Movement and Habitat of Juvenile Lake Sturgeon (*Acipenser fulvescens*) in the Sturgeon River/Portage Lake System, Michigan

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ABSTRACT

The Portage Lake/Sturgeon River system in Michigan contains one of the last self-sustaining stocks of lake sturgeon (*Acipenser fulvescens*) in the Great Lakes without barriers to impede natural movement of juveniles. We conducted visual surveys in the Sturgeon River and collected young-of-the-year and juvenile lake sturgeon from 1997 to 2000. Twenty-four fish, 9.8 to 28.8 cm total length (TL), were found predominately over pea gravel 16 to 26 km below the spawning site. With gillnets and trotline we collected an additional 24 fish (22-83 cm TL) and one sub-adult (103.5 cm TL) lake sturgeon in Portage Lake; four juveniles and the sub-adult were fitted with radio transmitters. Average daily linear movement of lake sturgeon varied from 0.3 to 1.6 km. Total linear distance traveled by sturgeon averaged 15.5 km over 83 days. Diel movements indicated that two juveniles moved into shallow (<5 m) inshore areas at night and into deeper (>7.5 m) offshore areas as light intensified.

INTRODUCTION

The lake sturgeon (*Acipenser fulvescens*) is currently considered threatened in Michigan and is protected in seven of the eight Great Lakes border states (Auer 1999a). Nearly all systems inhabited by lake sturgeon in the Great Lakes basin possess physical barriers that prevent migration during one or more periods of the fish's development. Currently, knowledge of the spatial ecology and life history requirements of lake sturgeon at different life stages remains incomplete. Understanding the required spatial attributes, such as range and habitat use, that promote successful completion of each life stage is best studied in stocks with unrestricted movement.

Recent research has described adult spawning habitat and pre- and post-spawning migrations, adult wintering behavior, and larval distribution patterns of lake sturgeon (Auer 1999b, Hay-Chmielewski 1987, Kempinger 1988, McKinley et al. 1998). The young-of-the-year (YOY), juvenile, and sub-adult stages (defined here as between 75 mm and 1 m TL) have received less attention; only a few recent works have described juvenile lake sturgeon populations with impeded movement (Kempinger 1996, Thuemler 1988).

Habitat and movement patterns for juvenile and sub-adult lake sturgeon have not yet been well identified. Distributions of food and habitat partition fish species (Gerking 1994) and influence migration patterns of fish species (Northcote 1978). Although the lake sturgeon is characterized as a shallow-water fish, juveniles were reported at depths >27 m (Harkness and Dymond 1961). Lake sturgeon are found over a variety of substrates including sand, gravel, clay, and silt (Chiasson et al. 1997, Harkness and Dymond 1961, Kempinger 1996).

Diel periodicity in movement and depth distribution for juvenile lake sturgeon is not documented. Helfmann et al. (1997) presented evidence for diel rhythms in fish

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movement and vertical distribution corresponding with photoperiod, and diel movements with respect to depth have been observed for other species of this genus. Juvenile Russian sturgeon (*Acipenser gueldenstaedti)* swam higher in the water during darkness and remained near substrate during high light intensity in a laboratory study (Levin 1981). Adult white sturgeon (*Acipenser transmontanus)* used shallow nearshore areas at night and moved to deeper strata as light intensity increased (Haynes and Gray 1981).

The goals of this study were to 1) find and identify habitat of juvenile lake sturgeon within the natal river, 2) describe range and movement of juvenile lake sturgeon within Portage Lake, and 3) determine if movement patterns of juvenile lake sturgeon are related to physicochemical and benthic invertebrate attributes of habitat.

METHODS

Study Area

Portage Lake separates the Keweenaw Peninsula from the Michigan Upper Peninsula and connects western Lake Superior with Keweenaw Bay (Fig. 1). It is 17 km² and has an average depth of 8 m and a maximum depth of 17 m. The northeast arm of Portage Lake (Torch Bay) connects to Torch Lake by a narrow canal. Torch Lake has a maximum depth of 32 m. In the southwest corner of Portage Lake is 1.3 km² Pike Bay with a maximum depth of 6 m and substrate of fine sediment and woody debris. The Sturgeon River enters Portage Lake at its most southern end and creates a slough habitat near the river mouth. A hydroelectric facility is located 69 rkm (river kilometers) upstream of the mouth, and sturgeon spawn in rapids located downstream of this facility (Auer 1996). Portage Lake supports a year round sport fishery that includes walleye (*Sander vitreus*), northern pike (*Esox lucius)*, smallmouth bass (*Micropterus dolomieui),* brown trout *(Salmo trutta),* and yellow perch (*Perca flavescens).* Other dominant fishes include rock bass (*Ambloplites rupestris)*, white sucker (*Catostomus commersoni),* and bullhead (*Icatalurus spp.).*

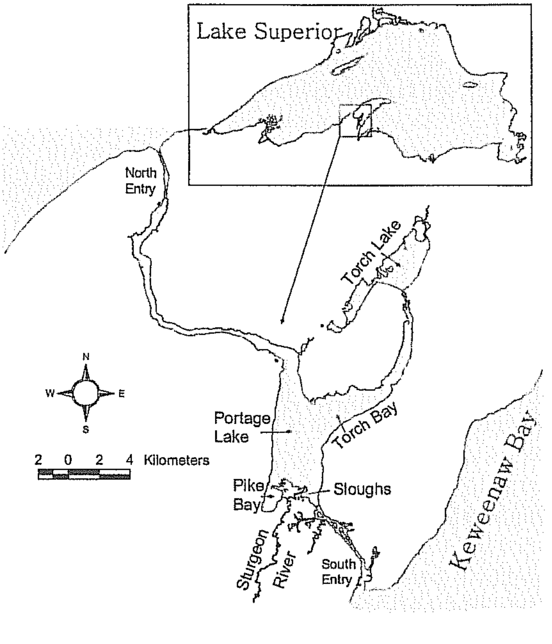

Figure 1. Location of Portage Lake, Pike Bay, Torch Bay and the Sturgeon River, Michigan.

Surveys in the Sturgeon River

Visual surveys for juvenile lake sturgeon were conducted from July through December at three locations in the Sturgeon River from 1997 to 2000 and in 2003. Observers walked upstream in the river at 14, 16 and 26 km below the spawning site and scanned areas of sand and gravel in waters 0.1 to 1.3 m deep. On one occasion in 1997 sturgeon were located by SCUBA divers. Fish were captured with dip-nets. In 1998-2000 all fish were marked with a punch on a pectoral fin. Captured lake sturgeon were weighed, measured to fork and total lengths, girth, and mouth width. In 1999 benthos was sampled at each site of capture of YOY using a triangular 30.5 cm face kick net, (1000 µm mesh). Also in 1999 water temperature, depth, and flow (General Oceanics Inc. – threshold 10 cm/sec) were recorded at each capture location (n=4).

Surveys in Portage Lake

Experimental gillnets (2.5 to 10.2 cm mesh) were deployed two to three times weekly to capture juvenile lake sturgeon from 4 August to 3 October 1997 at 3-14 m, from 7 July to 11 September 1998 at 8-16 m, and 20-24 July 1999 at 10-16.5 m. Gillnets were deployed at dusk, lifted at dawn, and set at depths > 3 m in 1998 and 1999 to decrease sport fish by-catch. Trotlines were deployed two to three times weekly at dusk and fished until early morning from 20 August to 6 November 1998 at 1.5-14 m and from 29 June to 10 August 1999 at 2 -14.5 m. Gillnets and trotlines were placed throughout Portage Lake, northeast Pike Bay, Torch Bay, and Torch Lake at sites where lake sturgeon had been captured previously.

For each lake sturgeon captured, water depth, total and fork lengths, girth, and weight were recorded. A sequentially numbered Floy tag was inserted at the posterior base of the dorsal fin for juveniles and the sub-adult fish. In 1999, a Hydrolab instrument (Hydrolab Corp., Austin, TX) was used to record dissolved oxygen, temperature, specific conductivity, and pH at 1 m intervals in the water column at each site where lake sturgeon were captured. Radio transmitters were fitted on five fish, one internally on 4 August 1997 and four externally from 4 to 10 August 1999. The implanted transmitter was an ATS model 10-18 (Advanced Telemetry Systems, Isanti, MN) with 10" antennae. External transmitters were Maxwell model 10-28 with 10" antennae.

Radio Tracking Portage Lake – Diurnal

Tracking was conducted from small boats using an ATS receiver. A hand-held loop antenna was used due to its high accuracy at close ranges (Winter 1977, Winter et al. 1978). Observation of instrument response upon adjustment of gain enabled estimation of distance to target fish. A Magellan GPS 315 (Magellan, San Dimas, CA) was used to describe the location of each fish.

Tracking began the day after implantation and continued a minimum of every two days during the first week. Throughout the duration of tracking, fish were located as often as time and weather permitted, usually between 1300 and 2000 hrs. Water depth and chemistry profiles were recorded at all fixed locations with a Hydrolab instrument. Analysis of variance (ANOVA) was used to test for differences in depth distribution of fish (Table 1).

Fish locations were plotted by Geographic Information System with ArcView (ESRI Inc., Redlands, CA), and measurements for linear distance and range were calculated. Total linear distance traveled by each sturgeon was established by summing all straight-line distances between consecutive fixed locations. Range size was estimated using the area of the minimum convex polygon (Mohr 1947, White and Garrot 1990). Daily range estimates were calculated by dividing total area covered by each individual fish by number of days tracked. Because of infrequent night tracking, estimates of range were derived only from fixed daylight locations.

Table 1. Water depth (m) at which five lake sturgeon fitted with telemetry transmitters were located in Portage Lake, Michigan during 1997 and 1999 tracking.

1997	Fish #	1999	Fish #			
Day of year	1	Day of year	22	23	24	25
233		216	6.7			
235	5.5	222	6.4	8.2		7.9
238	5.2	223			14.6	11.3
243		224	5.5		14.9	
247	12.2	225	6.7		15.9	9.1
248	12.2	226	10.4		15.9	10.7
250	12.2	227	10.7	11.3	11.3	10.7
253	14.3	228				12.5
254	14.0	229	16.2		13.4	12.5
263	13.7	230	16.2			11.0
269	12.2	231	16.5			11.6
276	12.2	232	14.9			11.0
283	13.0	233	15.9			11.6
286	12.2	238				7.9
		239	11.9			
		240	8.2			
		241	8.2	6.1		4.9
		242	9.1	5.8		5.2
		243	8.2			7.6
		245	8.8	4.9		4.9
		247	8.5			5.5
		250	10.7	7.3		4.6
		254	8.2	5.5		5.2
		258				
		259	13.4	7.3	7.3	4.9
		263	6.4		6.7	
		267	11.6	7.0	7.0	4.9
		272	11.3		7.9	4.3
		281		6.7	7.0	5.5
		285	10.4			4.3
		287	12.5	6.4		
		306		7.0	6.7	4.3
		316	11.3	6.7	9.8	4.3

Radio Tracking Portage Lake - Diel

Two 24-h tracking events were conducted in 1999. Depth, longitude, and latitude were recorded using a Hummingbird depth sounder and GPS at each fish location. Two fish were tracked hourly 25-26 August and three fish were tracked at 4 h intervals 24-25 September because of wider geographic distribution. During the August effort, pH, dissolved oxygen, specific conductivity, and depth measurements were taken with a Hydrolab instrument as frequently as tracking allowed.

Benthos and Sediment in Portage Lake

Sediment samples were collected with a Ponar grab at 1.5 m intervals from water depths of 3 to 13.5 m at one location where sturgeon were captured. Organic carbon and calcium carbonate contents were determined by gravimetric analysis following Johnson (1989). A measure of sediment grain size was achieved through wet sieving following Johnson (1989), and particle size was classified using the Wentworth scale (Folk 1980). Vegetation was identified by collecting video images of substrate along the same transects with a Splash-Cam (Ocean Systems, Everett, WA) underwater video camera and by SCUBA.

For each of the five tracked fish on one occasion during the day, duplicate Ekman grabs were collected along a transect perpendicular to the shoreline at a location where each fish was found. The transect was sampled at 1.5, 3.0, 4.5, 7.5, 10.5 and 15 m (if possible). Benthos samples were immediately washed through a 0.59 mm mesh sieve, and specimens were identified to family or genus and enumerated.

To examine the possibility that lake sturgeon exhibited diel depth patterns in response to varying invertebrate densities, total and taxa-specific invertebrate densities were compared at depth increments. Invertebrate density abundance was analyzed in relation to depth using a Kruskall-Wallace test. This test was chosen because samples from 1.5 and 3.0 m stations were not normally distributed. Multiple comparison procedures suggested by Dunn (1964) were used to determine statistically significant differences (at P=0.15) between depths for total invertebrate density. The recommended values are between 0.15 and 0.25 depending on size of k Gibbons (1997).

RESULTS

Surveys in the Sturgeon River

Twenty lake sturgeon 9.8 to 28.8 cm TL were captured and measured during river sampling July to August 1997 to 2000 (Table 2); four others were only observed. In July 2003, a single survey produced five YOY. No YOY lake sturgeon were observed in September to December of any year. The largest fish captured in the river was in a 1-m deep sand bottom pool below woody debris. Eight fish were observed in the river 16 rkm below the spawning site, and 16 were seen 26 rkm below the spawning site. No fish were recaptured.

Although surveys covered periods in the months of July through December, YOY in the river were only observed from 10 July to 9 August. These fish were observed over riffles and runs of pea gravel or pea gravel and sand. None of the fish < 200 mm were observed over pure sand. On most occasions these YOY were oriented into the current directly behind woody debris. In 1999 the YOY lake sturgeon were found in water 19 to 22.7°C, 0.3 to 0.5 m deep, and with flow of 39 to 48 cm/sec.

Benthic invertebrates were low in abundance throughout the river where YOY sturgeon were captured. Benthic organisms were more abundant and diverse at the station 16 rkm below the spawning site (Table 3). The aquatic invertebrates ranged from 1 to 31 mm in length. Mouth width of a subset of the YOY lake sturgeon measuring 12.3-18.4 cm TL and captured in the river ranged from 5 to 9 mm.

Surveys in Portage Lake

Twenty-five lake sturgeon were captured with gillnet or trotline sets (Table 4). Mean water depth at which sturgeon were captured was 11.3 m (±2.1 SD) for gillnets and 6.8 m (±1.0 SD) for trotlines. In 1999 juveniles were captured by trotline in water 19.9-21.3°C containing 8 mg/L DO. Organic carbon and calcium carbonate in surficial sediments at capture locations showed little variation. Organic carbon content averaged 8 to 9.6 % dry weight at 3 to 13.5 m, while calcium carbonate content averaged 0.9% at 3 to 4.5 m and 6.8 to 4.4% at depths > 6 m. Nearshore sediment samples were more than 75% sand at depths of 1.5 to 3 m, 37% sand with mud at 4.5 m, and predominately mud (>90%) at depths > 7 m.

Table 2. Date, location, and total length of 20 YOY lake sturgeon captured and four observed in the Sturgeon River, Michigan 1997-2000 and 2003.

Date of capture	Location downstream of spawning site (km)	Total length of YOY (mm)
7-28-1997	16	200
8-9-1997	16	288
7-10-1998	16	119
7-10-1998	16	119
7-15-1998	16	126
7-15-1998	16	Observed only
7-17-1998	26	98
7-17-1998	26	128
7-17-1998	26	Observed only
7-17-1998	26	Observed only
7-17-1998	16	Observed only
7-24-1998	26	127
7-24-1998	26	124
7-27-1998	26	132
7-27-1998	26	150
7-29-1998	26	152
7-29-1998	26	145
7-29-1998	26	110
7-31-1998	26	165
8-4-1998	26	140
7-27-1999	26	116
8-1-2000	26	126
8-3-2000	26	141
8-3-2000	16	160
7-16-2003	26	91
7-16-2003	26	94
7-16-2003	26	88
7-16-2003	26	75
7-16-2003	26	87

The juvenile sturgeon ranged in length from 21.8 to 83 cm TL. Those caught in gillnets averaged 31.4 cm TL (±5.42 SD) and were smaller than those captured on trotline. The juveniles captured by trotline averaged 74.1 cm TL (19.9± SD) and were all >50 cm TL. Smaller fish (<45 cm TL) were most often captured at depths > 8 m, while the five trotline captures were in water < 8 m. Gillnets captured sturgeon during all months sampled (July - October), whereas trotlines captured juvenile lake sturgeon only during August.

Radio Tracking in Portage Lake - Diurnal

From 4 August to 13 October 1997 and 4 August to 11 November 1999, 101 radio-telemetry contacts were made with the five tracked fish. Of the four juvenile fish all but one exceeded a linear distance of 6 km from the capture site by the end of the 100-day tracking study. Immediately after release, three fish displayed gradual, southeast, linear movements. The average linear distance traveled from the initial capture site for all fish was 5.6 km (±3.2 SD). The average daily linear movement of the five fish ranged from 0.3 to 1.6 km. Mean total distance traveled by all five tracked fish was 15.5 km

Table 3. Total number and total length of benthic invertebrate organisms from a set of three samples taken at sites 16 and 26 rkm below the spawning site in the Sturgeon River, MI.

Organism	16 rkm n=1	26 rkm n=2, combined	Range of TL (mm)	Average TL (mm)
Chironomidae	39	3	1.0-7.2	5.2
Corixidae	2	4	3.7-6.0	4.9
Elmidae	8	2	4.0-5.0	4.6
Gastropoda	2	0	6.0-10.0	8
Glossosomatidae	1	0	3.0	
Gomphidae	0	3	4.5-31.0	20.2
Hydropsychidae	1	5	3.5-12.0	7
Hudroptilidae	2	2	2.7	
Oligochaeta	3	1	8.5-17.0	13.5
Perlodidae	5	0	7.0-8.0	7.5
Plecoptera	3	3	2.7-8.0	5.3
Philapotamidae	0	1	7.5	

(±7.2 SD) (Table 5). The mean total range estimated for the juvenile fish was 11.0 km^2 (±9.9 SD) (Fig. 2). Daily range estimates varied between < 0.1 and 0.25 km^2.

Two of the four juvenile lake sturgeon tracked in 1999 demonstrated a range overlap of 12.1 km^2; however, these four fish did not appear to aggregate. Fish were located >1 km apart after the first week of capture. At last contact, all fish were separated by a distance >2 km, with a mean separation distance of 4.9 km (±3.0 SD) at end of tracking.

The four juvenile and one sub-adult lake sturgeon displayed mean depth use of 10.5 m (±3.5 SD) in August, 7.3 m (±2.5 SD) in September, 7.5 m (±2.9 SD) in October, and 7.1 m (±2.6 SD) in November. Depth utilization among lake sturgeon differed significantly (ANOVA, N=91, DF=4, $P<0.001$). The smallest fish was found at the greatest mean depth of 11.6 m (±3.0), and the two smallest fish were found at significantly greater depths (Tukey's test, $P<0.05$) than two of the three larger lake sturgeon. The sub-adult lake sturgeon was found at the most shallow average depth of 6.9 m (±1.6 SD). When located, all tagged fish were found at depths < 16 m; over 75% of these locations were at depths < 13 m.

Radio Tracking in Portage Lake - Diel

During two 24-h tracking events, three juvenile lake sturgeon were located at depths ranging from 1.5 to 17.1 m (Fig. 3). Two fish tracked in August stayed at depths of 4 to 17.1 m, while in September three fish occupied depths from 1.5 to 11.6 m. Two distinct movement behaviors were observed during both tracking events. First, fish #24 and #25 displayed a depth change in September moving into shallow warmer water after sunset and into deeper cooler water just before sunrise with maximum depths observed at peak sunlight. Fish #22 showed a different behavior, occupying a relatively constant deepwater depth and showing little movement throughout the diel period except a slight movement to greater depths during August at the time of peak sunlight. During both the August and September tracking events, fish #24 and #25 used shallow depths during nocturnal phases and greater depths at peak sunlight.

Benthos and Sediment in Portage Lake

Sediment particle-size composition varied with depth. Inshore areas had proportionally more coarse material than offshore areas. Inshore locations were

Table 4. Date, gear, depth and total length, girth and weight of juvenile lake sturgeon captured in Portage Lake, Michigan 1997-1999.

Fish number	Day of year	Method of capture	Depth (m)	Total length (cm)	Girth (cm)	Weight (g)
1	8/18/1997	Gillnet	9.1	37.2	13	229
2	8/19/1997	Gillnet	7.6	24.5	8.5	57
3	9/11/1997	Gillnet	12.2	24.6	8.5	57
4	9/11/1997	Gillnet	12.2	33.9	11.5	143
5	9/15/1997	Gillnet	13.4	21.8	7.5	28.6
6	9/26/1997	Gillnet	12.2	36.4	12.5	172
7	9/26/1997	Gillnet	11.9	33.7	12	157
8	10/03/1997	Gillnet	10.4	34	12	172
9	7/09/1998	Gillnet	12.8	39.5	13.5	257
10	7/23/1998	Gillnet	12.2	37.9	13.5	200
11	7/29/1998	Gillnet	13.4	28.4	10	100
12	7/31/1998	Gillnet	9.8	27	10	79
13	7/31/1998	Gillnet	9.8	29.5	11	93
14	8/03/1998	Gillnet	10.4	23	9	57
15	8/03/1998	Gillnet	9.5	34.1	13	171
16	8/03/1998	Gillnet	9.5	35	12.5	171
17	8/03/1998	Gillnet	15.2	35.9	12.5	200
18	8/03/1998	Gillnet	15.2	28.2	11	100
19	8/04/1998	Gillnet	10.4	28.7	10.5	86
20	9/02/1998	Gillnet	9.8	38.6	13.5	229
21	9/11/1998	Trotline	4.9	62.5	23	1114
22	8/04/1999	Trotline	6.7	52.2	17.2	514
23	8/09/1999	Trotline	7.3	103.5	37.8	5714
24	8/10/1999	Trotline	7.0	83	29.5	343
25	8/10/1999	Trotline	7.9	69.5	22.5	1257

predominately sand, whereas deeper regions were >90% mud (Fig. 4). Vegetation was observed at 60% of sediment transect locations ≤3 m; it was predominantly wild celery (*Vallisneria Americana)* and Eurasian milfoil (*Myriophyllum spicatum)*. No vegetation was observed beyond water depths ≥4.5 m. The composition of invertebrate benthos at diel depth transects was predominately Gastropoda 35%, Diptera 25%, and Annelida 18% (% of total abundance; Table 6).

Invertebrate abundance differed with depth (Kruskall-Wallace, N=25, P=0.03) and was greatest at shallow depths containing coarse sediment and vegetation. Forty-seven percent of organisms were observed at 1.5 m and 24% at 3 m. Abundance at 7.5 m was significantly lower (Dunn's test, P<0.15) than at shallower inshore depths and contained only 3% of the total organisms. The shallow-water community (≤4.5m) was dominated by Gastropoda, Annelida, and Diptera (Fig. 4). The offshore, fine-sediment community (≥7.5m) comprised primarily of Diptera, Annelida, and Mollusca. At locations containing >75% mud Gastropoda declined markedly.

DISCUSSION

Many lake sturgeon larvae (15-35 mm TL) drift quickly downstream from May through June (Auer and Baker 2002). However, our study indicates that some larvae must remain in the upper river system and begin to drift later (mid-July to August) as a group of YOY (75-200 mm TL), which utilize areas of sand and pea gravel just below

Table 5. Linear distance measurements during daytime telemetry tracking of four juvenile and one sub-adult lake sturgeon in Portage Lake, Michigan, 1997 and 1999.

Fish number	Shortest (km)/ days between tracking	Longest (km)/ days between tracking	Total (km)	Average distance between contacts (km)	Depth range (m)
1	0/2	2.82/6	9.06	0.7	5.2-14.3
22	0.08/1	1.68/1	22.56	0.78	5.5-16.5
23	0.03/1	5.75/5	15.65	1.04	4.9-11.3
24	0.05/1	3.66/1	22.84	1.63	6.7-15.9
25	0.03/1	1.14/1	7.6	0.26	4.3-12.5

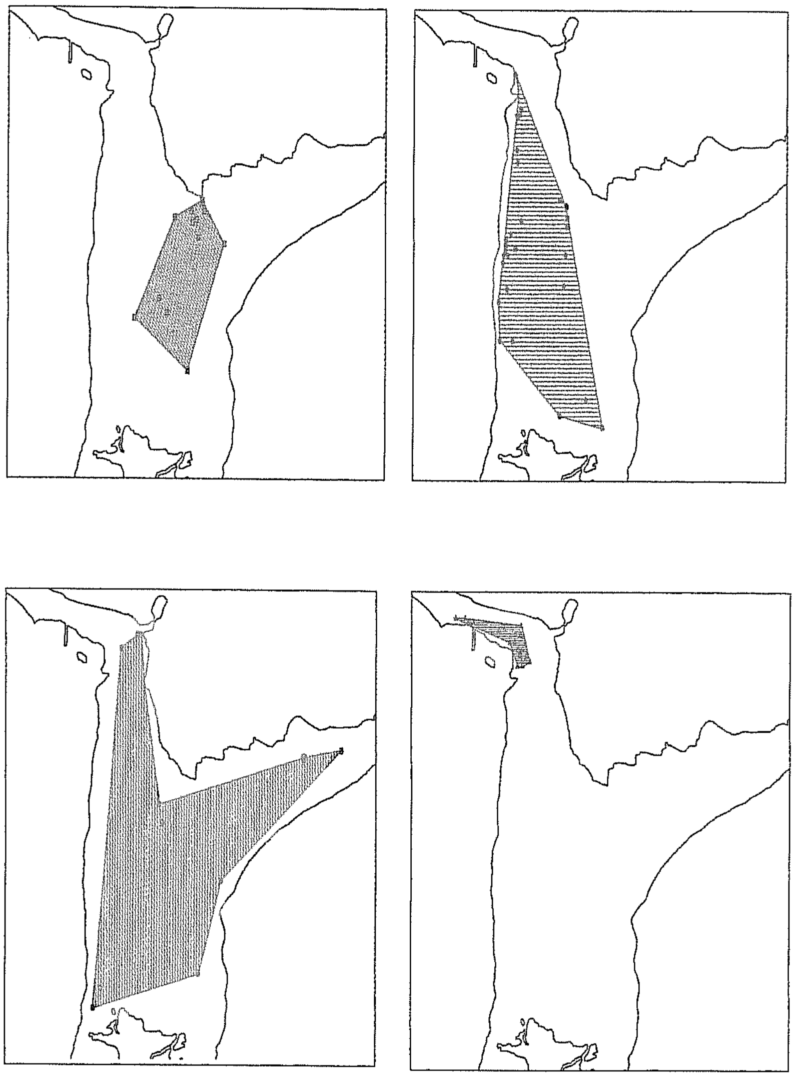

Figure 2. Range estimates determined by minimum-area-polygon for four juvenile lake sturgeon during August through November 1997 and 1999.

woody debris. Kempinger (1996) also found 79-281 mm lake sturgeon in 0.3-1.5 m water over pea gravel on the Wolf River, Wisconsin. In northern Ontario rivers, juvenile (460-1025 mm TL) lake sturgeon were documented most often adjacent to sand and clay sediment containing the highest abundance of benthic organisms (Chiasson et al. 1997). Lake sturgeon YOY in the Sturgeon River appear to have adequate prey, with Baetidae nymphs and dipteran larvae dominant in sediment samples. These organisms were present in the guts of YOY sturgeon taken from the Lake Winnebago system, Wisconisn (Kempinger 1996).

During the late summer and fall of their first year, lake sturgeon moved out of the Sturgeon River and into the deep water of Portage Lake. YOY and juvenile lake sturgeon also moved considerable distances, displayed rapid daily linear movement, and covered large ranges during August to November. This is instructive because other studies of range and movement of adult and juvenile lake sturgeon focused on systems where sturgeon could not move freely (Sandilands 1987, Hay-Chmielewski 1987, Thuemler 1988, Lyons and Kempinger 1992).

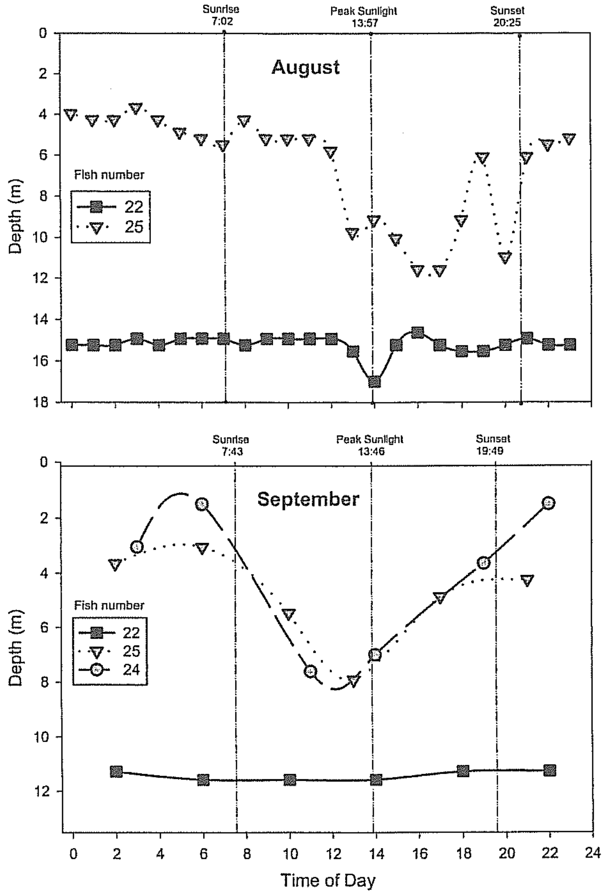

Figure 3. Diel depth profile for three juvenile lake sturgeon tracked 24-25 August and 24-25 September 1999 in Portage Lake, Michigan. Polynomial relationship between depth and time of day represented by trendlines and vertical dashed lines indicate unique photoperiod.

In our study juvenile lake sturgeon moved at depths between 4 and 17 m during daylight and were commonly located at depths >10 m. A prominent steep-ledge slope at 7 m extends around the Portage Lake basin, marking the change from littoral to profundal regions. During midday at 5-7 m, juvenile lake sturgeon occupy slope habitat possibly because food organisms may be concentrated there. Telemetry contacts revealed that fish also frequented water of 10 to 12 m, which may provide a refuge from predation and environmental disturbance (Auer 1999a, Donald et al. 1994). Harkness and Dymond (1961) observed juvenile (19-76 cm) lake sturgeon in Lake Nipigon, Ontario, predominantly at 3.5 m. Hay-Chmeilewski (1987) reported adult lake sturgeon preferred a 7-10 m slope region in Black Lake, Michigan.

Prior to this investigation, there was little evidence linking juvenile lake sturgeon behavior patterns to a 24-h cycle. Chiasson et al. (1997) suggested that juvenile lake sturgeon may be more active at night because of increased capture in gillnets during night sets. Data from this study show that the locations of some juvenile lake sturgeon in the water column correspond to photoperiod.

Invertebrate taxa collected from Portage Lake at depths used by juvenile lake sturgeon were similar to organisms observed in lake sturgeon diets in other studies. Kempinger (1996) reported that dipterans constituted 36.5% of the diet of 29-281 mm TL age-0 lake sturgeon and 49.7% in 267-749 mm TL fish in Lake Winnebago. Interestingly, 42% of the food items consumed in his study by larger juveniles were pelagic *Daphnia* spp. and *Leptodora kindti*. Harkness (1923) found Ephemeridae, Chironomidae, Mollusca, Amphipoda, Decapoda, Odonata, and Trichoptera were consumed by juvenile and adult lake sturgeon in Lake Nipigon, Lake St. Louis, and Moose River, Ontario. Probst and Cooper (1955) found the two most abundant taxa in the diet of 127 lake sturgeon (76-190 cm TL) were Chironomidae larvae (86.6%) and Hirudinea (10.2%).

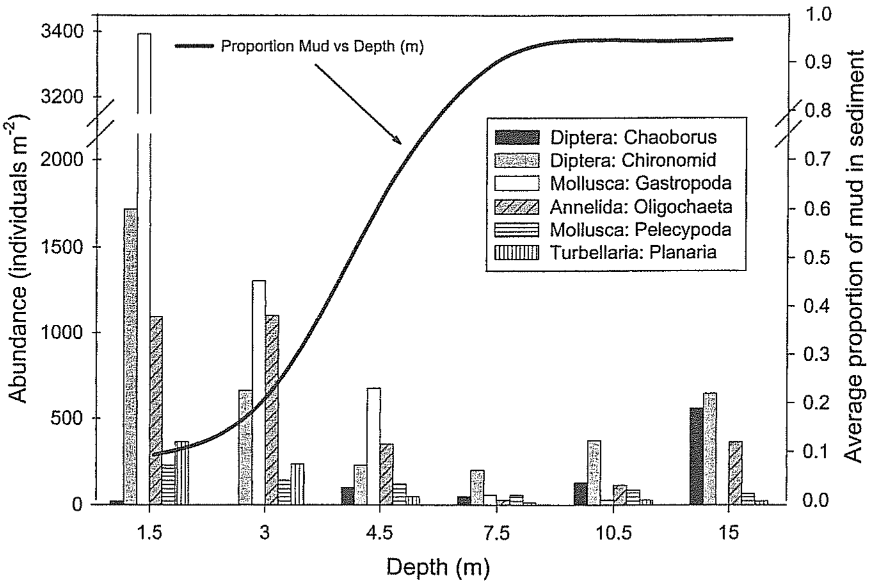

Figure 4. Abundance of dominant invertebrate species collected from six depths on a transect utilized by juvenile lake sturgeon during diel tracking events. Trendline plots average proportion of mud (particle size <0.0625 mm) from samples.

The increased abundance of Diptera, Gastropoda, Oligochaeta., Pelecypoda, and Turbellaria in nearshore Portage Lake sediment samples indicates an increasing positive dietary benefit from profundal to littoral zones. The more shallow depth occupied nocturnally by lake sturgeon could be due to the high relative abundance of invertebrates at shallow depths. Movement and activity patterns of aquatic insects in lakes are often higher at night than in the day (Moon 1940, Peckarsky 1984). This increased invertebrate activity at night may allow for greater foraging opportunities for lake sturgeon at night. Lake sturgeon were most often found over mud during daylight and over more sand/mud sediments at night in nearshore waters. None of the five tracked lake sturgeon was located in vegetated areas.

Conservation of species, populations, and ecosystems can be more effective through understanding the spatial dynamics of species that require large areas (Poiani et al. 2000). Our study demonstrates that YOY and juvenile lake sturgeon move through the river and occupy a variety of depths and areas within the Portage Lake system depending on size. Combining this result with adult movement patterns (Auer 1999b), it is clear that lake sturgeon from this population use ecologically diverse habitat and large spatial scales throughout their life history. Understanding the relationship between the development and movement of lake sturgeon will enhance protection measures for this species. The protection of a species like lake sturgeon, which requires a large and diverse ecosystem, may preserve additional species that inhabit smaller areas within the ecosystem due to specific needs (Poiani et al. 2000).

Table 6. Benthic invertebrate taxa collected at five transects at sites utilized by lake sturgeon in Portage Lake, Michigan, 1999.

Macrobenthos taxa	Relative abundance	Abundance (number/m^2±SE)
Annelida		
Oligochaeta spp.	0.18	528±146
Amphipoda		
Gammarus spp.	0.03	97±36
Cladocera (Daphnidae)	0.02	58±20
Coleoptera	<0.01	
Diptera		
Chaoborus spp.	0.03	92±34
Chironomus spp.	0.22	639±115
Ephemeroptera	<0.01	
Hemiptera	<0.01	
Hirudinea	<0.01	
Nematomorpha	<0.01	
Trichoptera	<0.01	
Polycentrapus spp.	0.01	15±5
Nematoda		
Mermithoidea	0.01	34±6
Mollusca		
Gastropoda	0.35	1023±260
Pelecypoda	0.04	124±21
Ostracoda	0.02	49±13
Turbellaria	0.05	132±44
Hydracarina	0.02	55±18

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ERRATUM

In the September issue of the *Journal* (vol. 19, no. 3), the figure on page 427 was inadvertently printed without complete labeling. The corrected figure appears below.

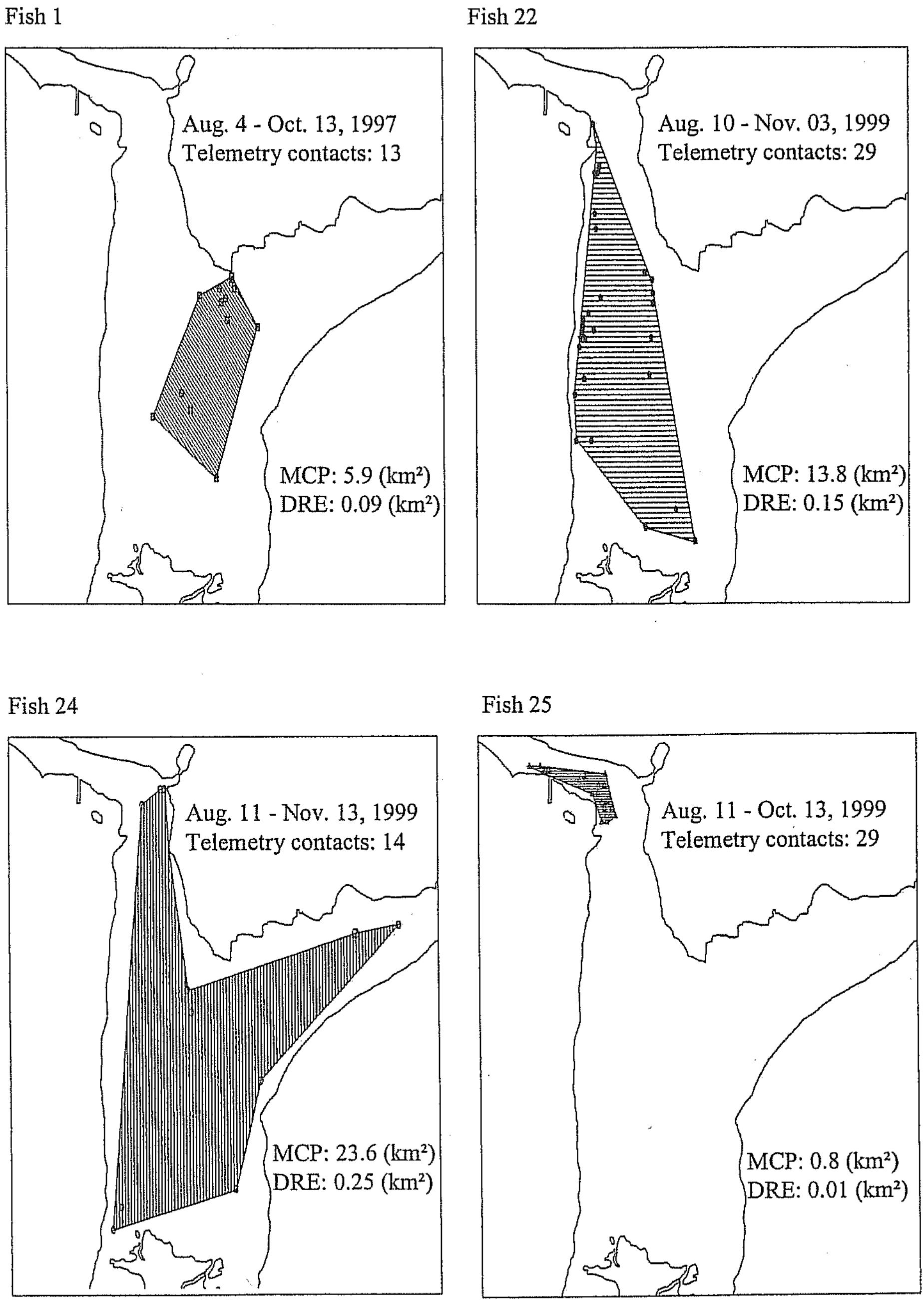

Figure 2. Range estimates determined by minimum-area-polygon for four juvenile lake sturgeon during August through November 1997 and 1999.