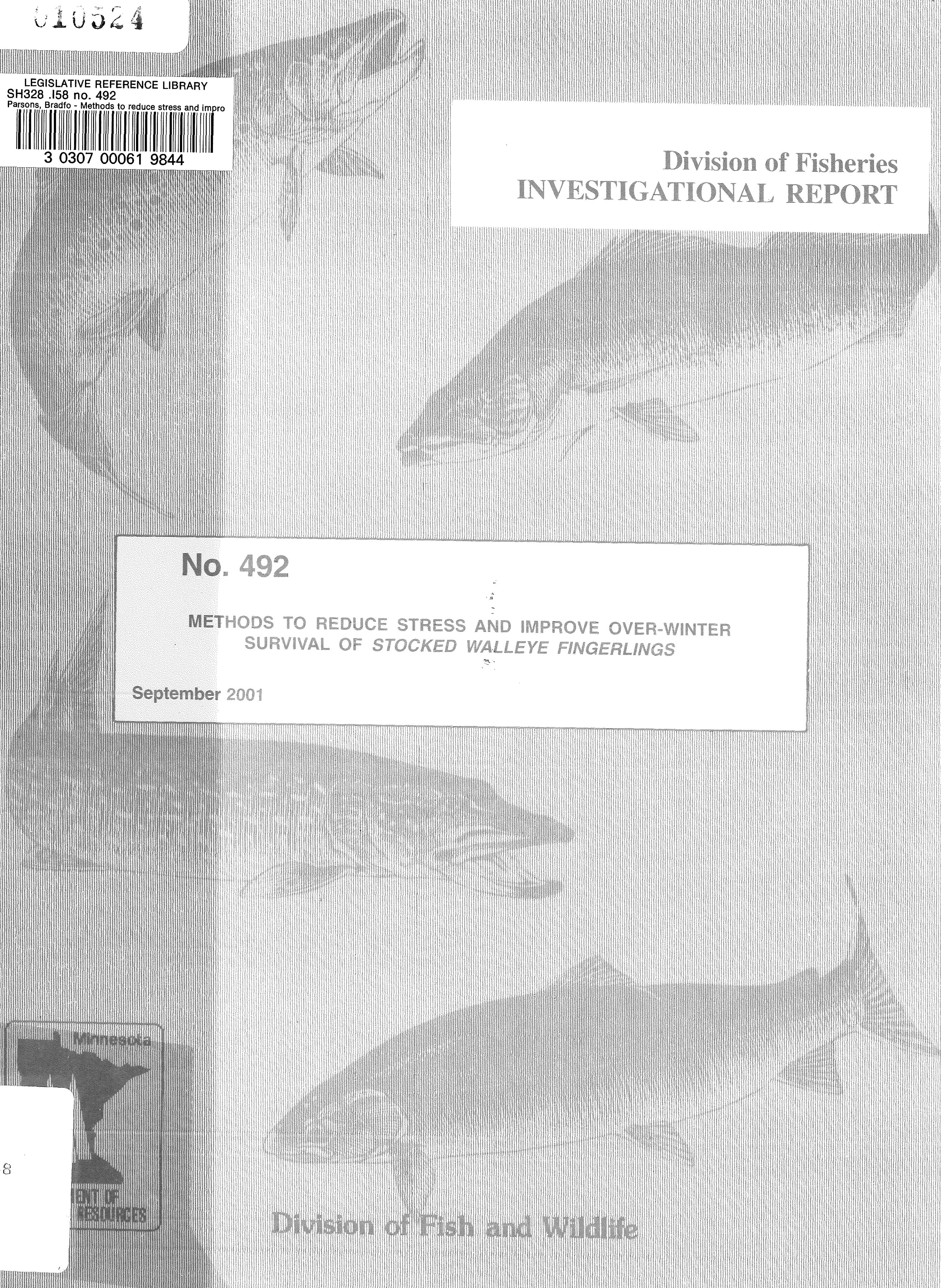

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METHODS TO REDUCE STRESS AND IMPROVE OVER-WINTER SURVIVAL OF *STOCKED WALLEYE FINGERLINGS*

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Methods to Reduce Stress and Improve Over-winter Survival of Stocked Walleye Fingerlings[1]

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Abstract.-- We evaluated stress and over-winter survival of walleye fingerlings during normal Minnesota harvest and stocking procedures. Blood chemistry showed walleye fingerlings were stressed during each stage of the process. Blood plasma cortisol generally returned to baseline levels after 24 hours, but blood plasma chloride did not. Over-winter survival of stocked walleye fingerlings ranged from 1% to 63% in three lakes where stocked fingerlings averaged about 140 mm, but survival was 99% in one trial where stocked fingerlings averaged 192 mm. Holding fingerlings in a crib in the lake for 24 hr prior to release did not improve over-winter survival. However, hauling fingerlings at a density of 0.06 kg/l (0.5 lb/gal) rather than 0.12 kg/l (1.0 lb/gal) did appear to improve over-winter survival.

Introduction

The Minnesota Department of Natural Resources Division of Fisheries annually stocks well over 1 million walleye *Stizostedion vitreum* fingerlings statewide into over 300 lakes. A study conducted for the Department of Natural Resources found average cost of US$0.30 per fingerling stocked (KMPG Peat Marwick 1990). In 2001 dollars, this would be a cost of $0.41 per fingerling, representing an annual investment of over $400,000. However, very little information is available regarding survival of these stocked fish. Improved survival of stocked fish would increase the efficiency of the stocking program, allowing fisheries managers to achieve similar results with fewer fingerlings, or increased walleye populations with the same number of stocked fingerlings.

The standard procedure for rearing and stocking walleye fingerlings is fairly consistent throughout Minnesota. Newly hatched walleye fry are transported to natural lakes and wetlands within 3 days of hatching in late April or early May. Walleye fry are stocked into rearing waters and allowed to grow throughout the summer. In September and October, the surviving walleye fingerlings are captured with trap nets. Nets are emptied into a container in the boat, and extraneous organisms (including fathead minnows *Pimephales promelas*, black bullhead *Ameirus melas*, crayfish *Orconectes spp.*, tiger salamanders *Ambystoma tigrinum*)

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are removed. Fingerlings are then transferred with dip nets into buckets to determine the pounds harvested, and the buckets are poured into distribution tanks with salted (<0.5%) water. The fingerlings are then transported to a lake and are either emptied into the lake through a pipe or dip-netted from the tank.

Walleye fingerlings are unavoidably subjected to stress during each step of this stocking procedure. Barton and Zitzow (1995) documented this stress by showing increased blood plasma cortisol levels in handled walleye. These results were confirmed for walleye fingerlings freeze-branded, transported, and stocked in Iowa lakes (Bruce Barton, University of South Dakota, unpublished data). This stress may be the cause of high mortality rates of stocked walleye by directly killing the fish or indirectly causing mortality through increased susceptibility to predation or disease.

Two investigations of standard Minnesota harvest, handling, and hauling techniques showed short-term mortality of walleye fingerlings. Schreiner (1985) found fingerlings held 48 hours in 1 m X 1 m wire mesh cribs in 1 m deep water had a 10% mortality rate, and an additional 10% were moribund. Parsons et al. (1994) found that mortality of fingerlings held in 1.8 m X 1.8 m cotton mesh cribs in approximately 1.2 m deep water for 72 hours averaged 12% mortality rates both for fish marked with coded wire tags and unmarked fish. In East Okoboji Lake, Iowa, Larscheid (1995) estimated that 70% of walleye fingerlings died within 3 weeks of stocking in 1992, and mortality exceeded 95% in 1993.

Low over-winter survival of stocked walleye fingerlings compared to fingerlings already in the lake due to fry stocking or natural reproduction has also been noted. McWilliams and Larscheid (1992) reported that fingerlings stocked in the fall in Iowa lakes experienced over-winter mortality rates 2 to 16 times higher than fingerlings originating from natural reproduction or fry stockings. Mitzner (1992) found mortalities of fall stocked fingerlings to be 1.2 to 11 times higher than that of fingerlings originating from fry stocking in Rathbun Lake, Iowa. Survival of native fingerlings after one year was 50 times greater than that of fingerlings stocked in Pike Lake, Wisconsin (Mraz (1968).

Fingerling walleye serve as prey for several species of fish. Cannibalism by older walleye can substantially reduce the number of walleye in succeeding year classes (Chevalier 1973). Johnson et al. (1992) found that 33% of the mortality of fingerling walleye from October 1988 to May 1989 in Lake Mendota, Wisconsin, could be accounted for by walleye and northern pike *Esox lucius* predation. Santucci and Wahl (1993) documented heavy predation by largemouth bass *Micropterus salmoides* on stocked walleye fingerlings. Hatchery-reared walleye fingerlings subjected to simulated handling stress took three times longer to seek cover compared to control fish (Barton and Haukenes 1999), increasing their susceptibility to predation.

The ultimate result of poor survival of stocked walleye fingerlings is low return to the angler's creel. Parsons et al. (1994) estimated that an average of 5% of walleye fingerlings stocked from 1986-1988 in two Minnesota lakes were eventually harvested by anglers, and return to the creel was only 1.5% in a third lake. In Escanaba Lake, Wisconsin, Kempinger and Churchill (1972) estimated that three of four summer fingerling stockings on top of a naturally reproducing population yielded only 1% of stocked fish to the creel, while the fourth yielded 13% to the creel.

The objectives of this study were to document the degree of stress experienced by walleye fingerlings during standard Minnesota harvest and stocking procedures, and to quantify immediate, short-term, and over-winter mortality of stocked walleye fingerlings. We also wished to evaluate the effectiveness of methods designed to reduce stress and improve survival. The first experiment was to determine if holding fingerlings for 24 hr after stocking in a mesh crib in the stocked lake would improve survival. We hypothesized that the fingerlings held in a crib would have time to acclimate to the receiving lake, recover from stress inflicted by harvest, hauling, and stocking, and have improved survival. The second experiment was to determine if fingerlings hauled at lower densities (fewer fish per volume of water) had better survival than fingerlings hauled at the maximum recommended density of 0.12 kg/l (1.0 lb/gal). We hypothesized fewer fish/l should experience less stress during transport and have improved survival.

Methods

The experiments were conducted on four small (42-125 ha) lakes in Douglas County of west-central Minnesota (Table 1). All four lakes had native predator fish communities dominated by northern pike and largemouth bass. Minnesota Department of Natural Resources lake survey data indicated that both species were abundant in all four lakes. Previous successful walleye stockings had created walleye populations in Bergen and Pocket lakes. Prior to this study, walleye stocking had not been attempted in Vermont Lake since 1951, and triennial walleye stocking from 1985 through 1994 had very limited success in Union Lake.

Bergen Lake was stocked on 26 September and 1 October 1996 with fingerlings from Barrett Pond (64 ha), Grant County. Pond and lake water temperatures were 15°C and 16°C, respectively on both dates. Pocket Lake (14°C) was stocked on 2 October 1996 with fish from Worm Pond (67 ha), Grant County (10°C). Union and Vermont lakes were stocked on 8 and 14 October 1997, respectively, with fingerlings from Stammer Pond (11 ha), Pope County. On 8 October, Stammer pond was 17°C, and Union Lake was 16°C. On 14 October, Stammer pond was 9°C, and Vermont Lake was 12°C. Water in the distribution tanks was tempered to match the rearing pond temperature. Water in the tanks was oxygenated and treated with 0.5% NaCl (Barton and Zitzow 1995).

Blood chemistry: Ten fingerlings were sacrificed for blood at selected times during the stocking procedure. Fingerlings were placed into a lethal dose of tricaine methanesulfonate anesthetic. A syringe was inserted along the ventral midline behind the anal fin to extract blood from the caudal artery (Houston 1990). Blood samples were centrifuged immediately after extraction to separate plasma. Plasma was pipetted and immediately frozen. Samples

Table 1. Lake class, area (ha), littoral area (ha), maximum depth (m), and predator fish community of Bergen, Pocket, Union, and Vermont lakes. Bold face type indicates relative abundance of northern pike (NOP), largemouth bass (LMB), or walleye (WAE) above the third quartile for the lake class from Minnesota Department of Natural Resources lake survey data.

Lake	Lake Class	Area	Littoral Area (m)	Max Depth (m)	Predator Fish Community
Bergen	31	74	21	13	**NOP**, LMB, WAE
Pocket	32	111	56	12	**NOP, LMB, WAE**
Union	31	42	22	15	**NOP, LMB**
Vermont	25	125	84	19	**NOP, LMB**

were sent to the fish physiology lab at the University of South Dakota for analysis of blood plasma cortisol and chloride, two physiological stress indicators.

Blood samples were taken seven times during the 1996 stockings of Bergen and Pocket lakes. Baseline samples were collected from fingerlings immediately after the trap net was lifted. Harvest samples were collected after several trap nets were lifted and the harvest boat had returned to the landing. Pre-haul samples were collected just prior to departure of the distribution truck from the harvest pond, and post-haul samples were collected when the distribution truck arrived at the lake. The final blood samples were collected at 1, 3, and 24 hr post-stocking from fish held in a mesh crib. Blood samples were collected 3 times during the 1997 stockings in Union and Vermont lakes - baseline, post-haul, and 24 hours post-stocking. Blood plasma cortisol and chloride levels were analyzed with one-way analysis of variance ($\alpha = 0.05$). If significant differences were found, we conducted Bonferroni multiple comparisons (Zar 1984).

Survival enhancement techniques: In the 1996 stockings of Bergen and Pocket lakes, we analyzed the effect of holding fish for 24 hr in a crib to improve survival. At the harvest pond, half the fingerlings were marked with 1 mm long binary coded wire tags (Nielsen 1992) in the left cheek musculature, and the other one-half were similarly tagged in the right cheek musculature. The two groups were transported in separate tanks on the same truck to the study lake. Upon arrival, one tank of fingerlings was transferred to a 1.8 m X 1.8 m X 1.2 m mesh crib in the lake and held for 24 hours. These fish were also used for the blood chemistry samples and analyzed for short-term mortality. The other tank of fingerlings was stocked directly into the lake without confinement.

In the 1997 stockings of Union and Vermont lakes, we examined the effect of hauling density on blood chemistry and survival. At the harvest pond, one-half the fingerlings were marked with 1 mm long binary coded wire tags in the left cheek musculature, and the other half were similarly tagged in the right cheek musculature. Fish tagged in the left cheek were placed in a tank with enough water to create a hauling density of 0.06 kg/l (0.5 lb/gal) (half density), and fish tagged in the left cheek were placed in a tank with enough water to create a hauling density of 0.12 kg/l (1.0 lb/gal) (normal density).

Mortality: Immediate mortality, determined on all four lakes in 1996 and 1997, included fish found dead or moribund (caudal necrosis) in the tank upon arrival at the lake. Short-term mortality was considered to be fish dead or moribund after 24 hr in the crib in the 1996 experiments on Burgen and Pocket lakes.

We estimated spring abundance to assess over-winter survival. This was assessed from 19 May to 13 June 1997 in Bergen and Pocket lakes, and from 5 May to 2 June 1998 in Union Lake. Sampling was also conducted on 6 and 12 May 1998 in Vermont Lake, but only three walleye were captured, so sampling was ended. Night pulsed DC boom electrofishing was conducted weekly for five weeks to collect yearling walleye. Sampling was terminated in each case due to macrophyte and algal growth, which severely limited visibility and reduced capture efficiency. A tag detection wand (Northwest Marine Technology) indicated the cheek that was tagged. Fish with a tag in the right cheek received a right pelvic fin clip, while fish with a tag in the left cheek received a left pelvic fin clip. If we could not detect the presence of a tag, the fish received an upper caudal fin clip. Population estimates were conducted with the Chapman modification of the Schnabel method (Ricker 1975). The 95% confidence intervals were calculated using recaptures as a Poisson variable. Over-winter survival was calculated by dividing the population estimate by the actual number of fish stocked. Difference in survival between groups was examined with chi-square tests with significance set at the 0.05 level.

Results

Harvest and stocking: The fingerlings from Barrett Pond for Bergen Lake were large with a mean length of 192 mm (SE = 2.0) and a mean weight of 57 g (SE = 2.0). Only 105 fish were captured during the first harvest on 26 September 1996, and all fish were tagged in the right cheek for crib stocking. Forty of these fish were used for blood samples, and 3 were found dead on 27 September. Therefore, 62 fingerlings were released after 24 hr in the crib. Harvest was more successful on 1 October 1996, with 811 walleye captured. Of these, 424 were tagged in the left cheek for stocking directly into Bergen Lake, and 387 were tagged in the right cheek for cribbing. After removal of fish for blood samples, 416 fish were stocked directly into Bergen Lake and 350 were stocked after cribbing. No mortality was found either after hauling or cribbing. Overall, 416 fingerlings were stocked directly into Bergen Lake, while 412 spent 24 hr in the crib prior to stocking (Table 2).

The fingerlings harvested on 2 October 1996 from Worm Pond for stocking in Pocket Lake had a mean length of 144 mm (SE = 1.9) and a mean weight of 24 g (SE = 1.0). Of 2,350 fingerlings harvested, 1,150 were tagged in the left cheek for stocking directly into Pocket Lake, and 1,200 were tagged in the

Table 2. Number of walleye fingerlings stocked and handled during electrofishing by survival treatment, and population estimates and 95% confidence intervals for Bergen, Pocket, and Union lakes.

Stocking	Number stocked	Number handled (%)	Population estimate (%)	95% CI Lower (%)	95% CI Upper (%)
Bergen Lake					
Cribbed	412	130 (32)	336 (81)	228 (55)	516 (100)
Not cribbed	416	150 (36)	395 (95)	269 (65)	602 (100)
No tag	0	31 (-)	59 (-)	31 (-)	124 (-)
All	828	311 (38)	816 (99)	628 (76)	1,085 (100)
Pocket Lake					
Cribbed	1,058	140 (13)	535 (51)	328 (31)	923 (87)
Not cribbed	1,150	171 (15)	685 (60)	437 (38)	1,131 (98)
No tag	0	20 (-)	78 (-)	24 (-)	142 (-)
All	2,208	331 (15)	1,381 (63)	989 (45)	1,999 (91)
Union Lake					
Normal density	1,086	84 (8)	271 (25)	157 (14)	509 (47)
Half density	1,089	126 (12)	535 (49)	316 (29)	966 (89)
No tag	0	11 (-)	12 (-)	5 (-)	31 (-)
All with no tag	2,175	221 (10)	792 (36)	551 (25)	1,179 (54)

right cheek for stocking into the crib. No immediate mortality was observed in either tank after transport. Sixty fingerlings were removed from the crib for blood samples. When the crib fingerlings were released on 3 October, 82 dead or moribund fish were recovered, representing a 7% short-term mortality rate. Mortality occurred primarily among the smaller fingerlings; dead and moribund fish had a mean length of 126 mm. A t-test indicated they were significantly smaller than fingerlings randomly sampled for blood ($P < 0.0001$). Final totals were 1,150 fingerlings released directly into Pocket Lake, and 1,058 fingerlings released after cribbing (Table 2).

On 8 October 1997, 2,240 fingerlings with a mean length of 140 mm (SE = 1.6) and a mean weight of 23 g (SE = 0.9) were harvested from Stammer Pond for stocking in Union Lake. One-half the fingerlings were tagged in the right cheek and placed into a hauling tank containing 189 l of water for the normal density (0.12 kg/l, 1.0 lb/gal) hauling experiment. The other one-half were tagged in the left cheek and placed into a hauling tank containing 379 l of water for the one-half density (0.06 kg/l, 0.5lb/gal) hauling experiment. Immediate mortality was very low with only 4 dead fingerlings in the normal density tank and 1 dead fish in the one-half density tank. Thirty fingerlings from the normal density tank and 29 from the one-half density tank were removed for blood sampling and placed in a crib in the lake. Therefore, 1,086 normal density fingerling hauling and 1,089 one-half density fingerling hauling were stocked into Union Lake (Table 2).

We harvested 3,200 fingerlings with a mean length of 138 mm (SE = 1.7) and a mean weight of 22 g (SE = 0.9) from Stammer Pond on 14 October 1997 for stocking in Vermont Lake. One-half the fingerlings were tagged in the left cheek and placed into a hauling tank containing 284 l of water for the normal density (0.12 kg/l, 1.0 lb/gal) hauling experiment. The other one-half were tagged in the right cheek and placed into a hauling tank containing 568 l of water for the one-half density (0.06 kg/l, 0.5 lb/gal) hauling experiment. Immediate mortality was again very low with only 1 dead fingerling in the normal density tank and none in the one-half density tank. We removed 28 fingerlings from the normal density tank and 29 from the one-half density tank for blood sampling. Therefore, 1,572 normal density fingerling hauling and 1,570 one-half density fingerling hauling were stocked into Vermont Lake.

Blood chemistry: Changes in blood chemistry were evident in all experiments. In the 1996 tests, blood plasma cortisol increased slightly from baseline levels just from harvest (Figure 1), and by the time the truck left the rearing pond, levels were significantly higher ($P < 0.0001$). Levels appeared to decrease slightly during transport and increased again after stocking, but there was no statistical difference among pre-haul, post-transport, 1 hr, and 3 hr samples. Blood plasma cortisol returned to near baseline levels after 24 hours in the crib.

Changes in blood plasma chloride levels were slower to respond and varied somewhat among trials (Figure 1). In general, there was no difference in baseline, harvest, and pre-haul levels. Levels declined post-haul and 1 to 3 hr after stocking. Recovery after 24 hr was noted only in the second Barrett Pond - Bergen Lake trial. The decline in blood plasma chloride noted in the Worm Pond - Pocket Lake trial may have been related to the extra time it took to tag the 2,350 fingerlings harvested versus 105 and 811 fingerlings in the two Barrett Pond - Bergen Lake trials.

There appeared to be differences in blood chemistry for the fingerlings from Stammer Pond hauled at normal and one-half density. The blood plasma cortisol of the Union Lake fish increased significantly ($P = 0.0021$) for both the normal and one-half density fish post-transport (Figure 2). Levels recovered to baseline after 24 hr, but recovery appeared to be somewhat better for the one-half density transported fish. Similar results were found for blood plasma chloride (Figure 2). However, baseline levels were unusually

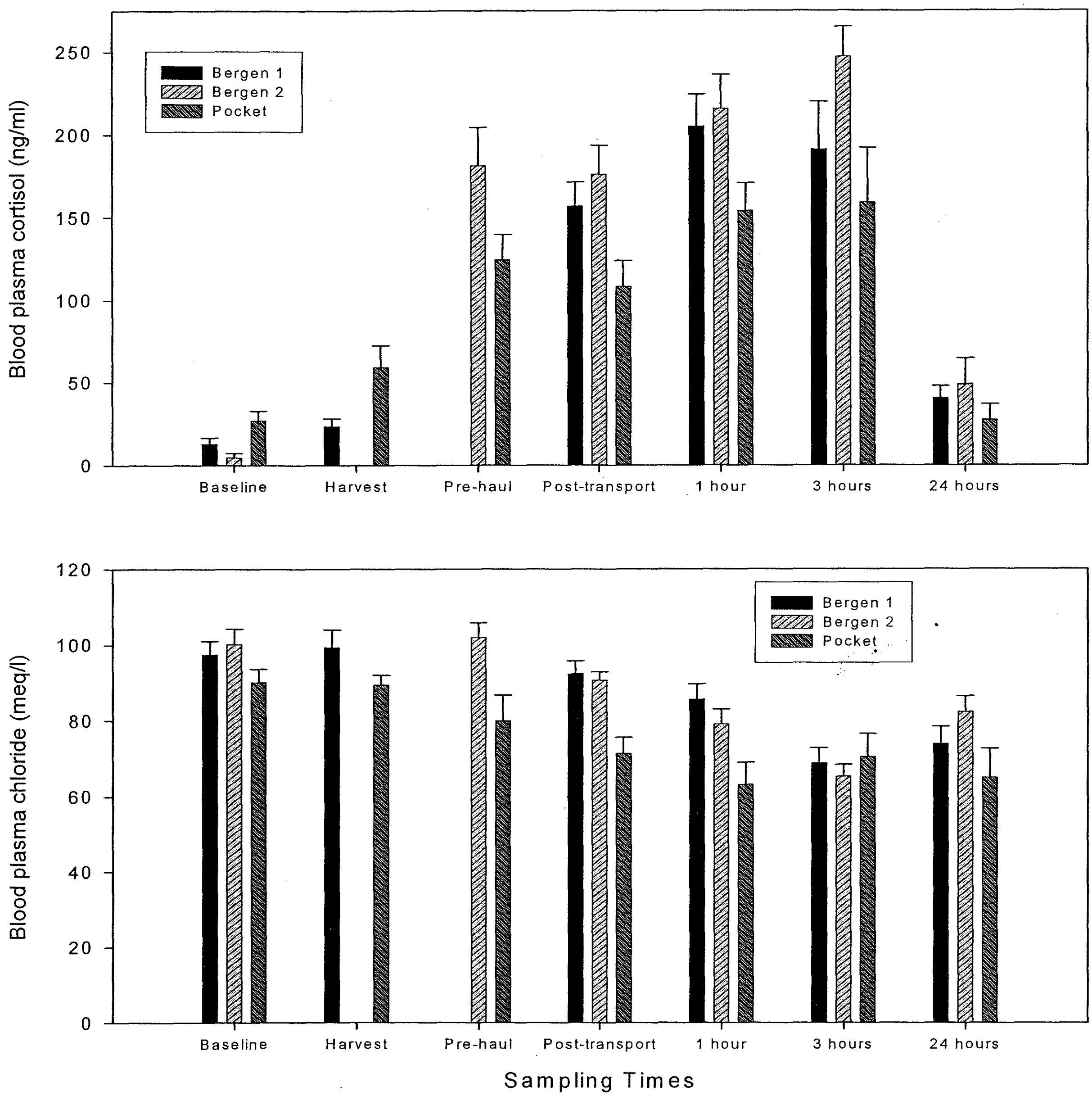

Figure 1. Blood plasma cortisol (ng/ml) and chloride (meq/l) levels for walleye fingerlings at seven different times during the harvest and stocking procedures for Bergen and Pocket lakes, 1996. Fingerlings were stocked on two separate dates in Bergen Lake (Bergen 1 and Bergen 2). Samples were collected from fingerlings at the following times: baseline - immediately after the trap net was lifted; harvest - after several trap nets were lifted and the harvest boat had returned to the landing; pre-haul - just prior to departure of the distribution truck from the harvest pond; post-transport - when the distribution truck arrived at the lake; and from fingerlings held in mesh cribs at 1, 3, and 24 hr post-stocking.

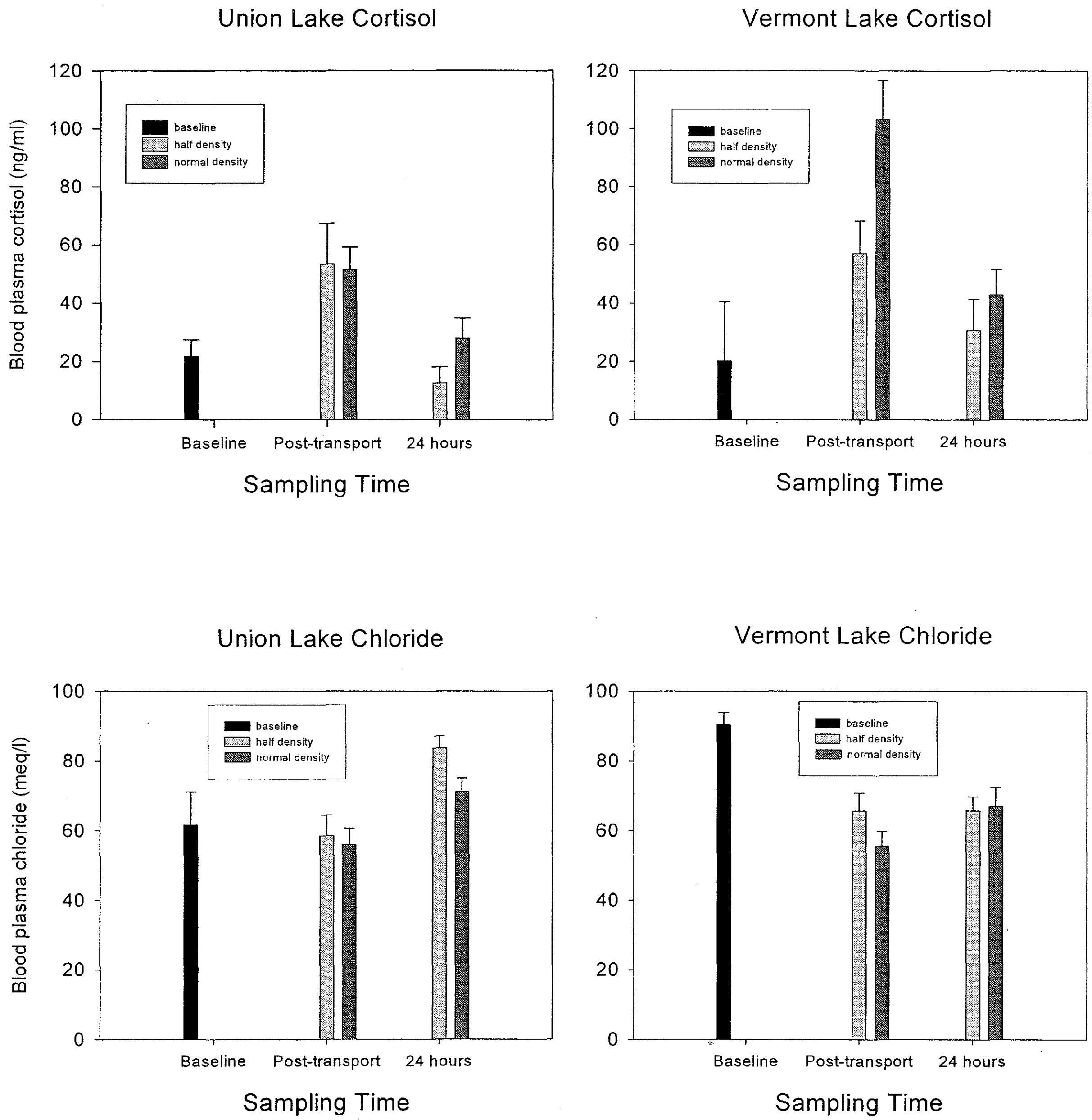

Figure 2. Blood plasma cortisol (ng/ml) and chloride (meq/l) levels for walleye fingerlings at three times during the harvest and stocking procedures for Union and Vermont lakes, 1997. Samples were collected from fingerlings at the following times: baseline - immediately after the trap net was lifted; post-transport - when the distribution truck arrived at the lake; and from fingerlings held in mesh cribs for 24 hr post-stocking.

low, leading to no significant differences among levels.

Blood plasma cortisol results were similar for the Vermont Lake trial, except that normal density fingerling transport had significantly higher ($P < 0.0001$) levels post-transport (Figure 2). Blood plasma chloride levels dropped significantly ($P < 0.0001$) post-transport, and little recovery was evident after 24 hr (Figure 2).

Over-winter survival: There was no survival advantage for the cribbed walleye. On Bergen Lake, 130 (32%) of the stocked cribbed walleye and 150 (36%) of the uncribbed walleye were caught at least once during electrofishing (Table 2). On Pocket Lake, 140 (13%) of the stocked cribbed walleye and 171 (15%) of the uncribbed walleye were caught at least once during electrofishing. The difference was not significant on either lake.

Walleye hauled at one-half density had significantly higher survival than those hauled at normal density in the Union Lake experiment ($P = 0.0394$). During electrofishing, 84 (8%) of the normal density walleye and 126 (12%) of the one-half density transported walleye were caught at least once (Table 1). The near failure of the Vermont Lake stocking left no replicate for this experiment. We did catch three walleye (2 one-half density, 1 normal density), but were unable to conduct population estimates.

During electrofishing, 10% of the walleye handled on Bergen Lake, 6% handled on Pocket Lake, and 5% handled on Union Lake did not have tags (Table 2). These fish could be the result of missed tagging, lost tags, or natural reproduction. There was no difference in mean length of tagged and untagged fish on any of the lakes (t-test, $P > 0.05$), and there is little historical evidence for natural reproduction in any of these lakes. Parsons et al. (1994) found no evidence of coded wire tag loss in walleye. Therefore, missed tagging at the pond was the likely cause. Difficult tagging conditions at the ponds prevented the use of a quality control device, which assures a tag has been correctly implanted. Because untagged walleye were likely stocked fish without a tag, they were included when population estimates were conducted.

Over-winter survival was high for each lake except Vermont Lake. The population estimates indicated over-winter survival of 99% on Bergen Lake, 63% on Pocket Lake, and 36% on Union Lake (Table 2; Figure 3). Given the significant difference in survival between the two lots on Union Lake, it is appropriate to calculate population estimates separately. The population estimate for the normal density transported fish indicated over-winter survival of 25%, while the population estimate for the one-half density transported fish indicated over-winter survival of 49%. To assign an over-winter survival estimate for Vermont Lake, we estimated catchability (q) for the Union Lake electrofishing. Overall electrofishing catch per unit effort (CPE) was 49.6/hr on Union Lake, and the population estimate was 792 walleye. Thus q = CPE/population estimate = 49.6/792 =0.0626. If we assume equal q, and since the electrofishing CPE was 1.4/hr on Vermont Lake, our population estimate for Vermont Lake is 22 walleye. If we divide this by 3,200 fingerlings stocked, we get 0.6% over-winter survival in Vermont Lake.

Figure 3 also includes results from a similar over-winter survival experiment on Round Lake (34 ha), Ottertail County (MDNR, unpublished data, 1986). In September 1985, 3,520 fingerlings averaging 125 mm were stocked. A modified Schnabel population estimate was conducted in June 1986 with nighttime AC electrofishing. The population estimate was 805, yielding an over-winter survival estimate of 23%. The results indicated a significant logistic regression between size at stocking and probability of over-winter survival ($P < 0.0001$, $R^2 = 0.1525$) where: $P(\text{Survival}) = 1/(1+e^{(11.32 - 0.0757*\text{size})})$.

Discussion

Cribbing the fish at stocking failed to improve over-winter survival. The blood chemistry results indicated that blood plasma

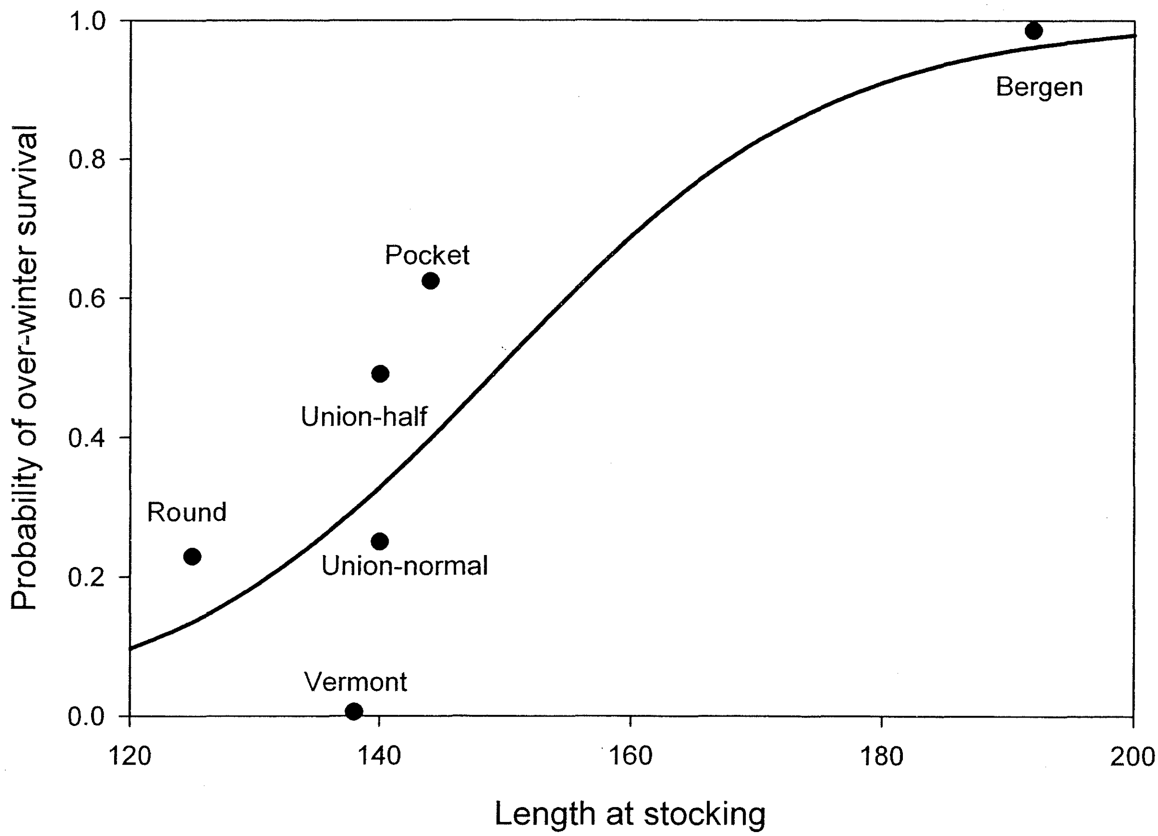

Figure 3. Relationship between the probability of over-winter survival and mean length (mm) of walleye fingerlings stocked in Bergen, Pocket, Union (for fingerlings hauled at normal (0.12 kg/l, 1.0 lb/gal) density and half density (0.06 kg/l, 0.5 lb/gal)), and Vermont lakes, 1996-1997.

cortisol levels were similar to baseline levels after 24 hours, but the blood plasma chloride levels were not. We captured more fish from the uncribbed group in both Bergen and Pocket lakes. It is possible that uncribbed fish swimming freely in the lake recovered from the handling stress differently from fish in the crib. We were unable to test for this effect. The manner in which the fingerlings were released from the cribs may also have been a factor. When we approached the crib to lower the sides and release the fish, some sought cover in the corners of the crib and had to be physically removed with a dip net. This may have caused additional stress. Unless a method can be designed where fish can be released from a crib without approaching the fish, there appears to be no value in holding stocked walleye fingerlings overnight.

The extremely high survival of the Bergen Lake walleye may be related to their large size at stocking (192 mm). Previous studies have indicated that survival of stocked walleye fingerlings can be related to size (Larscheid 1995; Parsons et al. 1994; Santucci and Wahl 1993). However, even the Pocket Lake and Union Lake survival rates were considerably higher than those previously reported in the literature. Lucchesi (1995) reported a maximum 15% over-winter survival rate for fingerlings in several South Dakota lakes. Only 3-6% of fingerlings stocked into East Okoboji Lake, Iowa, survived one year (Larscheid 1995). Additionally, Santucci and Wahl (1993) reported that 7% of medium-sized fingerlings (132-145 mm) and 31% of large fingerlings (186-216 mm) survived one year in an Illinois reservoir. Although Santucci and Wahl (1993) and Larscheid (1995) computed survival rates to the following fall, which subjects fish to an additional 3-4 months of mortality, it still does not fully explain the wide disparity.

There are several possible explanations for the higher survival in our study versus others reported in the literature. Iowa has expressed concerns about a buildup of carbon dioxide in their transport water, with its accompanying narcotic effect on their fingerlings (Forsberg et al. 1999). This was not a problem in this study. Our transport tanks were agitated and vented, and the pH of the water in west-central Minnesota is high enough (approximately 8.0) that free carbon dioxide in the water can not reach narcotic levels.

The transport times for our fingerlings were relatively short, ranging from 45-90 min. The time required for tagging added an additional 30-150 min to time spent in the transport tank. Our blood chemistry results showed a slight decline in blood plasma cortisol levels after transport in the Bergen and Pocket lake experiments. This may indicate the potential for stress recovery during hauling when hauling densities are low. Forsberg et al. (2001) found a similar pattern for blood plasma cortisol in walleye hauled at 0.06 kg/l (0.5 lb/gal) in Iowa. Their results showed blood plasma cortisol increased from baseline after tank loading, returned to baseline levels after a 5 hr haul, but increased significantly 2 hours after stocking.

All our lakes had relatively low resident walleye populations. Therefore, the stocked fingerlings in this study were not competing with a previous year class of walleye or with fingerling walleye already in the lake, either through natural reproduction, as was the case with South Dakota (Lucchesi 1995), or through fry or summer fingerling stockings as was the case in the Iowa study (Larscheid 1995). The success of stocking and the ultimate contribution of stocked fish to a fishery has been repeatedly linked to the presence of naturally produced fish for walleye (Parsons and Pereira, 2001; Li et al. 1996; LaJeone et al. 1992) and sauger *Stizostedeon canadense* (Heidinger and Brooks 1998).

If the significantly higher survival of fingerlings hauled at low density is in fact a true result, it could explain the very high survival by the Bergen Lake and Pocket Lake fish. Though not part of the hauling density experiment, the fingerlings for these stockings were hauled at densities < 0.05 kg/l.

In Minnesota, walleye stocking density is determined by a given weight of fingerlings per littoral (<5 m) ha of the receiving lake. Thus some fishery managers have expressed concerns that too few fish are stocked when large fingerlings are used. Bergen Lake fish averaged 192 mm long, which equates to about 15 fingerlings per kg. The fingerlings for the other three lakes were about 140 mm long, which equals about 44 fingerlings per kg. This means that if we stock a certain weight of fish in a lake, we would stock about 3 times more small fingerlings than large ones. The question then is does the survival advantage of the large fingerlings outweigh the numbers advantage of the small fingerlings? If we use only our two successful stockings of smaller fingerlings, the average survival was 46%, compared to 99% for the larger fingerlings. If, however, we include the 1% survival for the Vermont Lake stocking, the average survival for smaller fingerlings drops to 35%. Therefore, the survival advantage of the large fingerlings was roughly equal to the numbers advantage of the small fingerlings (Figure 3).

Although we were able to fit a significant logistic regression function between over-winter survival and size at stocking, there was a great deal of variation in our data. Numerous factors may have contributed to this including different water chemistry and weather conditions at the various rearing ponds, different resident predator communities in the stocked lakes, and different winter conditions experienced by the 1996 and 1997 stockings. Additional over-winter survival estimates should be conducted on these and other lakes to determine the relative importance of these variables and improve our ability to predict and improve overwinter survival of stocked walleye fingerlings.

Management Recommendations

Within the range of sizes used in this study, the survival advantage of larger fingerlings appears to be about equal to the numbers advantage of smaller fingerlings. Therefore, managers can maintain the use of a given weight of fish stocked by area, rather than being overly concerned about numbers. However, this study does not apply to fingerlings smaller than 60/kg or larger than 11/kg, and additional research, particularly with fingerlings from 150-180 mm, is warranted.

There was no advantage to holding fish in a crib prior to stocking. In fact, unless a quick, simple method for releasing the fish is developed, there may be a disadvantage due to re-stressing the fish during release.

Although there was no replicate, there did appear to be a survival advantage for fingerlings hauled at reduced density. Further research is necessary to determine the strength of this finding. In the meantime, harvest crews should be encouraged to utilize all available tank space and haul fingerlings at the lowest possible density. The potential survival advantage likely outweighs the additional personnel time and vehicle mileage necessary to accomplish this.

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