

Continued monitoring of the ecosystem dynamics of Moe Pond following the introduction of largemouth bass (*Micropterus salmoides*) and smallmouth bass (*M. dolomieu*)

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ABSTRACT

Moe Pond is a shallow 38.6 acre water body owned by the SUNY Oneonta Biological Field Station, and located just outside of Cooperstown, New York (McCoy et al. 2000). It was documented in 1971 as an atypically eutrophic water body, with a high density of planktonic algae and resultant low transparency (Harman 1972). McCoy et al. (2000) assumed that phytoplankton were abundant due to the prevalence of golden shiners (*Notemigonus crysoleucas*), which fed primarily on zooplankton and reduced their density in the pond. Low water clarity impaired macrophyte growth, decreasing available habitat for benthic invertebrates and creating a paucity of both (Harman 1972). In 1999, the first piscivorous fish species, largemouth bass (*Micropterus salmoides*) and smallmouth bass (*M. dolomieu*), were illegally introduced to Moe Pond (Wilson et al. 2000). This new predator eventually extirpated the golden shiner population. Consequentially, zooplankton density increased, phytoplankton abundance decreased, Secchi depth readings improved, and macrophyte cover expanded through 2003 (Albright et al. 2004). Golden shiners became absent from fish community samples starting in 2004, the same year that zooplankton were found in bass stomach content samples for the first time. This suggests that after the elimination of shiners as a staple prey item, bass necessarily began to exploit zooplankton for an additional food source. From 2004 to 2005 the pond's water quality reverted to pre-bass introduction conditions as the stunted bass population effectively replaced the planktivorous shiners, reducing zooplankton density (Dresser 2006). These trends continued into 2006, with the exception of a perplexing, substantial increase in water transparency and decrease in total phosphorus. Water quality in 2007 was consistent with conditions in 2006. However, zooplankton and benthic invertebrate abundances increased. It is challenging to explain the propulsion behind these changes in 2007 due to the complexity of ecosystem dynamics.

INTRODUCTION

Moe Pond (Figure 1) is a 38.6 acre (15.6 ha) water body situated on the SUNY Oneonta Biological Field Station's Upper Site, located in Otsego County near the village of Cooperstown, New York (McCoy et al. 2000). This man-made impoundment, constructed in 1939 on the site of a wetland, has an average depth of 1.8m and a maximum depth of 3.8m (Albright et al. 2004). Its 185.8 acre (75.2 ha) watershed is fully enclosed within the experimental, restricted-access Upper Site property (McCoy et al. 2000).

The first study conducted on Moe Pond was a basic biological survey in 1971, which characterized the duality of its trophic status. A profusion of phytoplankton that summer caused

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the shallow Secchi transparency readings and substantial levels of bacterial decomposition typical of highly eutrophic waters. However, the coinciding scarcity of aquatic macrophytes and benthic invertebrates observed was more indicative of an oligotrophic state (Harman 1972). An extensive study executed between 1994 and 1995 by McCoy et al. (2000) discovered the same incongruencies, classifying Moe Pond as atypically eutrophic, recognizing that the pond's natural water chemistry (low nutrient richness, hardness, and ANC) combined with a basin geology of acidic shales would normally result in oligotrophic conditions.

McCoy et al. (2000) largely attributed Moe Pond's eutrophic traits to the lack of a major piscivorous fish species in the ecosystem. At the time of their research, only two fish species were present in the pond: brown bullhead (*Ictalurus nebulosus*) and golden shiner (*Notemigonus crysoleucas*). Since golden shiner feed almost exclusively on zooplankton, and there was no major top-down predator control of the fish's population, phytoplankton thrived. Then in the spring of 1999, largemouth bass (*Micropterus salmoides*) and smallmouth bass (*M. dolomieu*) were discovered in the pond as a result of unauthorized stocking (Wilson et al. 2000). Since then, annual studies have been conducted on Moe Pond to document alterations in the ecosystem through monitoring its fish, zooplankton, aquatic invertebrate, and macrophyte communities. The purpose of this survey is to continue the evaluation of trophic changes and their influence on water quality caused by the introduction of bass to Moe Pond.

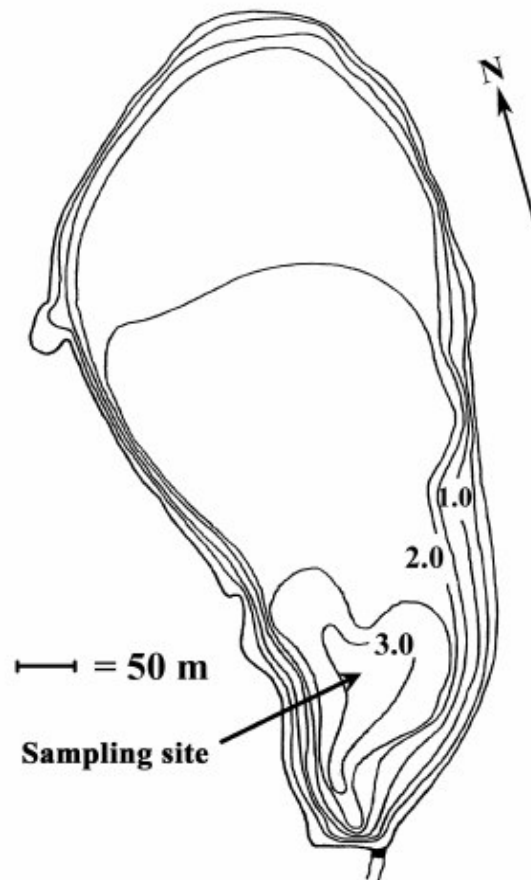


Figure 1. Bathymetry of Moe Pond, Otsego County, New York displaying the sampling location. Contours in meters (modified from Sohacki 1973).

METHODS

Water Quality

Moe Pond was surveyed on a weekly basis from 22 May to 24 July 2007. Data were collected at the deepest point at 3.1m (Figure 1). A Hydrolab Scout or Eureka Manta, calibrated prior to use according to the manufacturer's instructions (Eureka 2005; Hydrolab 1995), was used to measure temperature (°C), conductivity ($\mu\text{S}/\text{cm}$), dissolved oxygen (mg/l), and pH. These readings were taken at the surface and at one meter intervals to the bottom of the pond. Transparency was measured with a standard Secchi disk.

A Kemmerer sampler was used to collect 500mL at one meter depth for water chemistry and chlorophyll *a* analysis. These water samples were used to measure total phosphorus ($\mu\text{g}/\text{l}$) via the ascorbic acid method following persulfate digestion (Liao and Marten 2001), total nitrogen (mg/l) through the cadmium reduction method (Pritzlaff, 2003) following peroxodisulfate digestion (Ebina et al. 1983) ammonia (mg/l) using the phenolate method (Liao 2001), and nitrate+nitrite (mg/l) via the cadmium reduction method on undigested samples (Pritzlaff 2003). All of these variables were analyzed with a Lachat QuikChem FIA+[®] autoanalyzer.

Chlorophyll *a* (ppb) was analyzed by running 50mL of the 1m water sample through a Whatman GF/C filter in duplicate under subdued light. The filters were then blotted dry, cut into small pieces, and placed into test tubes with buffered acetone. A pestle on the end of an electric drill was used to grind each filter into a slurry to extract the chlorophyll. These mixtures were then centrifuged for ten minutes and their chlorophyll *a* concentrations were computed by a Turner fluorometric reader (Welschmeyer 1994).

Zooplankton Community

Zooplankton were analyzed weekly by using a Kemmerer sampler to collect five liters of water at one meter depth. This sample amount was concentrated through a 63 μm mesh plankton filter and brought back to the lab, where it was preserved with 70% ethanol. One milliliter subsamples were viewed in a Sedgwick-Rafter cell under a compound microscope until approximately one hundred zooplankton were measured and identified according to Pennak (1989). The initial volume of the filtered sample and the volume viewed were recorded in order to back calculate the zooplankton density per liter.

Fish Community

Moe Pond's fish community was sampled on 15 and 20 June and 3 and 16 July using a 200ft haul seine. A john boat was used to set the seine in the southwestern most corner of the pond. Measurements were only taken from collected piscivorous fish greater than 100mm in length; those less than 100mm were merely tallied. Scale samples were taken from these 100mm+ specimens immediately posterior to the pectoral fin and directly below the lateral line. The annuli of each scale sample were later examined under a dissecting scope for age analysis (Murphy and Willis 1996). Pulsed gastric lavage as described by Foster (1977) was performed on these same fish to obtain stomach content samples, which were identified according to

Pecharsky et al. (1990) and enumerated upon returning to the lab. The mean number and percent occurrence of each taxa classified was calculated via Murphy and Willis (1996). A largemouth bass population estimate for Moe Pond was calculated through the area extrapolation method (Wilson et al. 2000).

Invertebrate Community

Benthic invertebrates were surveyed on 30 May. Sampling was conducted at two sites with similar macrophyte cover and substrate composition, one at the South end of the pond, and one at the North end. A 7m stretch along the shore of each site was swept with three triangle nets for three minutes. The contents of each net were then emptied into glass jars and returned to the lab, where the invertebrates collected were identified (Pecharsky et al. 1990) and quantified by taxa.

RESULTS AND DISCUSSION

Water Quality

Limnological data collected for Moe Pond from 1972 to 2007 are presented in Table 1. Following the introduction of bass in 1999, the pond's water quality improved through 2003, as chlorophyll *a* concentrations steadily decreased and Secchi depth readings increased. In 2004 and 2005 conditions reversed: there was a substantial reduction in water transparency, reflecting a marked increase in chlorophyll *a* concentrations and total phosphorus. Trends changed again in 2006 when total phosphorus decreased and Secchi depth increased dramatically, despite a continuation in greater chlorophyll *a* density. These trends persisted in 2007.

	1972	1994	2000	2001	2002	2003	2004	2005	2006	2007
Secchi Depth (m)	NA	0.85 (0.1)	1.2 (0.2)	1.1 (0.1)	>2.2	>2.33	1.26 (0.13)	1.26 (0.13)	2.20 (0.15)	>2.62 (0.11)
Total phosphorus (µg/l)	40-70	36.7 (3.7)	NA	NA	26.4 (2.6)	29.05 (2.12)	42.29 (2.04)	56.64 (7.44)	26.91 (5.49)	20.5 (2.5)
Nitrite+nitrate (mg/l)	NA	<0.05	NA	NA	0.14 (0.02)	0.11 (0.02)	0.10 (0.01)	0.01 (0.006)	0.01 (0.04)	<0.01 (NA)
Chlorophyll <i>a</i> (ppb)	NA	37.1 (2.2)	25.6 (0.20)	20.4 (8.1)	12.0 (2.4)	9.76 (2.49)	22.94 (4.4)	17.03 (2.41)	20.53 (19.4)	23.63 (2.75)
Alkalinity (mg/l)	26-37	18.0 (0.4)	NA	17.0 (0.2)	16.0 (0.5)	NA	NA	NA	2.1 (0.1)	16.1 (0.35)
pH	6.8-10.2	7.93 (0.37)	8.63 (0.35)	8.66 (0.32)	9.08 (0.18)	6.84 (0.44)	7.3 (0.07)	7.66 (0.62)	7.30	7.54 (0.07)

Table 1. Mean values (+/- standard error) of Secchi disk transparency, total phosphorus, nitrite+nitrate, chlorophyll *a*, alkalinity, and pH in Moe Pond during the summers of 1972, 1994, and 2000-2007. Secchi transparency often exceeded water depth in 2002, 2003, and 2007. The 2007 chlorophyll *a* value represents the mean derived from concentrations on 17 and 24 July only.

Fish Community

The only fish species captured via haul seine in Moe Pond during 2007 was largemouth bass (Table 2). No golden shiners have been collected since 2003, suggesting the species has been extirpated. Smallmouth bass were absent from samples this summer, just as in 2006. Since largemouth bass are believed to be better suited to the environment in Moe Pond (Tibbits 2001), the consistent decline of smallmouth bass exhibited since their 1999 introduction has been proposed to be a result of interspecies competition.

Year	Golden Shiner <i>Notemigonus crysoleucas</i>	Largemouth Bass <i>Micropterus salmoides</i>	Smallmouth Bass <i>Micropterus dolomieu</i>
1994 (McCoy et al., 2000)	7,154: +12,701;-6,356	0	0
1999 (Wilson et al., 2000)	3,210+/- 1,760	1,588+/- 650	958+/- 454
2000 (Tibbits, 2001)	381+/- 296	2,536+/- 1,177	945+/- 296
2001 (Wojnar, 2002)	1,708+/- 1,693	3,724+/- 3,447	504+/- 473
2002 (Hamway, 2003) ¹	3	206	20
2003 (Hamway, 2004) ¹	2	318	1
2004 (Lopata, 2005)	0	6,924+/- 2,912	0
2005 (Dresser, 2006)	0	12,019+/- 3,577	223+/- 257
2006 (Reinicke & Walters, 2007)	0	11,555.17+/-	0
2007 (Current)	0	13,373+/- 249	0

Table 2. Estimates of golden shiner, largemouth bass, and smallmouth bass abundances (+/- standard error) in Moe Pond, based on numbers of individuals collected during the summers of 1994, 1999-2001, and 2004-2007.

¹ Indicates years in which electrofishing replaced seining as the sampling method due to excessive *Elodea* growth. Data is listed as fish captured per hour.

Length versus age data (Figure 2) suggests that Moe Pond's largemouth bass population may be stunted, as annual growth is limited. The four year age class does not show an increase in length over the three year age class. Stunting is likely the result of an insufficient abundance of large prey items, such as small fish, for a high density of bass. The consequent intense intraspecies competition could thus restrict growth.

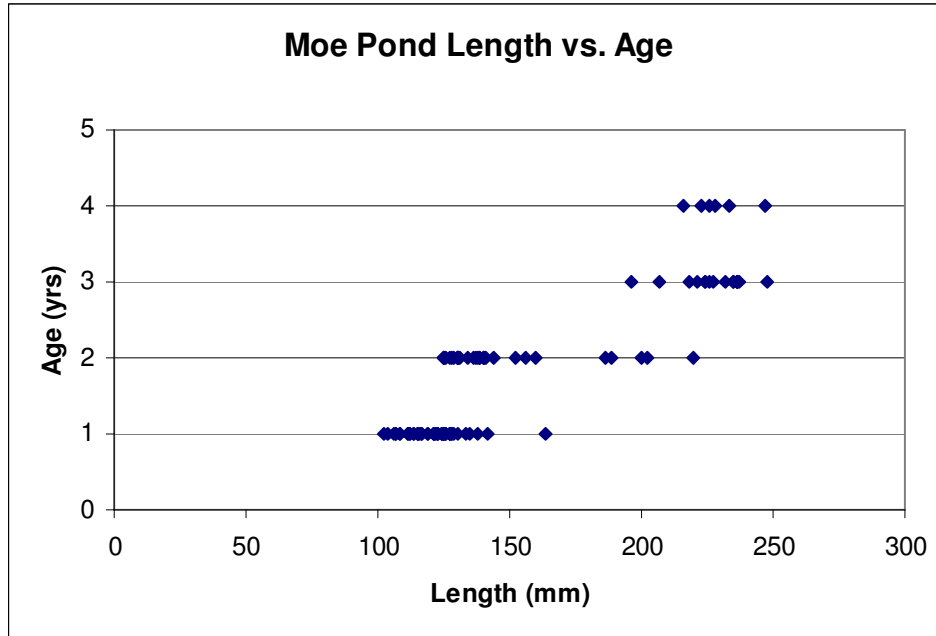


Figure 2. Length vs. Age for largemouth bass collected in Moe Pond during summer 2007.

Consistent with previous years, arthropods such as Odonata, Amphipoda, and Diptera represent considerable portions of the largemouth bass' diet (Table 3). Zooplankton, predominantly Daphnia, have become an increasingly exploited forage item over the years. Daphnia were first observed in bass stomach contents in 2004, when they comprised 12.50% of samples (Lopata 2005). Their percent occurrence has since increased annually. This year zooplankton occurred in a greater percentage of stomach content samples than any other food item. Although the mean number of zooplankton per stomach decreased from 2004 to 2006, there was a substantial increase in this average in 2007--from a mean per stomach of 11 in 2006 (Reinicke and Walters 2007) to an average of 524 in 2007.

Taxa	Mean per Stomach	% Occurrence
Amphipoda (Scuds)	2.95	33.64
Coleoptera (Beetles)	0.01	0.93
Diptera (True Flies)	0.99	21.50
Ephemeroptera (Mayflies)	0.72	16.82
Hemiptera	0.15	12.15
Hymenoptera	0.01	0.93
Ichthyoplankton (specific species unidentified)	0.44	6.54
<i>Ictalurus nebulosus</i> (Brown Bullhead)	1.31	11.21
<i>Micropterus salmoides</i> (Largemouth Bass)	0.47	5.61
Mollusca	0.09	3.74
Planorbidae (Rams Horn Snails)	0.01	0.93
Sphaeriidae (Fingernail Clams)	0.02	1.87
Physidae (Pouch Snails)	0.07	2.80
Odonata	2.36	60.75
Anisoptera (Dragonflies)	0.10	5.61
Zygoptera (Damselflies)	2.25	55.14
Trichoptera (Caddisflies)	0.93	24.30
Zooplankton (mainly Daphnia)	524.19	72.90

Table 3. Mean number and percent occurrence of each food item observed in the stomach content samples of largemouth bass captured in Moe Pond, summer 2007.

Zooplankton Community

Zooplankton density in Moe Pond was higher in 2007 than in 2006 (Table 4). Mean lengths of zooplankton species also generally showed a considerable increase from last year. A continued high concentration of chlorophyll *a* this summer (Table 1) may be attributable to an abundance of phytoplankton, which in turn could account for increased zooplankton density by providing adequate forage. At the same time, the greater zooplankton numbers observed this year are somewhat surprising, since bass demonstrated a heavy reliance on them as a food item.

This combination of bottom-up and top-down effects is difficult to rectify. If bottom-up effects are currently the most influential force in Moe Pond's ecosystem, a high concentration of chlorophyll *a* (and therefore probably phytoplankton) this summer may be providing for an increase in zooplankton populations, especially those of the larger cladocerans (Table 4). An increased availability of zooplankton for bass forage could then explain their prevalence in stomach content samples in 2007 (Table 3). On the other hand, top-down effects from an increased population of largemouth bass would be expected to create a lack of predation pressure on planktonic algae, augmenting their abundance. The most puzzling parameter documented this summer was a consistently high water transparency, which cannot be explained by either form of trophic effects.

Summer 2006		
Species	#/liter	mean length (µm)
Cladoceran		
<i>Bosmina longirostris</i>	3	360
<i>Daphnia pulex</i>	2	204
Copepods		
<i>Cyclopoid sp.</i>	13	446
<i>Calanoid sp.</i>	1	497
<i>Nauplius sp.</i>	37	171
Rotifers		
<i>Asplanchna priodonta</i>	7	353
<i>Kellicottia longispina</i>	7	134
<i>Keratella cochlearis</i>	22	109
<i>Polyarthra vulgaris</i>	0	234
Mean Total/L:	92	

Summer 2007		
Species	#/liter	mean length (µm)
Cladoceran		
<i>Bosmina longirostris</i>	16	385
<i>Daphnia pulex</i>	15	1248
Copepods		
<i>Cyclopoid sp.</i>	19	628
<i>Calanoid sp.</i>	6	645
<i>Nauplius sp.</i>	87	174
Rotifers		
<i>Asplanchna priodonta</i>	8	257
<i>Gastropus sp.</i>	11	201
<i>Kellicottia sp.</i>	16	120
<i>Keratella sp.</i>	201	107
<i>Polyarthra vulgaris</i>	20	150
Mean Total/L:	356	

Table 4. Zooplankton densities and mean lengths during the summers of 2006 and 2007.

Invertebrate Community

Benthic invertebrates collected in 2007 far outnumbered quantities documented in recent years, especially at the south end of the pond. The high abundance of invertebrates observed here may be attributable to a large accumulation of last year's *Elodea canadensis* growth near the southern shoreline as it flowed towards the slipway.

Taxa	# Collected	
	South End	North End
Acariformes (Water Mites)	8	0
Amphipoda (Scuds)	55	384
Anisoptera (Dragonflies)	10	4
Chironomidae (Blood Worms)	127	51
Coleoptera (Beetles)	54	8
Decapoda (Crayfish)	0	3
Diptera Larva (True Flies)	2	1
Ephemeroptera (Mayflies)	0	7
Hemiptera	3	6
Hirudinea (Leeches)	2	0
Physidae (Pouch Snails)	168	32
Planorbidae (Rams Horn Snails)	58	3
Trichoptera (Caddisflies)	10	37
Zygoptera (Damselflies)	168	261
Clam	1	2
TOTAL	666	799

Table 5. Count of invertebrates collected during benthic sampling of Moe Pond, summer 2007.

Macrophyte Community

Although an official survey of Moe Pond's macrophyte community was not completed in 2007, it was noted that emergent plant cover was scarce. The only obvious macrophyte present in high densities was the *Elodea canadensis* growth remnant from summer 2006 collecting on the south end of the pond near the spillway.

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