Table 17. Mean Amphipoda numbers and biomass (grams dry weight)/M^3 from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, water column samples 1984.

	Amphipoda											
Date	Erickson	SD	N	Amschler	SD	N	Date	Kruizenga	SD	N	Flaters	SD	N
26 May	0.0 (0.0)	0.0 (0.0)	6	5.5 (0.032)	8.7 (0.050)	6	19 May	49.5 (0.097)	47.4 (0.138)	5	887.2 (1.510)	303.2 (0.816)	3
8 June	2652.1 (0.302)	3545.7 (0.368)	6	8.8 (0.001)	9.9 (0.001)	6	1 June	39.8 (0.024)	29.9 (0.022)	5	3323.9 (2.157)	5276.0 (3.706)	3
22 June	1911.3 (0.645)	1918.4 (0.845)	6	25.2 (0.001)	61.6 (0.002)	6	15 June	592.0 (0.153)	833.1 (0.191)	5	2532.2 (1.306)	1094.7 (0.578)	3
6 July	1500.2 (0.401)	2335.9 (0.649)	6	75.9 (0.012)	70.6 (0.013)	6	29 June	290.9 (0.077)	438.0 (0.099)	5	2593.2 (1.327)	2373.6 (1.169)	3
20 July	514.3 (0.116)	627.1 (0.160)	6	130.5 (0.039)	146.0 (0.048)	6	12 July	590.7 (0.118)	771.7 (0.125)	5	2201.1 (0.999)	2174.0 (1.010)	3
3 Aug	7353.6 (0.832)	7578.3 (0.879)	6	185.6 (0.037)	269.4 (0.065)	6	26 July	121.3 (0.023)	161.3 (0.030)	5	2814.8 (1.408)	3537.2 (1.911)	3
Mean	2271.9 (0.383)	4104.2 (0.617)	36	71.9 (0.020)	138.9 (0.040)	36	Mean	280.7 (0.082)	515.0 (0.117)	30	2392.1 (1.451)	2592.1 (1.605)	18

Appendix B. Table 18. Mean Cladocera numbers/M^3 from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, water column samples 1984.

	Cladocera											
Date	Erickson	SD	N	Amschler	SD	N	Date	Kruizenga	SD	N	Flaters	SD	N
26 May	1773	3086	6	763	999	6	19 May	319.3	410.3	5	509.8	137.7	3
8 June	6535	12929	6	729	797	6	1 June	675.6	527.5	5	500.1	347.4	3
22 June	472	571	6	2721	2963	6	15 June	3997.4	3207.3	5	6475.5	8329.0	3
6 July	845	848	6	2483	3002	6	29 June	1636.1	1611.1	5	35.8	62.1	3
20 July	11	13	6	73	68	6	12 July	210.0	239.5	5	79.0	112.3	3
3 Aug	1145	2062	6	214	160	6	26 July	26.7	37.8	5	124.7	89.7	3
Mean	1797	5561	6	1164	1978	6	Mean	1144.2	1952.6	30	1287.5	3730.9	18

Appendix B. Table 19. Mean Gastropoda numbers and biomass (grams dry weight)/M^3 from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, water column samples 1984.

	Gastropoda											
Date	Erickson	SD	N	Amschler	SD	N	Date	Kruizenga	SD	N	Flaters	SD	N
26 May	48.0 (0.031)	82.4 (0.048)	6	0.0 (0.0)	0.0 (0.0)	6	19 May	273.0 (2.053)	574.5 (4.539)	5	1574.6 (1.900)	2624.6 (2.600)	3
8 June	398.8 (1.737)	502.4 (2.306)	6	3.7 (0.001)	8.9 (0.002)	6	1 June	192.6 (0.971)	135.4 (1.991)	5	230.7 (0.186)	296.2 (0.300)	3
22 June	322.8 (1.724)	303.1 (2.076)	6	82.4 (0.605)	92.7 (1.387)	6	15 June	1235.0 (1.459)	1341.1 (0.865)	5	285.0 (0.778)	284.6 (0.435)	3
6 July	201.8 (0.640)	312.8 (1.002)	6	29.0 (0.014)	29.9 (0.016)	6	29 June	1491.1 (6.106)	1817.6 (8.290)	5	288.3 (6.536)	439.5 (9.350)	3
20 July	140.9 (0.871)	190.3 (1.497)	6	64.2 (0.107)	87.8 (0.151)	6	12 July	327.5 (5.901)	184.8 (10.925)	5	136.4 (10.099)	119.2 (15.866)	3
3 Aug	213.8 (0.648)	274.1 (0.852)	6	5.4 (0.001)	13.2 (0.003)	6	26 July	69.9 (0.542)	50.3 (0.350)	5	119.7 (2.838)	207.3 (4.916)	3
Mean	221.0 (0.942)	305.8 (1.527)	36	30.8 (0.121)	59.5 (0.573)	36	Mean	598.3 (2.838)	1035.3 (5.904)	30	439.1 (3.720)	1066.4 (7.520)	18

Appendix B. Table 20. Mean Zygoptera numbers and biomass (grams dry weight)/M^3 from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, water column samples 1984.

Zygoptera

Date	Erickson	SD	N	Amschler	SD	N	Date	Kruizenga	SD	N	Flaters	SD	N
26 May	97.5	198.3	6	49.6	14.5	6	19 May	54.4	51.3	5	254.4	440.6	3
	(0.321)	(0.602)		(0.248)	(0.426)			(0.059)	(0.081)		(0.211)	(0.365)	
8 June	0.0	0.0	6	93.6	143.8	6	1 June	6.9	15.4	5	52.3	6.0	3
	(0.0)	(0.0)		(0.303)	(0.459)			(0.006)	(0.014)		(0.170)	(0.167)	
22 June	34.5	47.7	6	45.7	19.9	6	15 June	4.9	11.0	5	17.8	4.7	3
	(0.049)	(0.075)		(0.087)	(0.081)			(0.022)	(0.048)		(0.015)	(0.009)	
6 July	100.9	204.3	6	215.5	240.6	6	29 June	0.0	0.0	5	14.3	24.8	3
	(0.026)	(0.060)		(0.148)	(0.131)			(0.0)	(0.0)		(0.108)	(0.187)	
20 July	30.3	49.7	6	194.4	158.9	6	12 July	14.9	14.3	5	43.6	24.4	3
	(0.010)	(0.023)		(0.076)	(0.106)			(0.002)	(0.003)		(0.092)	(0.160)	
3 Aug	191.9	221.9	6	232.4	318.6	6	26 July	85.6	114.9	5	171.3	157.1	3
	(0.054)	(0.050)		(0.048)	(0.085)			(0.010)	(0.020)		(0.033)	(0.035)	
Mean	75.8	153.0	36	138.5	189.5	36	Mean	27.8	57.3	30	92.3	185.4	18
	(0.077)	(0.257)		(0.152)	(0.267)			(0.017)	(0.042)		(0.105)	(0.177)	

Appendix B. Table 21. Mean Corixidae numbers and biomass (grams dry weight)/M^3 from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, water column samples 1984.

	Corixidae											
Date	Erickson	SD	N	Amschler	SD	N	Date	Kruizenga	SD	N	Flaters	SD	N
26 May	25.5 (0.001)	47.3 (0.002)	6	4.7 (0.002)	11.5 (0.004)	6	19 May	33.2 (0.140)	65.7 (0.312)	5	74.2 (0.013)	75.3 (0.022)	3
8 June	480.5 (0.312)	1078.0 (0.745)	6	0.0 (0.0)	0.0 (0.0)	6	1 June	12.9 (0.001)	20.0 (0.002)	5	1600.6 (0.440)	701.8 (0.275)	3
22 June	25.6 (0.012)	44.3 (0.019)	6	18.8 (0.014)	46.1 (0.035)	6	15 June	83.9 (0.021)	187.7 (0.047)	5	2097.8 (1.601)	2415.1 (1.407)	3
6 July	39.9 (0.006)	53.0 (0.011)	6	3.1 (0.001)	7.5 (0.001)	6	29 June	18.6 (0.005)	19.9 (0.008)	5	249.7 (0.413)	108.8 (0.197)	3
20 July	22.8 (0.002)	24.8 (0.003)	6	6.5 (0.010)	16.0 (0.025)	6	12 July	41.9 (0.001)	93.8 (0.001)	5	246.2 (0.248)	373.9 (0.263)	3
3 Aug	39.6 (0.020)	65.0 (0.025)	6	2.4 (0.003)	5.9 (0.007)	6	26 July	69.7 (0.028)	56.6 (0.028)	5	2589.1 (1.289)	1108.3 (0.061)	3
Mean	105.5 (0.059)	443.5 (0.304)	36	5.9 (0.005)	20.3 (0.017)	36	Mean	43.4 (0.033)	88.9 (0.128)	30	1142.9 (0.667)	1399.4 (0.777)	18

Appendix B. Table 22. Mean Ephemeroptera numbers and biomass (grams dry weight)/M^3 from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, water column samples 1984.

	Ephemeroptera											
Date	Erickson	SD	N	Amschler	SD	N	Date	Kruizenga	SD	N	Flaters	SD	N
26 May	172.6 (0.018)	255.7 (0.034)	6	565.5 (0.305)	871.0 (0.349)	6	19 May	10.3 (0.013)	22.9 (0.030)	5	0.0 (0.0)	0.0 (0.0)	3
8 June	183.1 (0.033)	201.9 (0.043)	6	144.4 (0.017)	154.5 (0.018)	6	1 June	3.1 (0.001)	6.8 (0.002)	5	29.3 (0.009)	25.4 (0.011)	3
22 June	411.8 (0.212)	531.8 (0.356)	6	65.1 (0.006)	68.0 (0.007)	6	15 June	24.7 (0.006)	55.2 (0.013)	5	23.0 (0.010)	39.8 (0.017)	3
6 July	307.4 (0.104)	412.4 (0.151)	6	550.4 (0.024)	1138.4 (0.038)	6	29 June	14.8 (0.022)	33.1 (0.049)	5	0.0 (0.0)	0.0 (0.0)	3
20 July	188.6 (0.039)	291.5 (0.067)	6	515.9 (0.040)	1104.0 (0.081)	6	12 July	0.0 (0.0)	0.0 (0.0)	5	0.0 (0.0)	0.0 (0.0)	3
3 Aug	437.8 (0.067)	319.7 (0.056)	6	288.0 (0.033)	158.2 (0.022)	6	26 July	25.4 (0.001)	36.3 (0.002)	5	43.9 (0.005)	40.8 (0.007)	3
Mean	283.6 (0.079)	344.9 (0.165)	36	354.9 (0.071)	718.8 (0.173)	36	Mean	13.0 (0.007)	30.5 (0.023)	30	16.0 (0.004)	27.8 (0.009)	18

Appendix C. Aquatic plant species found in samples from Erickson, Amschler, Kruizenga, and Flaters Waterfowl Production Areas, 1983-1984.

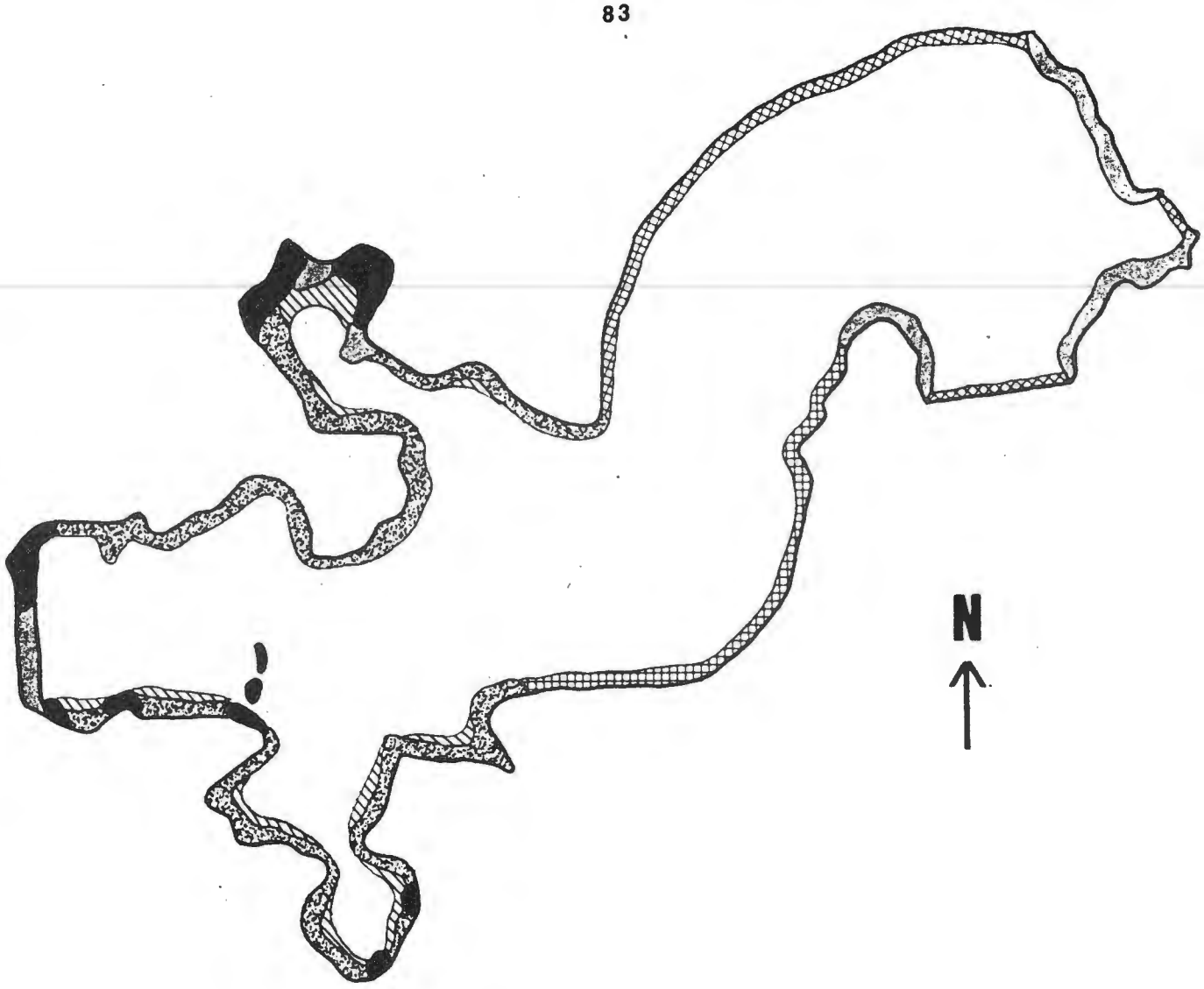
	Erickson	Kruizenga	Amschler	Flaters
Carex spp.	x	x		
Ceratophyllum demersum	x	x	x	x
Eleocharis spp.	x	x		
Elodea canadensis	x			x
Juncus spp.		x		
Lemna minor	x	x	x	x
L. trisulca		x		
Najas flexilis			x	
Myriophyllum spicatum			x	
Phalaris arundinacea	x		x	x
Polygonum spp.	x	x		
P. coccinium	x		x	x
Potamogeton friesii				x
P. gramineus			x	
P. natans		x	x	
P. pectinatus			x	
P. pusillus			x	
P. zosteriformis	x	x	x	
Riccia fluitans			x	
Saggitaria latifolia	x		x	
Scirpus heterachis	x		x	
Sparganium eurycarpum	x	x		
Spirodella polyrhiza	x	x		
Typha spp.	x	x	x	
Utricularia vulgaris		x		
Wolfia spp.		x		

Appendix D. Table 1. Significant differences ($P<0.05$) between Erickson (1), Amschler (2), Kruizenga (3), and Flaters (4) Waterfowl Production Areas for invertebrate numbers and biomass from benthic samples, 1983-1984.

	Area			
	Erickson	Amschler	Kruizenga	Flaters
Total invertebrates				
Numbers	2,3,4	1	1	1
Biomass	4	4	4	1,2,3
Chironomidae				
Numbers				
Biomass	4	4		1,2

Appendix D. Table 2. Significant differences (P<0.05) between Erickson (1), Amschler (2), Kruizenga (3), and Flaters (4) Waterfowl Production Areas for invertebrate numbers and biomass from water column samples,1983-1984.

	Area			
	Erickson	Amschler	Kruizenga	Flaters
Total invertebrates				
Numbers	2	1,3,4	2	2
Biomass	4	4	4	1,2,3
Chironomidae				
Numbers	2	1		
Biomass	2	1,3	2	
Amphipoda				
Numbers	2,4	1,4	4	1,2,3
Biomass	4	4	4	1,2,3
Cladocera				
Numbers				
Gastropoda				
Numbers		3	2	
Biomass		4		2
Corixidae				
Numbers	4	4	4	1,2,3
Biomass	4	4	4	1,2,3

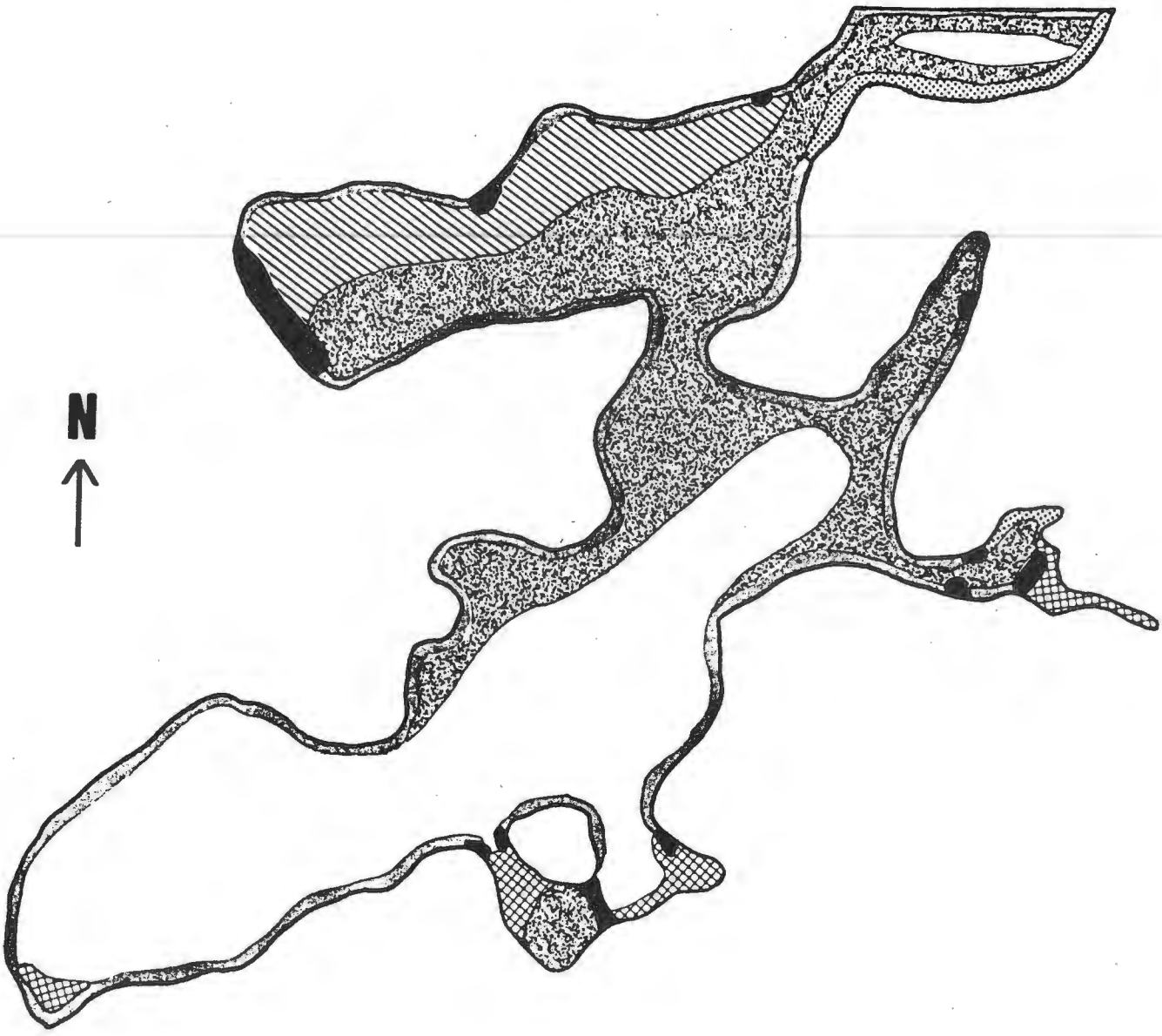


LEGEND

Coontail-Elodea
Reed canary grass
Cattail
Arrowhead-Burreed-Sedge
Willow
Open water

134 meters

Appendix E. Figure 1. Dominant plant associations on Erickson Waterfowl Production Area, 1983-1984.

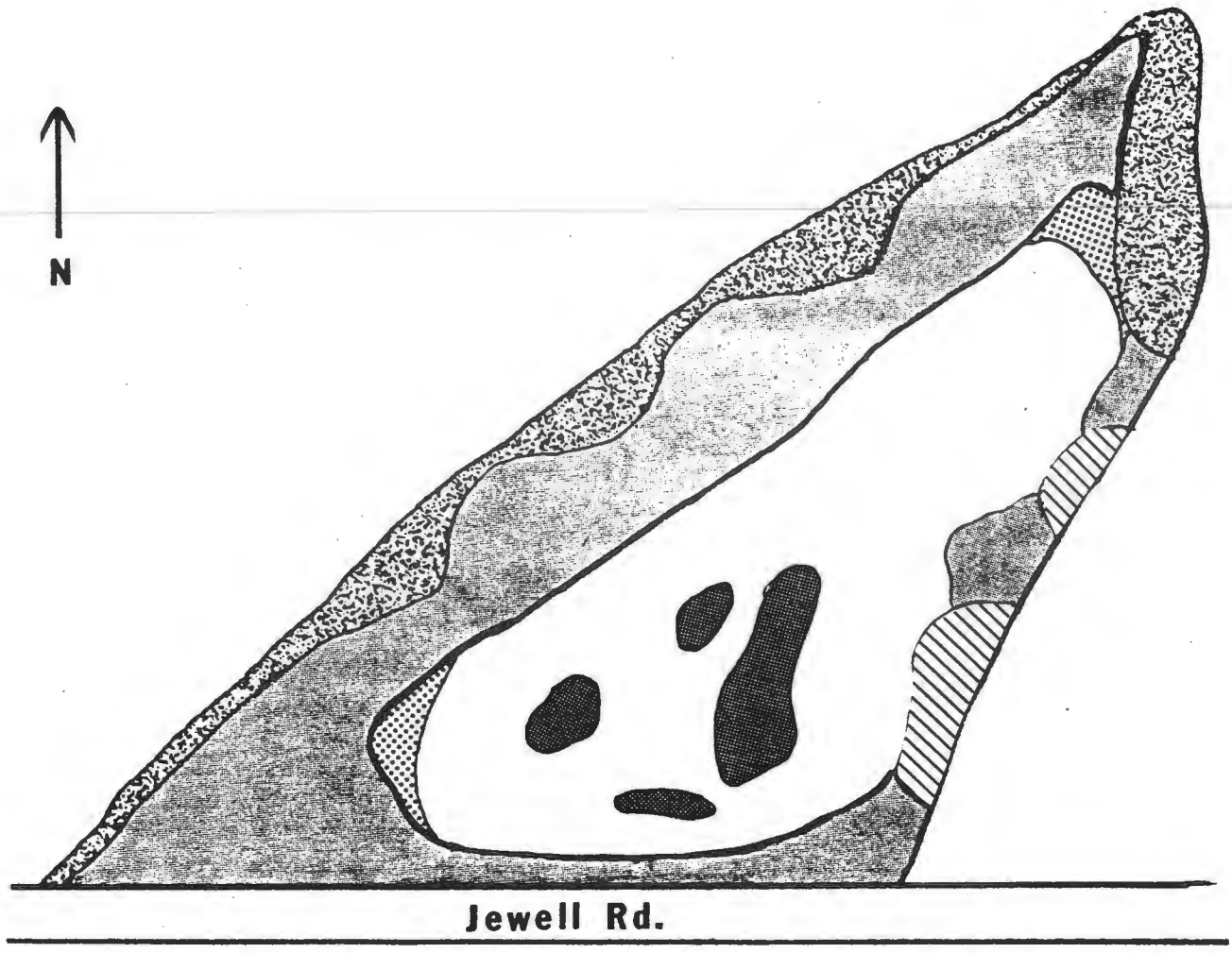


LEGEND

- Milfoil
- Milfoil – Smartweed
- Reed canary grass
- Arrowhead – Sedge
- Smartweed
- Cattail
- Open water

88 meters

Appendix E. Figure 2. Dominant plant associations on Amschler Waterfowl Production Area, 1983-1984.



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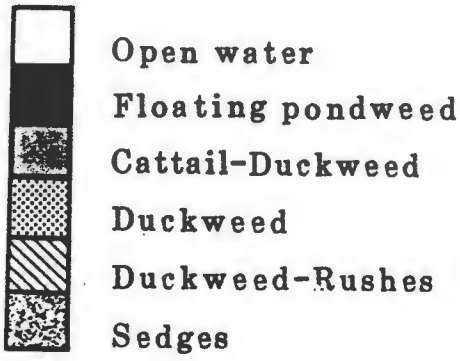
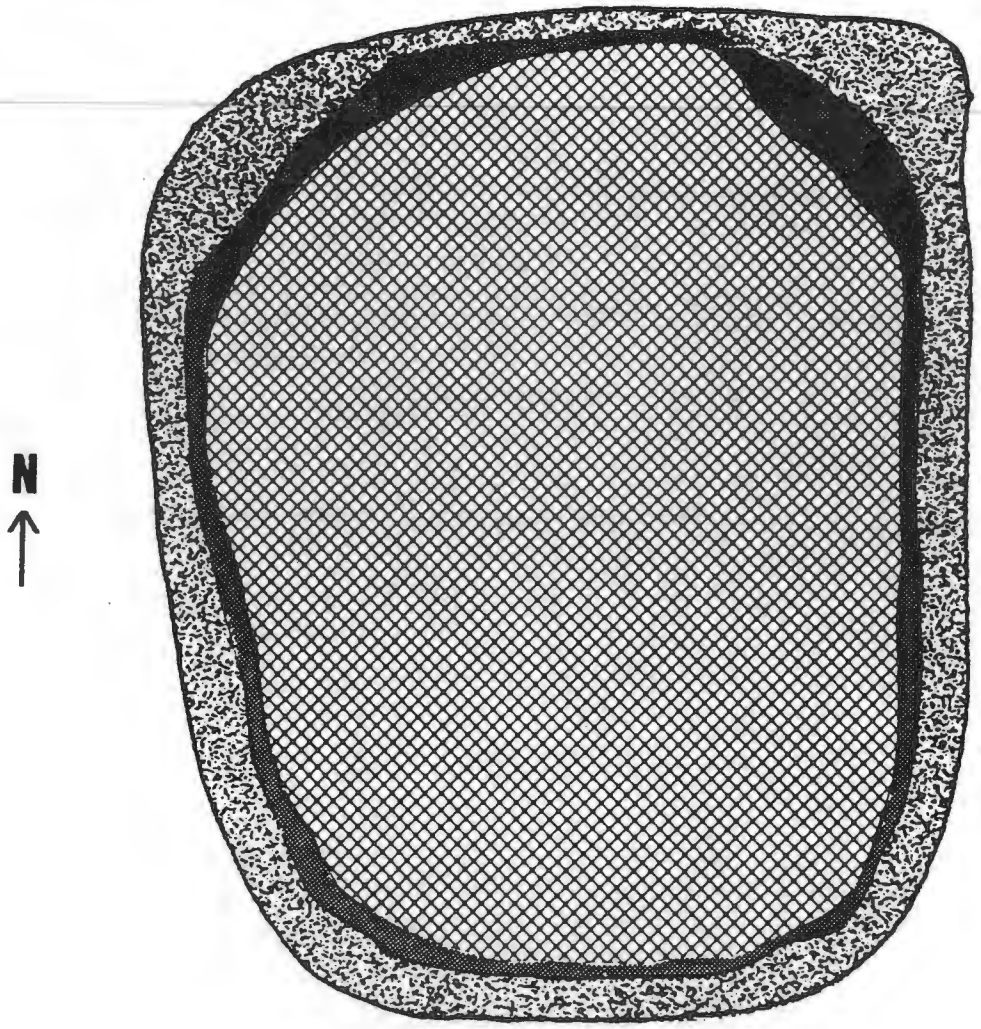


24 meters

Appendix E. Figure 3. Dominant plant associations on Kruizenga Waterfowl Production Area, 1983-1984.

Co. Hwy C



LEGEND

Fries pondweed
Duckweed
Reed canary grass

18 meters

Appendix E. Figure 4. Dominant plant associations on Flaters Waterfowl Production Area, 1983-1984.