Minnesota Department of Natural Resources
Investigational Report 550, August 2007

Light Trap Sampling of Juvenile Northern Pike in Wetlands Affected by Water Level Regulation[1]

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Abstract.—New approaches are needed for sampling northern pike *Esox lucius* in the complex habitats they use as nursery areas. We examined spatial and temporal variation in light trap catches of northern pike in potential pike nursery areas affected by water level regulation in Rainy and Namakan Reservoirs. Light trap catches varied greatly among eight sampling locations and between years during 2004-2006. Total numbers of pike caught each year were 56, 26, and 8 fish respectively, and by far the most common individual light trap catch was 0 fish. A single sampling location accounted for a majority of the fish, with 64% of all fish being caught in Dove Bay of Rainy Lake. Water level elevations coincident with the largest catches in Dove Bay were 102.85-102.90 m above sea level, surface water temperatures were 12.9-16.7 ^{o}C, and over 90% of the pike were caught 17-31 days after ice-out on Rainy Lake. We observed a nearly three-fold difference in individual lengths of pike early in their life history. Challenges encountered in light trapping were variable spring weather patterns making it difficult to achieve a consistent sampling scheme, rising water levels influencing the efficiency of light trapping, and the large size and complex nature of the habitats we sampled.

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[1]This project was funded in part by the Federal Aid in Sport Fish Restoration (Dingell-Johnson) Program. Completion Report, Study 641, D-J Project F-26-R Minnesota.

New approaches are needed for sampling juvenile northern pike *Esox lucius* in proportion to their abundance in natural nursery habitats. Nursery habitat for northern pike is difficult to sample because it consists primarily of marshes or shallow water with submerged and emergent vegetation (Bry 1996; Casselman 1996). Conventional methods for sampling larval fish (fish not yet developed into an adult form), such as towed ichthyoplankton nets, fail to adequately sample areas obstructed by vegetation, stumps, and other structures. Small-mesh bag seines have been used to sample juvenile northern pike (fish larger than approximately 35 mm total length (TL) that resemble the adult form), but seining is less efficient in submerged vegetation than in other types of habitat, so northern pike relative abundance is underestimated in submerged vegetation (Holland and Huston 1984). Forney (1968) and Morrow et al. (1997) sampled nursery areas with an enclosure that was swept with a dip net to remove fish. However, the enclosure method may only be useful in the shallowest water, and it is not clear how efficient the method is for catching different sizes of northern pike. Because of the difficulties in sampling larval and juvenile northern pike, it is hard to assess the relative importance of different habitat types as nursery areas, and the relationship between juvenile abundance and subsequent year-class strength.

Lighted plexiglass traps have been an effective method of collecting larval and juvenile fish (Kelso and Rutherford 1996). Fish that are positively phototactic are drawn into the traps by artificial light. Types of fish sampled with light traps have included fish from the families Clupeidae, Cyprinidae, Atherinidae, Percichthyidae, Centrarchidae, and Percidae. Several light trap designs, reviewed by Kelso and Rutherford (1996), have been developed for sampling larval fish. Floyd et al. (1984a) and Secor et al. (1992) developed "Quatrefoil" traps that consisted of four plexiglass cylinders, open to each other in the center, with a central light system. Slots in between the cylinders provided an entrance for larval fish. Quatrefoil traps can be used to sample larval fish in rearing ponds (Secor et al. 1992) and complex natural habitats (Killgore 1991; Dewey and Jennings 1992), and for live capture of larval and early juvenile stages of endangered fish species (Snyder and Meismer 1997). Furthermore, light traps offer the potential advantage of minimally disrupting fish nursery habitat compared to other sampling techniques.

Previous work has identified several potential field applications for sampling larval fish with light traps. Applications include identifying important habitat, studying seasonal succession of habitat use, and identifying emergence patterns of larval fish in fish communities. Dewey and Jennings (1992) compared larval fish use of open-water and vegetated sites in a backwater lake of the Upper Mississippi River. They found differences in fish species composition between the habitats, with taxonomic diversity being greatest in emergent vegetation. Gregory and Powles (1985) monitored larval fish abundance and their chronology of appearance in an Ontario lake. Light trap catches in the lake demonstrated spatial and chronological segregation of larval fish species. Floyd et al. (1984b) found considerable overlap in presence of larval fish species and spatial resource sharing in a small Kentucky stream. Paulson and Espinosa (1975) used lighted traps to determine which particular fish species was using a layer of water 10-15 m deep in a 61 m deep limnetic area. Thus, light traps have the potential for identifying spatial and temporal use of habitat by a variety of larval fish species.

Two previous studies have evaluated the potential of light traps for sampling young northern pike. Zigler and Dewey (1995) used a series of raceway and pond experiments to test for phototaxis in larval and juvenile northern pike. They compared catches in lighted (using chemical light sticks) versus unlighted Quatrefoil traps, and their results showed that catches of northern pike were 3-35 times greater in lighted traps. In our own previous work with light traps, Pierce et al. (2006) reported that 1) light trap catch rates discriminated between different densities of larval northern pike stocked into hatchery raceways; 2) light traps effectively caught all sizes of pike ranging from the stage when larvae first became active (12-13 mm TL) until they became too large to fit through the trap entrance

(>66 mm TL); and 3) light traps were capable of detecting patchy fish distributions as well as illustrating growth rates and differential survival among managed wetlands.

Rule curves have been implemented by the U.S.-Canadian International Joint Commission (IJC) to regulate water levels in important Minnesota-Ontario border water reservoirs such as Rainy and Namakan Lakes (Kallemeyn 2002). The rule curves are ranges of water levels that vary seasonally in each reservoir, allowing for declining water levels through late fall and winter followed by increasing water levels during spring and early summer. Cohen and Radomski (1993) considered that the northern pike might be a species sensitive to the frequency and amplitude of managed water level fluctuations in these lakes. Such manipulation of water levels during spring has the potential to affect northern pike reproductive success, although year-class strength may actually be influenced more by water levels later in spring and early summer when northern pike need nursery areas with protective cover and an abundant supply of food (Craig 1996; also see Franklin and Smith 1963). Casselman (1996) further suggested that the quality and quantity of nursery habitat affects growth and survival of young-of-the-year northern pike, and may be more critical and more limiting than spawning habitat. Evaluation of the ecological appropriateness of the IJC rule curves for managing water levels in border water reservoirs requires new approaches for sampling larval and juvenile northern pike. Thus, the objectives for this second phase of our studies were to 1) examine spatial and temporal variation in light trap catches in potential nursery areas affected by IJC water level regulations in Rainy and Namakan Reservoirs, and 2) make recommendations for establishing a longer-term monitoring program for northern pike production in relation to the water level regulations.

Methods

In cooperation with Voyageurs National Park and the Minnesota Department of Natural Resources area fisheries office in International Falls, spatial and temporal variations in light trap catch rates were examined among eight potential northern pike nursery areas located in the border water reservoirs of Rainy Lake and Namakan Reservoir. Sampling occurred during three successive spring seasons (2004-2006) in locations (potential nursery areas) selected from previously sampled northern pike spawning runs. Locations in Lake Kabetogama (Namakan Reservoir) were Sullivan Bay, Daley Brook, and Tom Cod Bay (Figure 1). Locations in Rainy Lake were Cranberry Bay, Dove Bay, and three sites in Black Bay (Rueters Creek, Emergency Bay, and the east end of Black Bay; Figure 1).

The Quatrefoil light traps used for sampling were designed and built by Southern Concepts (Birmingham, Alabama), and featured 6-mm entrance slots and light-emitting diodes (LED lights) powered by dry-cell batteries[1]. The 6-mm entrance width was the largest slot width custom built by the manufacturer, and was slightly wider than the 5-mm entrance width used by Zigler and Dewey (1995) in testing for phototaxis of larval pike. LED lights were chosen over chemical light sticks because they emit a very consistent light intensity for the duration of each sampling period.

A night of sampling in each location during spring 2004 consisted of setting 15 Quatrefoil light traps for 2 hours, beginning about 30 minutes after sunset. Additional traps were purchased in 2005 so that 20 traps were set each sampling night during 2005-2006. In one case, the east end of Black Bay, only 10 traps were set, and sampling at that site and at Emergency Bay was discontinued after 2004. Those two locations were also omitted from catch rate calculations. Other locations were sampled no more than once per week and sampling dates each year are reported in Table 1. Light traps were floated from 1.2 m long fiberglass stakes driven into bottom substrates in water 0.3-1.0 m deep. We attempted to scatter light traps among sites that sampled much of the variation in vegetation density in each location. Daily mean water levels were obtained from gauging stations operated by the Lake of the Woods Control Board. Surface water temperatures were recorded each sampling night, and additionally,

[1] Use of trade names does not imply endorsement of the products.

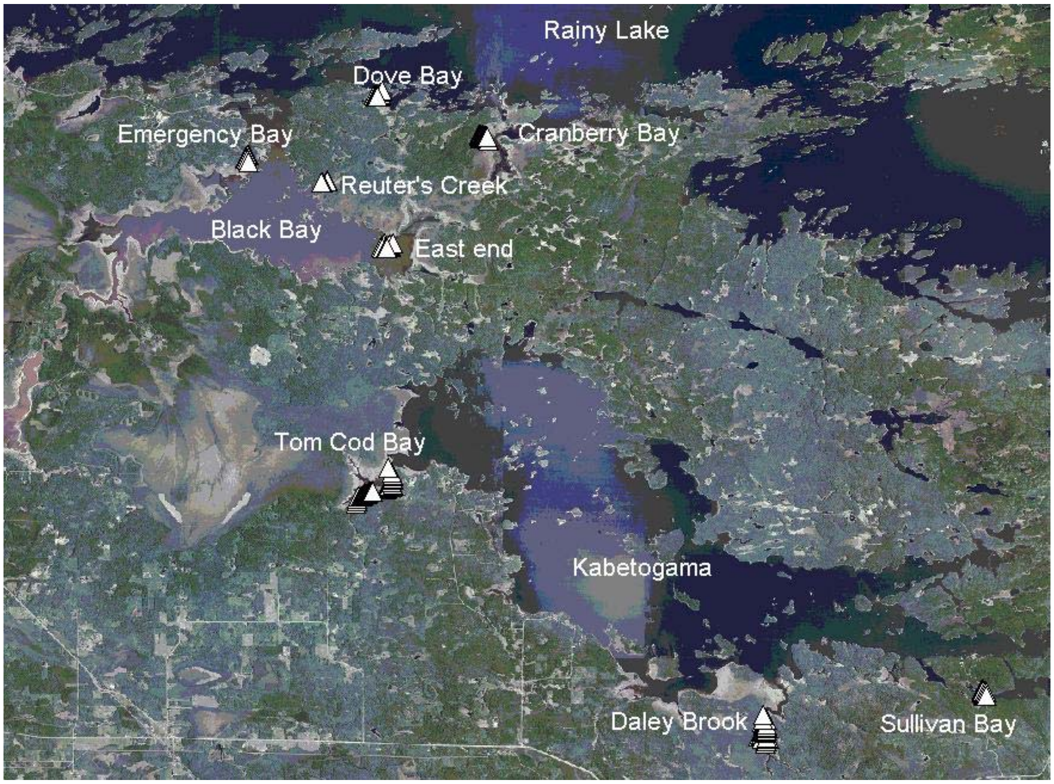

Figure 1. Sampling locations in Rainy Lake and Lake Kabetogama (Namakan Reservoir).

Table 1. Numbers of young-of-the-year northern pike caught by light trapping at each location during each sampling week, 2004-2006. Effort at each location and date in 2004 was 15 traps per night. Effort was increased to 20 traps per night during 2005-2006. Dashes indicate no sampling.

	Lake Kabetogama			Rainy Lake		
Sampling Dates	Sullivan Bay	Daley Brook	Tom Cod Bay	Dove Bay	Cranberry Bay	Reuters Creek
2004						
24-27 May	12	1	0	19	4	-
1-3 June	0	0	1	18	1	0
2005						
9-11 May	-	-	-	11	1	2
16-17 May	1	3	-	1	-	0
23-26 May	1	1	-	2	-	1
31 May-3 June	-	-	-	2	0	0
2006						
1-2 May	0	-	-	0	-	1
8-11 May	0	1	0	5	1	0
15-17 May	0	-	-	0	0	0

electronic temperature loggers were used to record spring water temperatures after ice-out in Cranberry Bay, Dove Bay, and Reuters Creek during spring 2006.

Light trap catch rates from the location with the greatest catches (Dove Bay) were used to compare differences in catches among years using one-way ANOVA and two sample t-tests. A prospective power analysis for these comparisons was conducted using the Sample Size and Power Facility in the statistical software package JMP (SAS Institute Inc., Cary, North Carolina, USA).

Results and Discussion

Light trap catch rates varied greatly between years and among sampling locations. Greatest catch rates were during spring 2004 (mean = 0.34 fish/trap; SE=0.07; n=165; Table 1). Catches during spring 2005 were substantially lower (mean = 0.09 fish/trap; SE=0.02; n=280), and very few pike were caught during spring 2006 (0.03 fish/trap; SE=0.01; n=260). Total numbers of pike caught each year were 56, 26, and 8 fish respectively, and by far the most common individual light trap catch was zero fish. Ice-out dates were 27 April 2004, 20 April 2005, and 16 April 2006 in Lake Kabetogama, and 1 May 2004, 23 April 2005, and 16 April 2006 in Rainy Lake. No fish were caught in the east end of Black Bay and Emergency Bay, so those locations were not included in Table 1. A single location accounted for the majority of the catch with 64% of all fish being caught in Dove Bay of Rainy Lake (Table 1). In only 1 other location were more than 10 fish sampled in 1 night; a total of 12 fry were caught in Sullivan Bay of Lake Kabetogama during the night of 24 May 2004.

Light trap catch rates in Dove Bay illustrated the differences in fish densities among years. Greatest catches for each year in Dove Bay were during the nights of 25 May 2004, 10 May 2005, and 10 May 2006. Mean catch rates for these nights were 1.27 (SE=0.22), 0.55 (SE=0.19), and 0.25 (SE=0.19) fish/trap, respectively. Nonparametric Kruskal-Wallis one-way analysis of variance and Wilcoxon rank sum tests showed significant differences in catches among these nights (*Kruskal-Wallis statistic*=9.552; *P*=0.008) that were attributed to higher catch rates in 2004 compared to the other two years (*P*=0.003-0.054). Parametric one-way ANOVA and t-tests showed similar results (*F*=6.28; *P*=0.004 and *T*=2.13-3.13; *P*=0.006-0.040). Power analysis indicated that the power to detect these differences with parametric tests was 0.96, and suggested that our current effort level of 20 traps per night should be reasonably effective for detecting differences in relative abundance of young pike.

For perspective, comparisons of our catch rates can also be drawn with light trap catches in hatchery raceways stocked with known numbers of northern pike, and with wetlands managed for production of pike fingerlings. Individual light traps in Dove Bay caught up to 3 fish/trap, and during one night, light traps in Sullivan Bay caught up to 5 fish/trap. Individual light traps set in hatchery raceways caught 4-5 fish/trap when the raceways were stocked at a density of 10 fish/m^3 (equivalent to 4 fish/m^2 of surface area in the raceways; Pierce et al. 2006). Fish lengths in the raceways were 12.5-13.3 mm TL compared to 20.0-33.6 mm in Dove Bay, and 12.8-16.8 mm in Sullivan Bay. Another comparison that can be drawn between catch rates in Dove Bay and Sullivan Bay is with light trap catch rates found in Cedar Pond, a wetland near Waterville, Minnesota, that was stocked with pike fry during April 2003 and 2004 (Pierce et al. 2006). Individual light trap catches in Cedar Pond on 30 April 2003 were 0-27 fish/trap (mean = 11.0; SE=3.6), but were only 0-3 fish/trap on 5 May 2004 (mean = 0.9; SE=0.3). Stocking rates of pike fry into Cedar Pond were 14,900 fry/ha in 2003 and 2,800 fry/ha in 2004. The mortality rates of fry after stocking into Cedar Pond are unknown, however, the differences in light trap catch rates between the two years were consistent with the differences in stocking rates (Pierce et al. 2006).

With the exception of Dove Bay and a single sampling occasion at Sullivan Bay, light trap catches indicated very low densities of young-of-the-year pike in locations where we sampled. Figure 1 shows our sampling locations in the lakes, whereas Figures 2–3 show examples of sites where individual light traps were set at two sampling locations. These figures help illustrate the large size and complex structure of these border water ecosystems. Even single sampling locations such as Daley Brook were large and complex. Daley Brook has a well-known spawning run of pike (Miller et al. 2001) and Figure 2 shows all of the light trap sets that occurred in Daley Brook in our efforts over three years to find nursery habitat. Intensive sampling in Daley Brook found no particularly important nursery habitat as only 6 young pike were caught in a total of 90 light trap sets. At 21,910 ha surface area for the Minnesota portion of Rainy Lake, and 10,425 ha for Lake Kabetogama, perhaps it is lucky that we encountered any pike fry at all during the light trapping.

Since the majority of young northern pike were captured in Dove Bay, light trap catches from Dove Bay were used to investigate a matrix of environmental and chronological conditions in which larval and juvenile fish occurred in the bay. Conditions examined were water level, Julian calendar date, water temperature, and the number of days after ice-out. Water level elevations coincident with the largest light trap catches were 102.85 to 102.90 m above sea level. The total range of water levels during which fish were caught was only 0.13 m (102.85-102.98 m; Figure 4). Julian calendar dates showed some variability because of different spring climatic conditions among years, with Julian dates for the highest catch rates ranging from 130 to 153 (Figure 5). Surface water temperatures when fish were caught ranged from 12.9 to 21.7 ^{o}C, with the highest catches from 12.9-16.7 ^{o}C (Figure 4). Over 90% of the pike were caught between 17 and 31 days after ice-out on Rainy Lake, although fish were caught as late as 40 days after ice-out (Figure 5). Weighting of the days after ice-out by numbers of fish caught each day, then averaging the weighted mean for each year across all three years, showed that optimum catches of young-of-the-year pike were about 24 days after ice-out.

Lengths of larval and juvenile northern pike caught at Dove Bay give an indication of the variation in pike growth in the bay. Figure 6 illustrates lengths of individual fish in relation to number of days after ice-out for all three years. Although these data are somewhat limited by sample size (especially for spring 2006), a striking feature of these data is the wide range of individual sizes attained by young pike early in their life history. A nearly threefold difference in length can even be seen within a single year class; the 2004 year-class sampled 31 days after ice-out ranged from 21.9 to 62.5 mm TL. Some of this variability is likely due to differences in hatching date, but differences in food consumption among individuals might be even more important since the variability seems to increase with time after ice-out.

One of the principal challenges for light-trap sampling of juvenile northern pike during spring is variable spring weather patterns that make it difficult to achieve a consistent sampling scheme. Year-to-year differences in precipitation affect the rate at which water levels increase, and therefore the habitat available for juvenile northern pike. Spring weather patterns affect ice-out dates and subsequent water temperatures, which in turn influence hatching dates and pike growth. Temperature loggers remained in place in Reuters Creek, Dove Bay, and Cranberry Bay from shortly after ice-out through 19 May 2006. Such temperature logger data may be useful in the future for comparing spring temperatures during egg incubation and larvae development.

The IJC rule curves allow for increasing water levels during spring in both reservoirs. April and May water levels were maintained within upper bounds of the rule curves with only one exception during the three years. The exception was late in May 2005 when heavy runoff caused water levels in both reservoirs to increase above the rule curve limits. Another potential complicating factor in this study may be the influence that rising water levels have on the efficiency of light traps. For example, water flow and turbidity were noticeably increased at the Daley Brook site on 26 May 2005 following an unusually large rain event the previous day. Gregory and Powles (1985) and Zigler and Dewey (1995) reasonably cautioned that factors reducing light trap visibility would detract from the effectiveness of light trapping to measure relative abundance.

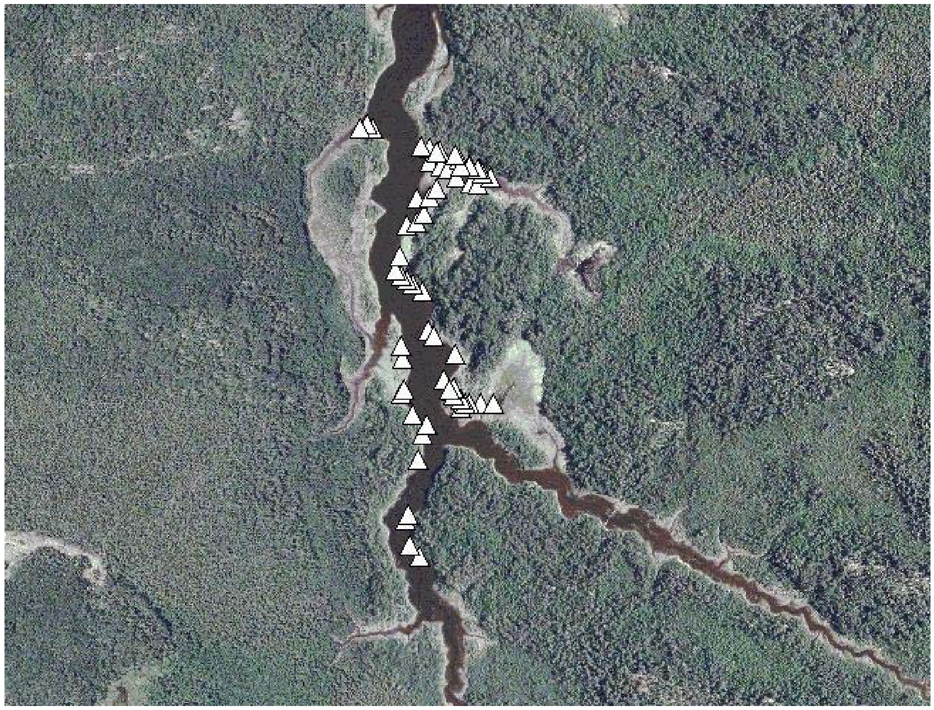

Figure 2. Sites where individual light traps were set in Daley Brook, Lake Kabetogama, 2005-2006.

Figure 3. Sites where individual light traps were set in Dove Bay, Rainy Lake, 2005-2006.

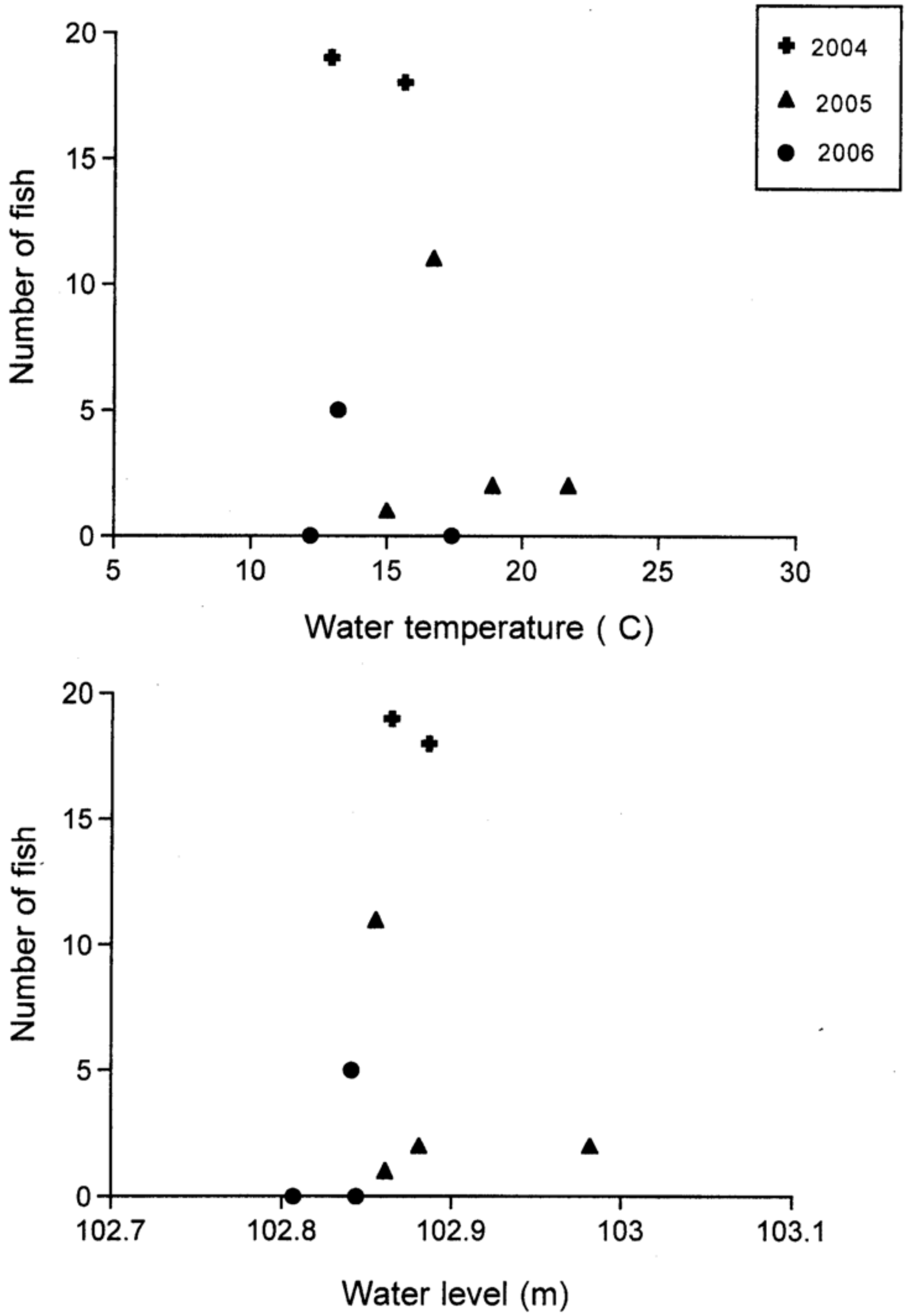

Figure 4. Environmental conditions (water level and water temperature) during which young-of-the-year northern pike were caught in Dove Bay, 2004-2006.

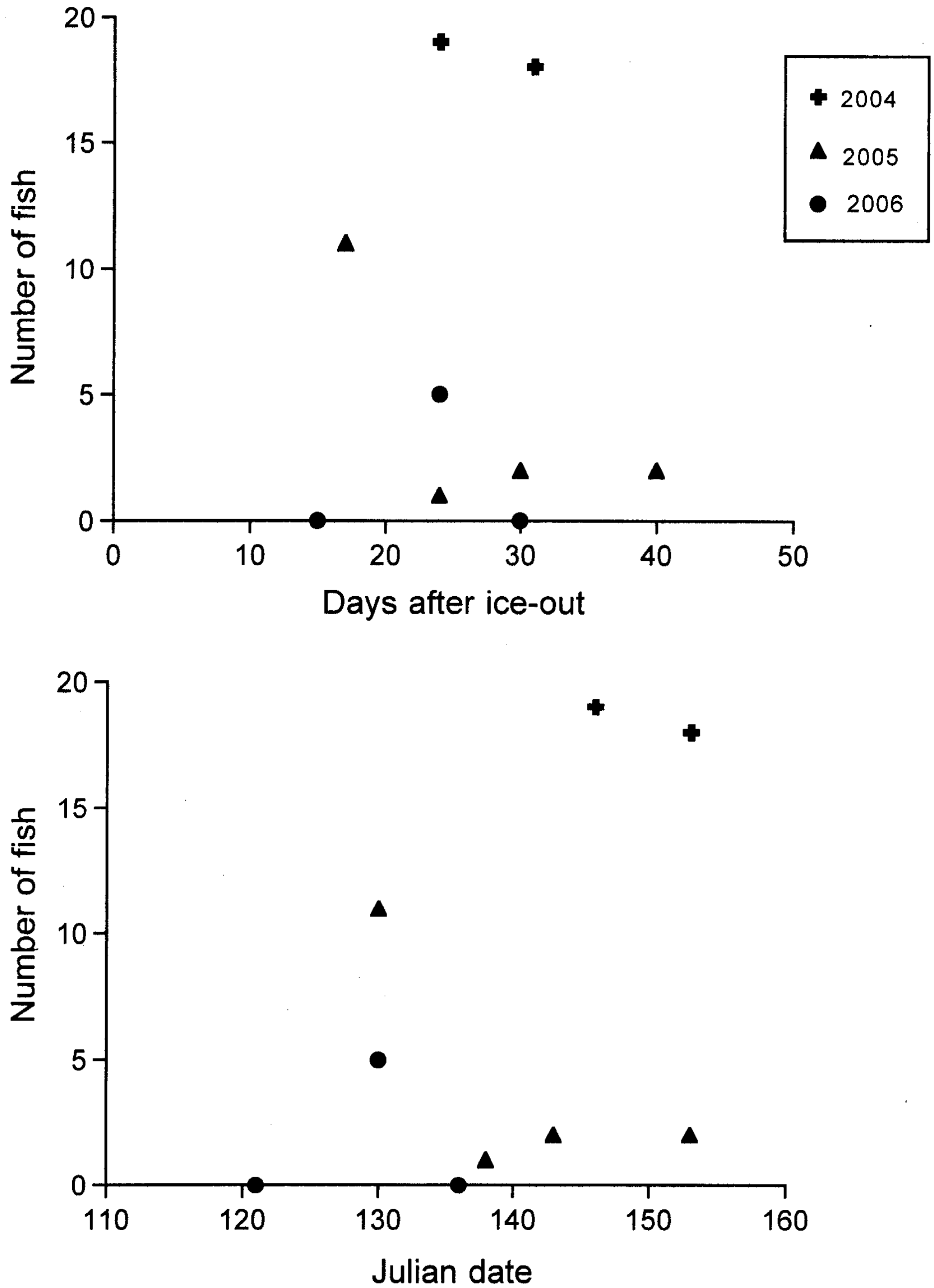

Figure 5. Chronological conditions (Julian calendar date and number of days after ice-out) during which young-of-the-year northern pike were caught in Dove Bay, 2004-2006.

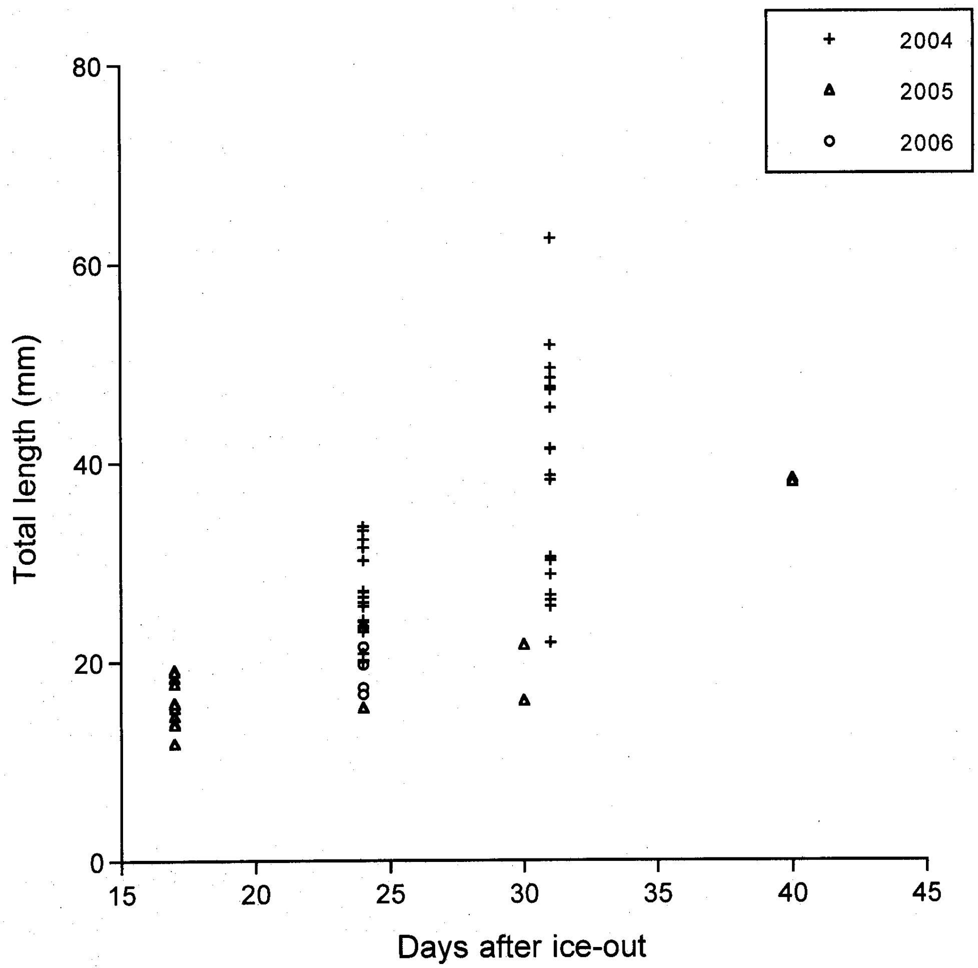

Figure 6. Individual lengths of northern pike caught by light trapping in Dove Bay, 2004-2006, in relation to number of days after ice-out.

Recommendations for Long-term Studies

The IJC has mandated that we study how the water level rule curves affect fish populations in Rainy and Namakan Reservoirs. The most useful study design for our work would have included routine sampling at numerous nursery areas, but despite our fairly intensive sampling program, only 2 study locations have accounted for 80% of the larval and juvenile northern pike that were trapped. Expanding the sampling program to sample additional nursery habitat is needed to better evaluate the effect of water levels on pike production. Lack of personnel is currently an issue for expanding sampling effort.

Alternatively, future efforts could focus on a more restricted study of year-to-year variations in northern pike production in Dove Bay and Sullivan Bay. Light trap sampling could be used to more specifically describe characteristics of the most productive nursery habitat by sampling different vegetation types, depths, and bottom substrates available to larval and juvenile northern pike in Dove Bay and Sullivan Bay. An extensive GIS-based sampling of aquatic vegetation is currently occurring in Rainy and Namakan waters of Voyageurs National Park. Specific information about nursery habitat, in combination with GIS, might provide useful indications of how water level affects nursery habitat of young pike. Staff gauge and water temperature monitoring in nursery habitat should be continued. Additionally, any successional changes in vegetative cover, such as expanding patches of cattails due to water level regulation, should be documented in the nursery areas.

References

Bry, C. 1996. Role of vegetation in the life cycle of pike. Pages 45-67 *in* J. F. Craig, editor. Pike biology and exploitation. Chapman and Hall, London.

Casselman, J. M. 1996. Age, growth and environmental requirements of pike. Pages 69-101 *in* J. F. Craig, editor. Pike biology and exploitation. Chapman and Hall, London.

Cohen, Y., and P. Radomski. 1993. Water level regulations and fisheries in Rainy Lake and the Namakan Reservoir. Canadian Journal of Fisheries and Aquatic Sciences 50: 1934-1945.

Craig, J. F. 1996. Population dynamics, predation and role in the community. Pages 201-217 *in* J. F. Craig, editor. Pike biology and exploitation. Chapman and Hall, London.

Dewey, M. R., and C. A. Jennings. 1992. Habitat use by larval fishes in a backwater lake of the Upper Mississippi River. Journal of Freshwater Ecology 7:363-372.

Floyd, K. B., W. H. Courtenay, and R. D. Hoyt. 1984a. A new larval fish light trap: A Quatrefoil trap. The Progressive Fish-Culturist 46:216-219.

Floyd, K. B., R. D. Hoyt, and S. Timbrook. 1984b. Chronology of appearance and habitat partitioning by stream larval fishes. Transactions of the American Fisheries Society 113:217-223.

Forney, J. L. 1968. Production of young northern pike in a regulated marsh. New York Fish and Game Journal 15: 143-154

Franklin, D. R., and L. L. Smith, Jr. 1963. Early life history of the northern pike, *Esox lucius* L., with special reference to the factors influencing the numerical strength of year classes. Transactions of the American Fisheries Society 92: 91-110.

Gregory, R. S., and P. M. Powles. 1985. Chronology, distribution, and sizes of larval fish sampled by light traps in macrophytic Chemung Lake. Canadian Journal of Zoology 63:2569-2577.

Holland, L. E., and M. L. Huston. 1984. Relationship of young-of-the-year northern pike to aquatic vegetation types in backwaters of the Upper Mississippi River. North American Journal of Fisheries Management 4:514-522.

Kallemeyn, L. W. 2002. Establishment of an assessment program to evaluate the long-term effects of changes in the water management program for Rainy Lake and Namakan Reservoir. Final report to: International Joint Commission, U.S. Geological Survey, Columbia Environmental Research Center, International Falls Biological Station, Service Order S01761-100545.

Kelso, W. E., and D. A. Rutherford. 1996. Collection, preservation, and identification of fish eggs and larvae. Pages 255-302 *in* B. R. Murphy and D. W. Willis, editors. Fisheries Techniques, second edition. American Fisheries Society, Bethesda, Maryland.

Killgore, K. J. 1991. Techniques used in fishery evaluation studies. Pages 71-85 *in* L. G. Sanders, editor. Techniques for evaluating aquatic habitats in rivers, streams, and reservoirs. U. S. Army Corps of Engineers, Waterways Experiment Station, Miscellaneous Paper W-91-2, Vicksburg, Mississippi.

Miller, L. M., L. Kallemeyn, and W. Senanan. 2001. Spawning-site and natal-site fidelity by northern pike in a large lake: mark-recapture and genetic evidence. Transactions of the American Fisheries Society 130: 307-316.

Morrow, J. V., Jr., G. L. Miller, and K. J. Killgore. 1997. Density, size, and foods of larval northern pike in natural and artificial wetlands. North American Journal of Fisheries Management 17: 210-214.

Paulson, L. J., and F. A. Espinosa, Jr. 1975. Fish trapping: A new method of evaluating fish species composition in limnetic areas of reservoirs. California Fish and Game 61:209-214.

Pierce, R. B., S. Shroyer, B. Pittman, D. E. Logsdon, and T. D. Kolander. 2006. Catchability of larval and juvenile northern pike in Quatrefoil light traps. North American Journal of Fisheries Management 26: 908-915.

Secor, D. H., J. M. Dean, and J. H. Hansbarger. 1992. Modification of the Quatrefoil light trap for use in hatchery ponds. The Progressive Fish-Culturist 54:202-205.

Snyder, D. E., and S. M. Meismer. 1997. Effectiveness of light traps for capture and retention of larval and early juvenile *Xyrauchen texanus* and larval *Ptychocheilus lucius* and *Gila elegans*. Final report to Cooperative Parks Study Unit, U.S. National Park Service. Fort Collins, Colorado.

Zigler, S. J., and M. R. Dewey. 1995. Phototaxis of larval and juvenile northern pike. North American Journal of Fisheries Management 15:651-653.