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Date July 25, 1991

TRANSPORT AND STOCKING STRESSES
ON JUVENILE STRIPED BASS

A Thesis

Presented for the

Master of Science Degree

The University of Tennessee, Knoxville

Jeffrey P. Durniak

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DEDICATION

To Walter and Phyllis Durniak

for a limitless supply of love and support.

Thank you, Mom and Dad.

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ABSTRACT

The effects of harvest, transport, and stocking stress on juvenile striped bass (Morone saxatilis) stocked into Kentucky Lake were assessed via field observations, laboratory handling, confinement and temperature change tests, and transport simulations. Although the majority of striped bass released into Kentucky Lake survived the stocking trip, an estimated 10% - 20% died due to the stocking procedures. Laboratory tests and transport simulations indicated that handling, especially during initial capture, was the most stressful component of the stocking procedure. When combined with handling, confinement and acute temperature change produced cumulative stress effects. The established procedure of transport in 1.0% NaCl solution greatly reduced stress and increased striped bass survival. Reduced handling appeared to further enhance striped bass survival. Recommended striped bass stocking procedures included maintenance of water quality in both rearing ponds and transport tanks, continued addition of salt to transport tanks to reduce the osmotic gradient between fish and water, and the use of less stressful handling methods during fish transfer.

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CHAPTER 1

INTRODUCTION

The striped bass (Morone saxatilis; Table 1) is a popular anadromous game fish which has been successfully introduced into many inland reservoirs (Axon and Whitehurst 1985). Most of these impoundments lack suitable habitat necessary for natural reproduction of the species, so sport fisheries are maintained on a "put-grow-take" basis through hatchery rearing and stocking of fingerlings (Stevens 1984).

As a cultured species the striped bass is often subject to stressful hatchery practices including handling and transport between rearing facilities and stocking sites. Fish may be exposed to substantial differences in water quality and temperatures during transfer from hatchery to stocking truck to reservoir release site. A combination of these usually sublethal stressors may contribute to acute or delayed mortality of stocked fish through mechanical injury (Kelly 1969; Murai et al. 1979), thermal shock (Carmichael et al. 1984a, 1984b), osmoregulatory failure (Tomasso et al. 1980; Carmichael et al. 1984b), increased susceptibility to disease (Reeves 1973; Long et al. 1977), or predation (Thompson and Tufts 1967; Stein et al. 1981). Recent surveys of striped bass culturists and managers have identified these problems as major areas of concern (Stevens 1984; Axon and Whitehurst 1985; Geiger and Parker 1985).

Table 1. Common and scientific names of fishes referred to in this document (After Robins 1980).

Common name	Scientific Name
American shad	*Alosa sapidissima*
Blue catfish	*Ictalurus furcatus*
Bluntnose minnow	*Pimephales notatus*
Channel catfish	*Ictalurus punctatus*
Chinook salmon	*Onchorynchus tschawytscha*
Flathead catfish	*Pylodictis olivaris*
Freshwater drum	*Aplodinotus grunniens*
Largemouth bass	*Micropterus salmoides*
Logperch	*Percina caprodes*
Muskellunge	*Esox masquinongy*
Northern pike	*Esox lucius*
Red drum	*Sciaenops ocellatus*
Redhorse	*Moxostoma* spp.
Skipjack herring	*Alosa chrysochloris*
Sockeye salmon	*Onchorynchus nerka*
Spotfin shiner	*Notropis spilopterus*
Spotted bass	*Micropterus punctulatus*
Striped bass	*Morone saxatilis*
White bass	*Morone chrysops*
White crappie	*Pomoxis annularis*
Yellow bass	*Morone mississippiensis*

The Tennessee Wildlife Resources Agency (TWRA) first introduced striped bass into state waters in 1958, when adult and yearling fish were stocked into Kentucky Lake (TWRA 1979). Populations of the popular sport fish were subsequently established in several Tennessee reservoirs after improvements in artificial spawning (Stevens 1966) and rearing techniques, and stocking of fingerlings rather than adults or fry became common (Jarman and Harper 1969; Braschler 1975). With further improvements in culture techniques (Bishop 1975) and the completion of Eagle Bend State Fish Hatchery in 1977, TWRA was able to develop a striped bass stocking program in eight state reservoirs. During the early 1980's, the stocking priority order was Kentucky, Percy Priest, Cherokee, Watts Bar, Tims Ford, Norris, Boone, and Old Hickory reservoirs (TWRA 1979).

Striped bass harvest, transport, and stocking follow standardized procedures at Eagle Bend Hatchery. Drawdown of rearing ponds begins the afternoon prior to harvest. Piped inflow of cold water (14-18 C) from the Norris tailwater is also introduced at the collection basin to maintain dissolved oxygen levels and to lower water temperatures as the pond volume is reduced. The next morning, the pond volume is further cut to confine striped bass fingerlings to the concrete collection basin. They are seined from the basin, placed in buckets containing a known weight of water, weighed in the buckets, and then emptied into a three-compartment stocking truck containing chilled river water and 10 g/L NaCl. Several ounces of furacin were traditionally placed in each tank as a bacteriostat, but this practice was stopped soon after this study when the Food and Drug Administration (FDA) would no longer approve its use on food fish (Mike Smith, Eagle Bend Hatchery, personal communication). Fish are usually hauled at a density of 60 g/L to the stocking site, where tanks are tempered with reservoir water for 15-30 min until temperature differences between tanks and reservoir are minimal. If a small sample of fish show no signs of stress after stocking, the load is then dip-netted into the reservoir.

Kentucky Lake, a 64,000 hectare mainstream reservoir on the Tennessee River, had been stocked annually since the development of the state reservoir striped bass program. At the time of this study (1983), roughly 540,000 fingerlings per year were scheduled for release into Kentucky Lake. This represented approximately 44% of the total yearly fingerling production by TWRA at all striped bass rearing facilities during that time. Despite those substantial stockings, Kentucky Lake was the only one of the eight reservoirs that failed to support a successful striped bass fishery (Doug Peterson, TWRA, personal communication). Over one-half of Kentucky Lake's annual fingerling allotment was produced at Eagle Bend State Fish Hatchery in Clinton, TN, and those fish were transported by truck for about six hours to reach the stocking site almost 400 km away. Stress due to harvest from hatchery ponds, prolonged transport, and release methods were suspected as contributing to substantial loss of stocked fingerlings and subsequent low harvest rates by anglers (TWRA, unpublished creel data). The objectives of this study were: 1) to assess the impacts of transport and stocking methods on mortality of newly introduced striped bass fingerlings in Kentucky Lake; 2) to identify those aspects of harvest, transport, and stocking that affect fingerling survival; and 3) to determine the most effective transport and stocking procedures for striped bass fingerlings introduced to Tennessee reservoirs.

CHAPTER 2

LITERATURE REVIEW

Most of the early literature regarding fish transportation methods is fairly generalized, with reference mainly to those species that have been intensively cultured for some time. Particular emphasis has been placed on salmonid species. Fish transport and stocking methods are outlined in Norris et al. (1960), U.S. Fish and Wildlife Service (1978), and Piper et al. (1982), while recommended salmonid transportation techniques are summarized in Leitritz and Lewis (1980). Early attempts at transport of striped bass were documented by Schoumacher (1969) and and Powell (1970). Recommended hauling and stocking procedures for intensively cultured striped bass fingerlings were presented in Jarmann and Harper (1969), Bonn (1976), Tomasso et al. (1980), Lewis and Heidinger (1981), and briefly in Piper et al. (1982). A survey of striped bass transport methods in use was presented by Geiger and Parker (1985).

More recent attention has been given to transportation of both salmonids and nonsalmonids, as more fish species have been intensively cultured and/or stocked over a wider range. The attention has increased in response to concern over the stressful aspects of transport and stocking and their effects on survival of released fish. Again, research on salmonids has been most intensive (Thompson and Tufts 1967; Long et al. 1977; Mazeaud et al. 1977; Specker and Shreck 1980; Barton and Peter 1982; Barton et al. 1986; Nikinmaa et al. 1983; Maule et al. 1988). Transportation and stocking effects have been studied for American shad (Chittenden 1971a), largemouth bass (Carmichael et al. 1984b), northern pike, muskellunge, and their hybrid (Miles et al. 1974; Mathur and Wahl 1989), freshwater drum (Johnson and Metcalf 1982), red drum (Caldwell and Tomasso 1986; Robertson et al. 1988), and hybrid striped bass (Tomasso et al. 1980).

Those studies have shown that different aspects of transportation and stocking can be stressful or even fatal to fish, and their effects are often cumulative in nature (Barton et al. 1986). Stressful components include handling, especially during the initial disturbance (Wedemeyer 1972; Miles et al.1974; Pickering et al. 1982; Maule et al. 1988; Robertson et al. 1988), crowding and confinement (Strange and Shreck 1980; Schreck 1981; Redding and Schreck 1983), water quality changes among the rearing areas, stocking tanks, and receiving waters, and reduced water quality in transport tanks. Changes in water quality often include altered temperatures (Barton and Peter 1982; Mathur and Wahl 1989), increased ammonia levels (Carmichael et al. 1984a), decreased dissolved oxygen and increased carbon dioxide levels (Piper et al. 1982), and osmotic or ionic gradients between hauling media and receiving waters (Carmichael et al. 1984b).

Documentation of the effects of transportation stress on juvenile striped bass is limited. Tomasso et al. (1980) transported age-1 striped bass X white bass hybrids (hybrids) for 2 h with and without salt and anesthetic. The most effective transport method was anesthetization with 50 mg/L tricaine methanesulfonate (MS-222) prior to capture and then hauling in a combination of 25 mg/L MS-222 and 10 g/L NaCl. A very recent study (Mazik et al. 1991) showed that 10 g/L NaCl added to the hauling medium reduced physiological stress and increased survival of larger juvenile striped bass (mean weight, 72 g) transported for 5 h. Handling and transport losses of fingerling striped bass, which are typically under 100 mm total length (TL) when stocked into reservoirs, are a concern among both managers and culturists (Axon and Whitehurst 1985; Geiger and Parker 1985), but there are apparently no studies that quantify the magnitude of the problem.

Although striped bass transport studies are limited, much work has been done on individual factors that contribute to transport stress. Handling appears to be a major stressor to juvenile striped bass. Tomasso et al. (1980) and Davis et al. (1982) showed that handling juvenile hybrids and striped bass caused significant physiological stress. Otwell and Merriner (1975) observed juvenile mortality of 12-20% due to handling and confinement. Dunning et al. (1989) observed short-term handling losses of 16-17% of adult fish seined and trawled from the Hudson River.

Temperature effects on survival and growth of striped bass have been well documented. Water temperatures preferred by juveniles appear to be in the range of 24-26 C, while upper avoidance temperatures are usually in the range of 32-34 C (Meldrim and Gift 1971; Meldrim et al. 1974; Hall et al. 1983; Coutant et al. 1984). Optimum growth temperatures were found to be much lower in a fluctuating thermal environment (14-22 C) than at a constant temperature (24 C; Cox and Coutant 1981). Temperature acclimation of juvenile striped bass is relatively rapid when compared to other species, and acclimation to higher temperatures is faster than acclimation to lower temperatures (Davies 1973). Acclimation temperature strongly influences juvenile striped bass response to temperature change (Davies 1973; Cox 1978) and other stressors, such as net confinemnet (Davis and Parker 1990). Rapid temperature changes of 8 C or greater can be stressful or fatal to fingerlings (Meldrim and Gift 1971; Otwell and Merriner 1975).

Water hardness and salinity may affect survival of juvenile striped bass (Tagatz 1962; Otwell and Merriner 1975). Grizzle et al. (1985, 1990) found that addition of

$CaCl_2$ to soft-water hatchery ponds and holding troughs increased postharvest survival of juvenile striped bass. NaCl additions, when not accompanied by calcium additions, actually decreased postharvest survival. Those results, together with the findings of Tomasso et al. (1980) and Mazik et al. (1991) that NaCl additions were beneficial in higher harness waters, indicate that striped bass survival may be improved where osmotic and ionic gradients between the fish and their environment are minimized.

Reduced water quality can be stressful to juvenile striped bass. Chittenden (1971b) found that oxygen levels below 3 mg/l affected behavior of juvenile striped bass. Hazel et al. (1971) found 96 h median lethal concentrations of 1.5-2.8 mg/L un-ionized ammonia for juvenile striped bass. Tolerance appeared to be higher for fish in brackish water.

In many studies on transportation effects on fish, physiological responses have often been used as indices of the magnitude and duration of sublethal stress (Wedemeyer and Yasutake 1977). Mazeaud et al. (1977) outlined the relationship between stress and the generalized response pattern that many, but not all (Schreck 1981), stressors induce in fish. This generalized stress response appears to be common to all vertebrates and has been termed the General Adaptation Syndrome by Selye (1950). The response can be broken down into primary and secondary effects. Primary effects are the neuroendocrine reactions to the stress, which trigger rapid increases in plasma levels of catecholamines and corticosteroids. Release of those hormones in turn causes secondary effects on metabolism and osmoregulation. Increased plasma glucose levels and altered electrolyte balance are two of those secondary effects. If stress is of sufficient magnitude or duration, the ultimate response of the organism is death (Elliott 1981). Plasma glucose, plasma chloride, and survival were all used as indicators of transport-related stress in the present study.

CHAPTER 3

METHODS

Stocking Evaluation

During August 1983, an actual harvest, transport, and stocking regimen for Kentucky Lake striped bass fingerlings was followed from pond drawdown through reservoir release on August 3 to evaluate potential stressors to the fingerlings. Water quality of the rearing pond, transport tanks, and the reservoir was assessed. Water temperature, pH, and dissolved oxygen (DO) levels were measured 1 m below the surface of the hatchery rearing pond (Pond #M3) at 0730 hours for five days prior to drawdown and at 4-h intervals during the 24 h preceding harvest. Hauling medium temperature, pH, total ammonia, and DO were recorded prior to fish loading and at roughly hourly intervals during transport. Water temperature, DO, and pH were also assessed at the stocking site, the Spring Branch boat ramp on the Duck River near Waverly, TN. Temperature was measured with either a hand-held mercury thermometer or with the temperature probe on a Yellow Springs Instruments (YSI) Model 57 meter. Dissolved oxygen was measured with the DO meter; however, a Hach chemical kit (modified Winkler method) was used for the hauling tank samples when the DO probe failed. Total hardness was determined for water samples taken from the rearing pond, hauling tanks, and the reservoir release site, using a Hach chemical kit; pH was assessed using a Hach portable pH meter. Total ammonia levels were measured in the hauling tanks using a Hach colorimeter. Un-ionized ammonia levels were determined using Table 1 and the equation for calculating F (the fraction of aqueous ammonia present in un-ionized form) in Emerson et al. (1975).

Post-stocking survival of striped bass was assessed via seining and electrofishing. Using a 6.1 m X 1.2 m X 3.2 mm mesh seine, three quarter-hauls were taken at the boat ramp release site 2 h after stocking, and striped bass caught were counted. A boat-mounted electrofishing unit was used to sample fish populations in the 3 km river reach around the boat ramp at 3, 26, and 32 h following stocking. All striped bass captured were counted and released. All potential striped bass predators captured were either preserved whole in a 10% formalin solution or had their stomachs dissected, examined, and the contents preserved.

At the Kentucky Lake stocking, approximately 400 striped bass fingerlings were put in a fine-meshed 2 m X 1 m X 1 m live cage and anchored 10 m from shore in 1.5 m deep water to further assess short-term survival. At 24 and 48 h after stocking, reaction of confined fish to the introduction of pelleted feed was recorded and mortalities were picked from the net. After two days, individuals from a sample of surviving fish were measured for total length before the remaining striped bass were released.

Predation of stocked striped bass was also evaluated by gillnetting. At an upstream and a downstream site, each about 250 m from the boat ramp, a 45.7 m X 1.8 m X 3.8 cm bar mesh net was attached to the near shore and set across channel. Nets were set 2.5 h post-stocking, fished and reset 2.5 h later, and fished again after 5 h. At 1400 hours the next day, both nets were set at the downstream location, with one net extending from each shore toward midchannel. Stomachs from all potential predators captured were dissected, examined, and preserved. In the laboratory, stomach contents were identified to the lowest possible taxon and counted.

Analysis of forage conditions for stocked striped bass were adapted from TWRA pre-stock sampling procedures (TWRA 1979). After sundown on the day of stocking, two 5-m plankton tows with a 22.9-cm diameter, 60-mesh plankton net and two Ekman dredge samples were taken adjacent to the boat ramp. Rose Bengal stain was added to the dredge samples to facilitate later detection of benthic invertebrates. At a shallow bar 250 m upstream, two quarter hauls with the 6.1 m seine were taken. Plankton, dredge, and fish samples were preserved and brought back to the laboratory. Dredge samples were poured through a series of standard brass sieves (1.5, 3, and 6 openings per square cm) and the organisms were picked from the sieve mesh. All invertebrates found in the dredge and plankton samples were identified to the lowest practical taxon and counted with the aid of a 40X dissecting microscope. Fish from the seine hauls were identified to species, measured for total length and counted.

On August 17, 1983, water quality changes experienced by striped bass fingerlings were again assessed during a TWRA stocking trip to Tims Ford Reservoir, approximately 250 km away from the hatchery. Prior to loading of fingerlings and then just prior to reservoir stocking 5 h later, water temperature and pH of the hauling tanks were measured. Water samples were taken at those two times in 500 mL bottles containing 0.4 mL of concentrated sulfuric acid, and samples were placed on ice. Reservoir water temperature at time of stocking was also recorded. Water samples were returned to the lab and sample ammonia nitrogen levels were measured using the direct Nesslerization method (APHA 1971).

1983 Laboratory Trials

On August 2, 1983, approximately 2,800 striped bass fingerlings were transported in fresh water from Eagle Bend Hatchery to Oak Ridge National Laboratory (ORNL) using a 1.8 m X 1.2 m X 0.6 m dual compartment, fiberglass hauling tank mounted in the back of a pickup truck. Flow-through laboratory tanks were fed by well-water (pH, 7.4; total alkalinity, 100 mg/L; total harness, 120 mg/L; calcium, 30 mg/L), through inflow pipes with separate valves for chilled and heated water that enabled temperature control. Trip survivors were placed in a 3.05-m circular holding tank with water temperature equal to the hauling temperature (approximately 20 C). Two days after hauling, tank temperature was increased by 2 C per day for five days. On August 9, fish were graded and smaller individuals were placed in a separate holding tank. The next day both tanks were started on a daily temperature cycle of 27 to 31 C to imitate the temperature regime measured in the Eagle Bend Hatchery rearing ponds. Fish were fed pelleted trout chow *ad libitum* once daily. During August 12-13, all fish were anesthetized with MS-222 and cold branded. A straightened paper clip was held in liquid nitrogen and then placed on either the left or right side of the fish, just below the spiny dorsal fin, to produce a small bar mark. Marked striped bass were returned to the stock tanks.

Trial 1

During the last week of August, test tanks were set up to assess the effects of handling, confinement, and temperature change on striped bass fingerlings. For each of three tests, six 1.2-m tall, wedge-shaped, wooden-framed, polypropylene mesh holding cages were placed into a 1.8 m diameter test tank; the cages occupied the entire tank volume. A 0.5-m standpipe was placed in the tank to give a cage water volume of 0.077 m^3, and water temperature of the flow-through system was set at 30 C. Fingerlings (mean TL, 75 mm) from the stock tank were then randomly distributed among the six cages until each contained 30 fish. After 24 h mortality was recorded and fingerling striped bass were removed from or added to test cages so that 25 fish per cage remained.

The caged fish were then subjected to one of four temperature treatments (Table 2). In Treatment 1 (No Tempering), three cages were transferred from the 30 C tank to a second tank set at 15 C, the water temperature of the stocking truck compartments at the start of the Kentucky Lake trip. After 6 h, the cages in the cold water tank were removed and replaced into the original 30 C tank. This water temperature was close to that recorded at the Kentucky Lake stocking site. Treatment 2 (Simulation) followed the same regimen, except that after caged fish were transferred, the second tank water temperature was increased to 25 C to simulate the gradually increasing thermal regime in the stocking truck recorded during the Kentucky Lake trip. Those three cages were then transferred from the second tank (25 C) to the original tank (30 C). In Treatment 3 (Slow Tempering), caged fish moved to the second tank were then subjected to a 2 C/h temperature increase to 30 C before

Table 2. Handling, confinement, and temperature treatments applied to juvenile striped bass held at Oak Ridge National Laboratory during summer, 1983.

Trial	Fish Size (mm TL)	Initial Handling	Confinement Unit	Temperature Treatment	Acclimation Temp (C)	Treatment - Test Temp (C)	Regime Time Held (h)	- Recovery Temp (C)
1	75	Net	Cage	No Tempering	30	15	6	30
				Simulation	30	15	6	30
				Slow (2C/h)	30	15	6	30
				No Change	30	30	6	30
2		Net	Cage	Simulation	30	15	6	30 (Preda)
				Slow (2C/h)	30	15	6	30 (Preda)
3	79	Net	Cage	No Change	30	30	24	30
				No Tempering	30	25	24	30
				No Tempering	30	20	24	30
				No Tempering	30	15	24	30
4	80	Net	Cage	Simulation	30	30	24	30
				Slow (2C/h)	30	25	24	30
				Slow (2C/h)	30	20	24	30
				Slow (2C/h)	30	15	24	30
5		None	Tank	No Change	29	29	24	29
				Rapid	29	15	24	29
6	90	Net	Tank	No Change	29	29	24	29
				Immediate	29	15	24	29

transfer back to the original tank. In Treatment 4 (No Change), cages were handled in like manner, but water temperatures were held constant between transfers. Treatment 4 was repeated three times to serve as temperature controls for the three other treatments. Water levels were maintained at 0.5 m and DO levels were checked periodically during all cage tests. Mortality in all cages was recorded 24 h after the last transfer back to the original tanks. Survivors were placed in a recovery tank.

Trial 2

The Simulation and Slow Tempering treatments were repeated with new striped bass, using predation rate as an index of sublethal stress (Coutant et al. 1974). Differentially marked striped bass were used for each of the two treatments within a test. Instead of transferring cages back to the original tank for 24 h, lots of 20 fish from each treatment were dip-netted simultaneously into each of six 30 C tanks containing five largemouth bass. Predators were removed from the tanks after 15 min, and surviving striped bass were removed and examined for marks 24 h later.

Trial 3

Temperature effects were further assessed in another series of tests. Fingerlings (mean TL = 79 mm) from the stock tank were randomly distributed via dip net among eight cages, two in each of four test tanks set at 30, 25, 20, and 15 C, until there were 30 fish per cage. After 24 h in the test tanks, cages were transferred to four other tanks set at 30 C. Striped bass mortalities were recorded 24 h after each transfer. Total length and weight of survivors were recorded.

Trial 4

The effects of reduced handling and gradual temperature change were evaluated. Two cages were placed in four tanks set at 30 C and each cage received 30 fingerlings (mean TL, 80 mm). Mortality was recorded 24 h later, then water temperatures were reduced stepwise at 2 C/h until lower limits of 30, 25, 20, and 15 C, respectively, were reached by the tanks. After 24 h at those temperature limits, mortalities were recorded. Temperatures were then increased at 2 C/h back to 30 Cand mortalities were recorded 24 h later.

Trial 5

The effect of rapid temperature change without handling was then tested on uncaged fish. Remaining fingerlings (N = 176) in the stock tank (27-31 C daily fluctuation, 29 C at test) were randomly dip-netted among four test tanks of equal water temperature. Mortality was recorded 24 h later. In two tanks water temperature was then dropped suddenly by pulling the standpipe, draining to a level of 5 cm, and then introducing chilled (13 C) water. Tank water temperature fell to 15 C within 10 min, then inflow was adjusted to 15 C. After 24 h at this temperature, the standpipe was again pulled and warm water introduced to bring the final temperature to 29 C within 15 min. Striped bass in the other two tanks were also subjected to drawdown and refilling, but with no change from the original water temperature of 29 C. Fingerling mortalities in the four tanks were recorded 24 h after each refilling.

Trial 6

The effects of temperature and handling were tested on uncaged fish. Survivors (mean TL, 90 mm) in the four tanks from Trial 5 were acclimated to 29 C for two weeks. Fish from the two tanks that had not been subjected to the wide temperature change in Trial 5 were dip-netted into two tanks set at 15 C. Striped bass in the other two tanks were transferred to two tanks set at 29 C. After 24 h fish were dip-netted back into the four original tanks (now set at 30 C) and feeding behavior and survival were monitored for 96 h.

Physiology Trials

A second shipment of striped bass was transported from Eagle Bend Hatchery to ORNL on August 22, 1983. They were held in a 1.5-m diameter circular tank with continuous flow and were acclimated to 26 C water temperature. Fish were fed pelleted trout chow *ad libitum* daily, with a supplement of fathead minnows several times per week. Surviving fish were distributed among additional tanks as they grew. Fish were starved for 24 h prior to experiments.

During July 1984, responses of juvenile striped bass to transport and stocking were tested using the truck-mounted dual compartment, fiberglass hauling tank. An aerator was added to each compartment, which then received 330 L of chilled (14-15 C) well-water and 33 g (100 mg/L) of the bacteriostat Furacin. All striped bass from a stock tank were equally divided between the two compartments via random selection and netting, and were held for a 6-h "transport" simulation of the Kentucky Lake trip before release into lab recovery tanks set at 26 C. The stocking truck was driven on paved roads for approximately 15 min each hour, and 3.8 g of ammonium chloride were added to each compartment after each of the first 5 h of confinement. Compartments were slowly drained and tempered with 30 C lab water for 5-10 min prior to release of fish.

Striped bass were subjected to one of three transport and stocking treatments. Treatment 1 (FW + NET) was transport in a compartment containing fresh water, followed by dip-netting into the recovery tanks. Treatment 2 (CHEM + NET) was transport in a 1.0% NaCl solution containing 25 mg/L of the anesthetic MS-222, followed by dip-netting to the recovery tank. Treatment 3 (CHEM + QR) also used the chemical additions to the hauling medium, but employed a different release method. Instead of dip-netting, fish were quick-released through a 15-cm diameter drain valve into a 164-L plastic garbage can. Striped bass were then poured from the can into the recovery tank.

Three separate transport trials were run (FW + NET versus CHEM + QR, FW + NET versus CHEM + NET, CHEM + NET versus CHEM + QR) so that each treatment was replicated. Compartment sample sizes and loading densities for the three trials were 37 fish (24 g/L), 30 fish (12 g/L), and 15 fish (12 g/L), respectively. Water temperature, pH, dissolved oxygen, and conductivity were monitored in the compartments using a Hydrolab unit, and total ammonia concentrations were measured with an Orion meter and ammonia probe. Water quality in the circular recovery tanks was recorded just before fish were stocked.

Physiological responses of striped bass to the treatments were assessed using the sample collection and analysis methods of Wedemeyer and Yasutake (1977) and Tisa et al. (1983). Blood samples were taken from previously undisturbed fish immediately prior to a transport trial. Remaining fish were then loaded and hauled. Blood was sampled 1 h after release of fish into recovery tanks and then periodically over the next 14 days (typically, days 1, 2, 7, and 14). Samples were also taken periodically from undisturbed tanks of fish to serve as additional controls. Five-fish samples were netted and anesthetized in 200 mg/L MS-222, and blood was immediately collected from the caudal artery using Vacutainer tubes containg EDTA. The fish samples were processed within 5 min. Blood samples were immediately centrifuged and the plasma drawn off and frozen in sealed vials. Plasma sample sizes occasionally dropped to four or three fish due to difficulty in obtaining blood from an individual fish and to treatment mortalities, which reduced the number of fish available at later sampling dates.

Plasma glucose was used as the indicator of short-term metabolic stress and plasma chloride was used to evaluate osmoregulatory dysfunction (Mazeaud et al. 1977). Glucose was measured using enzymatic assays (Sigma Chemical Company, St. Louis, MO) and chloride was determined through titration with 0.02 N mercuric nitrate solution. Two separate chloride tests were run on each plasma sample and the results averaged for the final chloride concentration.

1984 Transport Simulations

Fingerling striped bass harvested from Eagle Bend Hatchery ponds during August and September 1984 were subjected to transport simulations. During regular hatchery pond harvest operations, the dual compartment hauling tank on the pickup truck was filled with hatchery water. Groups of 3-5 striped bass were randomly dipnetted from the loaded hatchery truck into one of the two compartments or into an aerated bucket, until all three groups contained about 100 fish. Individuals in the bucket were measured for total length in mm, weighed to the nearest 0.1 g, and returned to the hatchery truck. Fish in the hauling compartments were driven for approximately 45 min to ORNL and were subjected to the simulation used previously for juvenile striped bass (5.25 additional h confinement, Furacin and ammonium chloride additions, transport 15 min/h). Water quality was again monitored in the transport compartments and checked in the recovery tanks.

The transport treatments tested included the three used previously (FW + NET, CHEM + NET, CHEM + QR) plus three new regimes: transport in fresh water and quick release (FW + QR), transport in 1.0% NaCl solution and netting (NaCl + NET), and transport in 1.0% NaCl solution and quick release (NaCl + QR). Striped bass were stocked into flow-through recovery tanks set at 26 C. Mortalities were recorded daily for 14 days before survivors were counted, measured, and weighed. Seven separate trials comparing two treatments per trial were conducted (Table 3). Trial 7 was conducted on surviving fish from Trials 1-3 that had been placed in a lab tank and acclimated to 26 C for at least 20 days.

Table 3. Information on the fish, hauling media, and release methods used to assess survival of striped bass fingerlings in response to simulated transport during summer, 1984.

Trial	Date	Fish Source	Length (mm)	Truck Tank	Density (g/L)	Hauling Medium	Release Method
1	7/12	Pond R11	54	A	0.4	Fresh water	Net
				B	0.4	Fresh water	Quick release
2	7/17	Pond R10	45	A	0.2	Fresh water	Net
				B	0.2	NaCl, MS-222	Quick release
3	7/18	Pond R7	41	A	0.2	Fresh water	Net
				B	0.2	NaCl, MS-222	Net
4	7/30	Pond M2	46	A	0.3	NaCl	Net
				B	0.3	NaCl, MS-222	Quick release
5	8/1	Pond M5	50	A	0.3	NaCl	Net
				B	0.3	NaCl, MS-222	Quick release
6	9/1	Pond R1	60	A	0.6	NaCl	Quick release
				B	0.6	NaCl, MS-222	Quick release
7	9/7	Survivors	72	A	0.9	NaCl	Quick release
		Trials1-3		B	0.9	NaCl, MS-222	Quick release

Data Analysis

Data sets generated during 1983 and 1984 were analyzed using appropriate statistical tests in the SAS (1982) software package. A significance level of P = 0.05 was assigned to all tests unless indicated otherwise. For 1983 laboratory trials, percent mortality among treatments was analyzed using the FUNCAT or PROBIT procedures.

For each of the three physiology trials, differences in blood plasma constituents among treatment and control groups within a day were identified via one-way analysis of variance and a multiple range test on log-transformed data, using the GLM procedure and either the DUNCAN (equal N) or LSMEANS (unequal N) options. Glucose and chloride sample means among all control groups were tested similarly. Differences between treatment groups lacking a daily control were evaluated with the TTEST program. The effects of fish length, weight, and condition on plasma glucose and chloride levels were tested with regression analysis (REG).

The FUNCAT procedure was again used to evaluate percent survival of striped bass fingerlings among treatment groups in the 1984 transport trials. Relationships among survival, fish size (total length at start), and hauling media conditions (total and un-ionized ammonia concentrations, pH, initial and ending temperature, temperature change) were investigated with correlation analysis (CORR).

CHAPTER 4

RESULTS

Reservoir Striped Bass Stocking

On August 3, 1983, approximately 48,750 striped bass fingerlings averaging 2.6 g were harvested from Eagle Bend Hatchery pond #M3, loaded into a three-compartment stocking truck at 60 g/L, transported for 6 h, and stocked into Kentucky Lake at the Spring Branch access on the Duck River. Substantial changes in water temperature were recorded during harvest, transport, and stocking. Prior to drawdown, pond surface temperatures ranged from 27 C in the morning to 31 C in late afternoon. During pond drawdown water temperature dropped from 30 to 22 C over a 10-h period. Fingerlings harvested from the 22 C pond water were placed in 15 C hauling water, which then warmed to 23 C during the 6-h trip as air temperatures reached 38 C. Upon arrival, fish were tempered with 30 C lake water for 5 min, which raised the hauling water temperature to 25 C, before being dip-netted into the lake (Figure 1).

Other water quality parameters measured in the stocking truck compartments varied during striped bass transport. Ammonia nitrogen concentrations increased from less than 1 mg/l before loading to over 9 mg/L (0.17 mg/L un-ionized

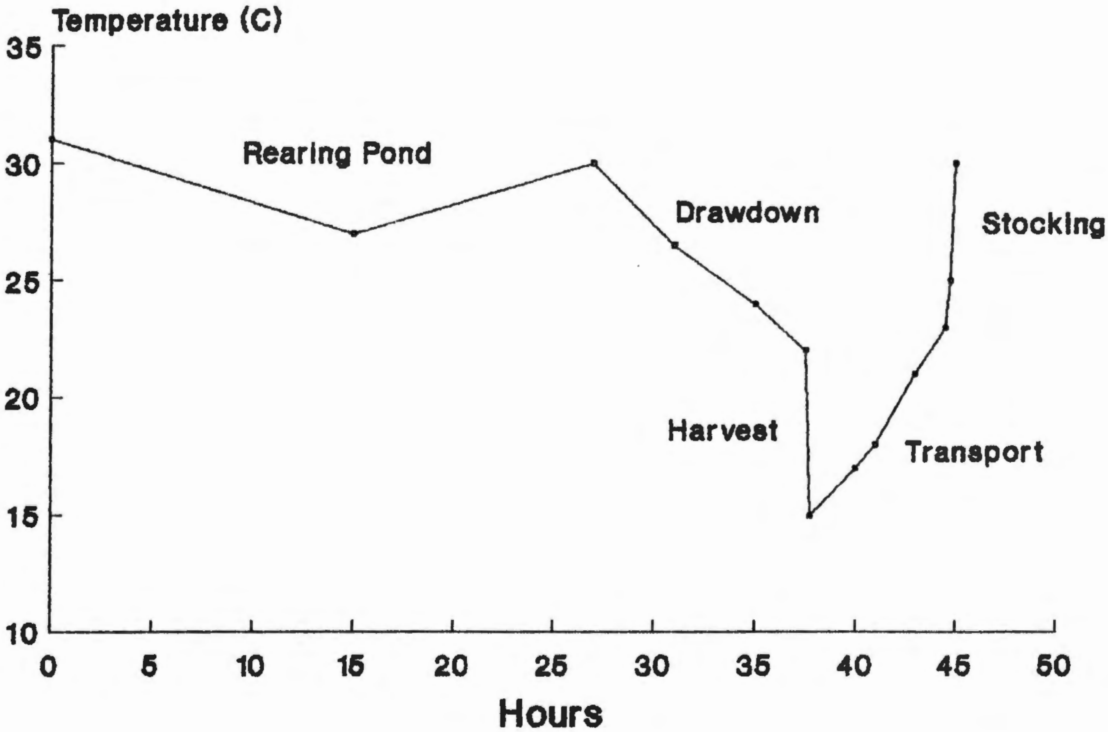

Figure 1. Water temperatures (C) encountered by fingerling striped bass in Eagle Bend Hatchery Pond M3 prior to and during pond drawdown, in hatchery truck transport tanks during a 6-h trip to Kentucky Lake, and at the reservoir release site during stocking on August 3, 1983.

ammonia) by the end of the trip. Dissolved oxygen concentrations fell from 9 mg/L to 7 mg/L, while pH rose slightly from 7.2 to 7.6 by the end of the trip.

Water quality monitoring of the Tims Ford stocking trip two weeks later substantiated the Kentucky Lake findings. Water temperature in the hauling tanks rose steadily from 15.5 to 21 C, pH increased slightly from 7.1 to 7.2, and ammonia nitrogen levels rose to approximately 12-14 mg/L (up to 0.10 mg/L un-ionized ammonia). Striped bass were tempered with reservoir water and then stocked into 28.8 C surface temperatures.

Fingerlings stocked into Kentucky Lake appeared healthy and dispersed rapidly from the stocking site. No obvious mortalities were observed immediately after release. Seining the Spring Branch boat ramp one hour after stocking produced only 26 dead and 14 live striped bass. Two hours post-stocking, electrofishing produced about 50 fingerlings in a 300-m reach of shoreline immediately downstream from the ramp. Fifteen fingerlings were also observed along 100 m of shoreline on the opposite side of the river, about 150 m across from the ramp. Further sampling over the next 36 h produced only two fingerlings, which were taken at the boat ramp on the night of August 4.

Caged fingerlings exhibited good survival over 48 h and apparent normal behavior soon after stocking. Of the estimated 400 striped bass stocked into the cage, observed mortalities one and two days post-stocking were 58 and 12 fish, respectively. Precise survival figures could not be calculated because turtles had chewed several holes in the mesh bottom of the cage one day after stocking and an unknown number of fish may have escaped. After one day, caged fingerlings actively fed on trout chow cast into the pen, and the next day approximately 300 healthy fingerlings were released from the cage. A sample of fish from the cage averaged 58 mm TL (N=93, SE=0.15).

Predation on striped bass fingerlings at the stocking site appeared to be confined to the first several hours post-stocking. Skipjack herring, largemouth bass, channel, blue, and flathead catfish, and one striped bass caught soon after stocking had newly stocked fingerlings in their stomachs (Table 4). Of those guts containing striped bass, most held from one to three fingerlings. However, one skipjack herring did contain 14 striped bass. Most of the predators containing striped bass were caught downstream rather than upstream from the stocking site. Sampling during late evening and again the day after stocking failed to produce evidence of continued predation on fingerlings near the release site (Table 5).

Some forage appeared to be available to newly stocked striped bass. Plankton and benthos sample concentrations were 228 and 62,285 organisms/m^3, respectively. Plankton samples were numerically dominated by emerging mayfly nymphs

Table 4. Predation of newly stocked striped bass by Kentucky Lake resident fishes within five hours after stocking, based on the catch from one hour of electrofishing and five net-hours of gillnetting within 0.5 km of the August 3, 1983, stocking site on the Duck River.

Species	Length Range (mm)	Number Caught	Number With Striped Bass	Maximum Per Gut
Skipjack herring	270-380	29	9	14
Largemouth bass	255-370	6	1	4
Channel, Blue, Flathead catfish	280-480	6	2	5
Striped bass	212	1	1	2
Yellow bass	195-205	4	0	
White crappie	220	1	0	

Table 5. Predation of newly stocked striped bass by Kentucky Lake resident fishes between 5 and 32 hours post-stocking, based on the catch from two hours of electrofishing effort and 15 net-hours of gillnetting within 3 km of the August 3, 1983, stocking site on the Duck River.

Species	Length Range (mm)	Number Caught	Number Containing Striped Bass
Skipjack herring	270-410	14	0
Largemouth bass	130-350	15	0
Spotted bass	180-240	5	0
Channel, blue and flathead catfish	300-360	4	0
Yellow bass	115-210	5	0
White crappie	150-230	3	0

(63%) and cladocerans (29%). Dipteran (chironomid) larvae, copepods, and a larval cyprinid accounted for the rest of the plankton sample. Dredge samples were dominated by aquatic oligochaetes (85%), with chironomid larvae (8%), mayfly nymphs (4%), nematodes, and cladocerans also identified.

The seine hauls at the upstream sand bar during the evening of August 3 produced 49 fish representing 8 different species (Table 6). Bluntnose minnows (24) and spotfin shiners (8) were most abundant, with shad (Dorosoma spp.) absent from the catch. Two newly stocked striped bass fingerlings were also captured.

1983 Laboratory Trials

Trials 1 and 2

Even without a change in water temperature, dip-netting fingerling striped bass between the stock tank and test cages resulted in substantial mortality after 24 h. Mortality among the 18 test cages averaged 10% (Table 7). Analysis of pooled cage data by tank showed a significant effect due to handling and/or confinement (PROC FUNCAT; intercept different from zero; P=.0001;).

The analysis showed a significant treatment effect as well (P = .0001). Striped bass mortality was over 10 times higher in Treatment 1, where fish were subjected to an instantaneous temperature change of 15 C, than in the other

Table 6. Total number and length range of fish captured in two quarter hauls of a 6.1 m X 3.2 mm seine taken after sunset near the Spring Branch access on Kentucky Lake, August 3, 1983.

Taxa (mm)	Number Caught	Length Range
White crappie	6	96-105
White bass	2	91-105
Yellow bass	5	105-148
Striped bass	2	47-58
Redhorse spp.	1	133
Logperch	1	50
Spotfin shiner	8	23-67
Bluntnose minnow	24	27-55

Table 7. Mortality of striped bass fingerlings during 24 h cage acclimation and 24 h after cage transfers among four different temperature treatments. No Change - cage transfers between tanks set at 30 C acclimation temperature; No Tempering - instantaneous transfers from 30 C to 15 C for 6 h, back to 30 C; Simulation - 30 C to 15 C (6 h), increase at 1 C/h to 25 C, transfer back to 30 C; Slow Tempering - 30 C to 15 C (6 h), increase at 2 C/h to 30 C, transfer to 30 C.

Test	Temperature Treatment	Cage	Acclim Mort (%) Cage	Acclim Mort (%) Treatment	Test Mort (%) Cage	Test Mort (%) Treatment
1	No Tempering	1	0		96.0	
		2	0		88.0	
		3	6.7	2.2	56.0	80.0
	No Change	1	0		0	
		2	3.3		0	
		3	6.7	3.3	20.0	6.7
2	Simulation	1	6.7		0	
		2	3.3		0	
		3	16.5	8.9	12.0	4.0
	No Change	1	20.0		0	
		2	26.6		4.0	
		3	6.7	17.8	4.0	2.7
3	Slow Tempering	1	3.3		0	
		2	23.3		4.0	
		3	10.0	12.2	0	1.3
	No Change	1	23.3		0	
		2	13.3		0	
		3	10.0	15.6	0	0
	Grand Mean		10.0			
	Standard Error		0.5			

five treatments (Table 7). Subsequent analysis on the dataset after omitting Treatment 1 values showed no significant differences in mortality among the Simulation, Slow Tempering, and No Change temperature treatments. Predation tests also failed to show a difference between the Simulation and Slow Tempering treatments (X^2; $P > 0.05$). During those tests, however, overall predation rates were extremely low due to the reluctance of the largemouth bass to feed (Table 8).

Trials 3 and 4

In Trial 3, mortality was significantly different among the four temperature treatments. Mortality of caged striped bass subjected to intantaneous temperature changes appeared to increase as a function of the degree of change (Table 9). Fish acclimated to 30 C and then transferred to 25 C for 24 h exhibited mortality almost three times the rate for fish handled without a temperature change. This higher rate then doubled and tripled, respectively, in the two tests with progressively greater temperature drops. The data resembled a dose/response relationship, but the relationship could not be quantified by probit analysis ($P > 0.5$).

The temperature-dependent trend observed in Trial 3 was not repeated in Trial 4. Over the same range of water temperatures, striped bass survival did not appear to be affected by gradual temperature change prior to cage

Table 8. Survival of fingerling striped bass (N=20) to 15 min of largemouth bass predation following one of three temperature treatments to caged fingerlings. Fish from two treatments were simultaneously stocked into each tank of 5 predators. No Change - water temperature held constant between transfers; Simulation - water temperatures simulated Kentucky Lake hauling regimen; Slow Tempering - water temperatures changed at 2 C/h until receining temperatur reached, then cage transfer. Temperature treatments were conducted over the range of 15 C to 30 C.

Test	Replicate	Treatment	
		No Change	Simulation
1	1	15	16
	2	18	17
	3	13	9
		No Change	Slow Tempering
2	1	18	18
	2	15	11
	3	20	19

Table 9. Cumulative mortality of caged striped bass fingerlings transferred from 30 C to cooler water temperatures and held for 24 hours prior to transfer back to original water temperatures.

Test	Temperature Change (C)	Cage	Cumulative Mortality (%) 24 Hours	48 Hours
1	0	1	3.3	10.0
		2	10.0	13.3
		Mean	6.7	11.7
2	5	1	16.7	30.0
		2	23.3	36.7
		Mean	20.0	33.3
3	10	1	16.7	63.3
		2	26.7	73.3
		Mean	21.7	68.3
4	15	1	73.3	93.3
		2	66.7	100.0
		Mean	70.0	96.7

transfer (Table 10). Initial handling and confinement contributed the most mortality to the experiment and averaged 18% (range, 3.3-36.7%).

Trials 5 and 6

In Trial 5, mortality of uncaged striped bass 24 h after dip-netting into the test tanks ranged from 0 to 4.6%. No mortalities were recorded in either the test or control tanks when water levels were reduced and temperatures rapidly decreased and later increased (Table 11). Test fish subjected to the 15 C change were slightly more sluggish than controls, but still fed actively immediately after both the decrease and increase in tank temperatures.

Two weeks later, when the same fish were dip-netted from 29 C tanks to either 29 C or 15 C tanks, a slight but nonsignificant difference in mortality was observed (PROC FUNCAT; $P = 0.34$). No fish transferred between tanks of equal temperature died, while 4.8% of those subjected to temperature change expired during the 4 days following the test (Table 12). Normal feeding behavior was disrupted in both treatment groups immediately following dip-netting and continued for two days. More individuals in the temperature-change treatment refused to feed initially and took longer to recover that behavior than those in the constant temperature group.

Table 10. Cumulative mortality of caged striped bass fingerlings 24 h after confinement, then after water temperatures were reduced by 2 C/h to lower limits, held for 24 hours, increased by 2 C/h back to starting temperatures of 30 C, and held for another 24 hours.

Test	Temperature Change (C)	Cage	Cumulative Mortality (%) 24 h after confinement	24 h after decrease	24 h after increase
1	0	1	16.7	20.0	20.0
		2	23.3	26.7	26.7
		Mean	20.0	23.3	23.3
2	5	1	10.0	13.3	13.3
		2	10.0	10.0	10.0
		Mean	10.0	11.7	11.7
3	10	1	20.0	20.0	20.0
		2	23.3	23.3	23.3
		Mean	21.7	21.7	21.7
4	15	1	36.7	36.7	40.0
		2	3.3	3.3	3.3
		Mean	20.0	20.0	21.5

Table 11. Mortality of unconfined fingerling striped bass (N=44), acclimated to a 27 C - 31 C fluctuating temperature regime, subjected to tank drawdown and refilling with either ambient (29 C) or chilled (15 C) water. Mortalities recorded 24 h after netting into the tanks and 24 h after each refilling.

Treatment	Start Temp (C)	Initial Mortality (number)	Test Temp (C)	Mortality (number)	End Temp (C)	Mortality (number)
No Change						
Tank 1	29	2	29	0	29	0
Tank 2	29	0	29	0	29	0
Rapid Change						
Tank 1	29	2	15	0	29	0
Tank 2	29	1	15	0	29	0

Table 12. Mortality of fingerling striped bass, acclimated to 29 C, 24 h after dipnetting to either 15 C or 29 C tanks and 96 h after dip-netting back to tanks set at 29 C.

Treatment	N	Test Temp	Mortality (number)	End Temp	Mortality (number)
No Change					
Tank 1	42	29	0	29	0
Tank 2	42	29	0	29	0
Instantan					
Tank 1	41	15	0	29	1
Tank 2	43	15	0	29	3

Transport Stress Physiology

Fish used in Trial 1 transportation were in poor condition and appeared to suffer from a bacterial infection, presumably Aeromonas. Almost 65% (24/37) of the fish hauled in fresh water and netted died within one day after transport, compared with only one mortality in the chemical and quick release treatment. Mean plasma glucose was not significantly different among the three groups immediately after hauling, but treatment levels were significantly elevated over controls at one and two days post-haul (Figure 2). The freshwater group was also significantly higher than the other treatment at one day post-haul. Plasma glucose in fish hauled in chemicals and quick released appeared to recover by 7 days.

In the same trial, plasma chloride levels dropped in response to transport. Compared to controls, both treatment groups had significantly depressed plasma chloride concentrations just after hauling (Figure 3). In the freshwater group, chloride continued to decline and stayed at about 65 meq/L for two days post-haul before all survivors had been bled. Striped bass hauled in chemicals and quick released showed slight recovery after 24 hours, a secondary decline at 48 hours, maintenance of depressed levels at 7 days, and recovery by 14 days.

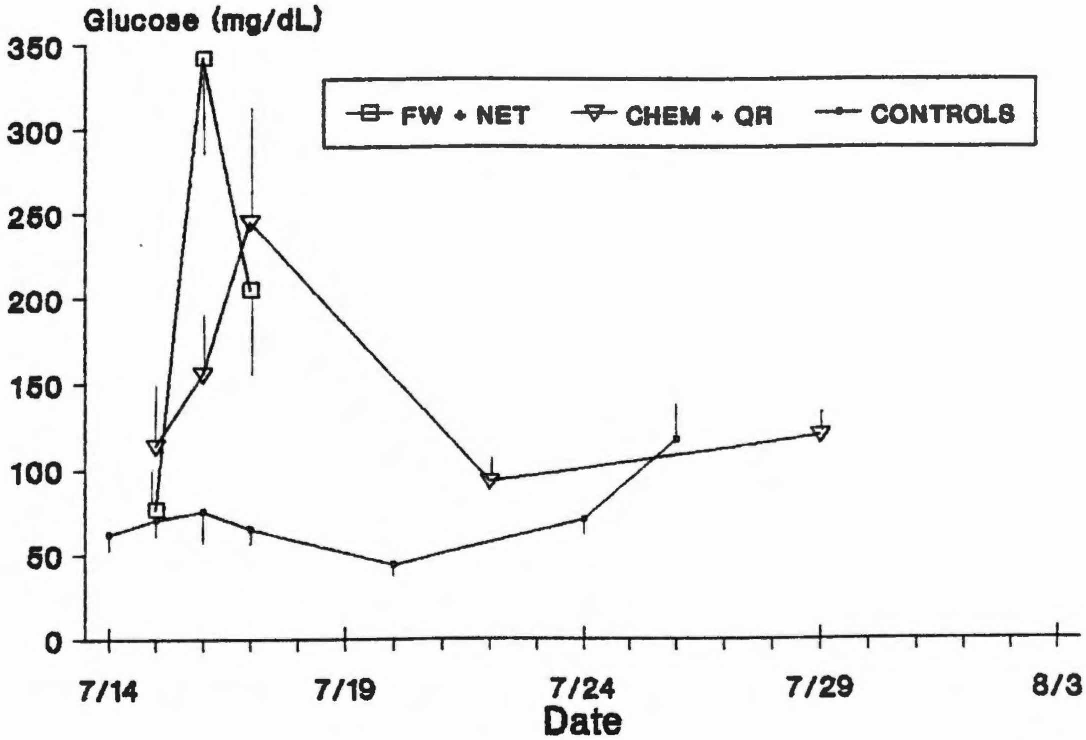

Figure 2. Mean blood plasma glucose levels of juvenile striped bass, acclimated to 26 C, before and after a simulated 6-h transport and stocking into recovery tanks on July 15, 1984. Treatments were transport in fresh water and net release (FW + NET) or transport in a 1.0% NaCl solution with 25 mg/l of tricaine methanesulfonate, followed by quick release (CHEM + QR).

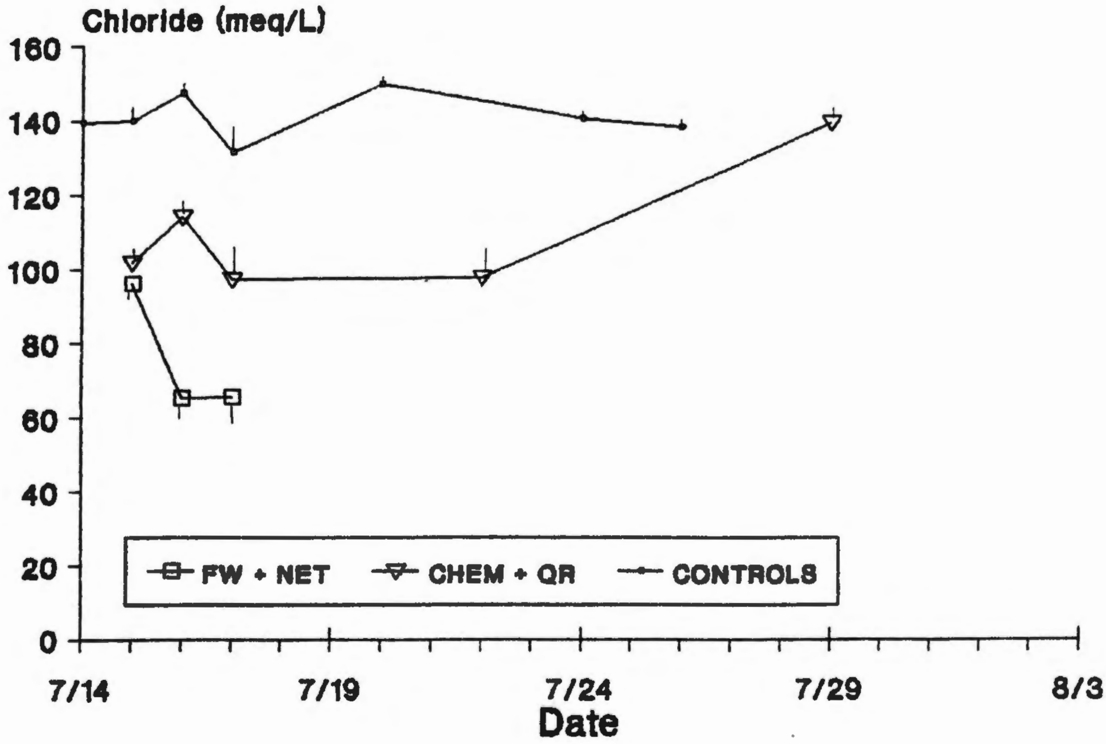

Figure 3. Mean blood plasma chloride levels of juvenile striped bass, acclimated to 26 C, before and after a simulated 6-h transport and release into recovery tanks on July 15, 1984. Treatments were transport in fresh water and net release (FW + NET) or transport in a 1.0% NaCl solution with 25 mg/l of tricaine methanesulfonate, followed by quick release (CHEM + QR).

Fish used in Trial 2 appeared to be in much better health than those from the previous trial. Still, striped bass hauled in fresh water and netted into recovery tanks suffered higher mortality (7/30) than those hauled in chemicals and net-released (3/30). Glucose levels rose immediately after transport and showed only a slight decline over the next two days (Figure 4). There were no significant differences between treatments, although means for the chemical treatment group were slightly but consistently lower than those for the freshwater group.

Both treatment groups showed significantly depressed plasma chloride levels immediately after transport, with the chemical treatment group mean also significantly lower than that for the freshwater group (Figure 5). Chloride concentrations fell slowly over the next two days in both treatments, with no significant differences between their means. Chloride levels of striped bass hauled in chemicals appeared near recovery after 7 days, while levels in the freshwater group were still significantly depressed after 14 days.

In Trial 3, both treatment groups exhibited rising glucose levels (Figure 6) and falling chloride levels (Figure 7) in response to transport stress. Although there were no significant differences between treatment means, fish that were quick released always had lower mean plasma glucose levels and slightly higher chloride concentrations.

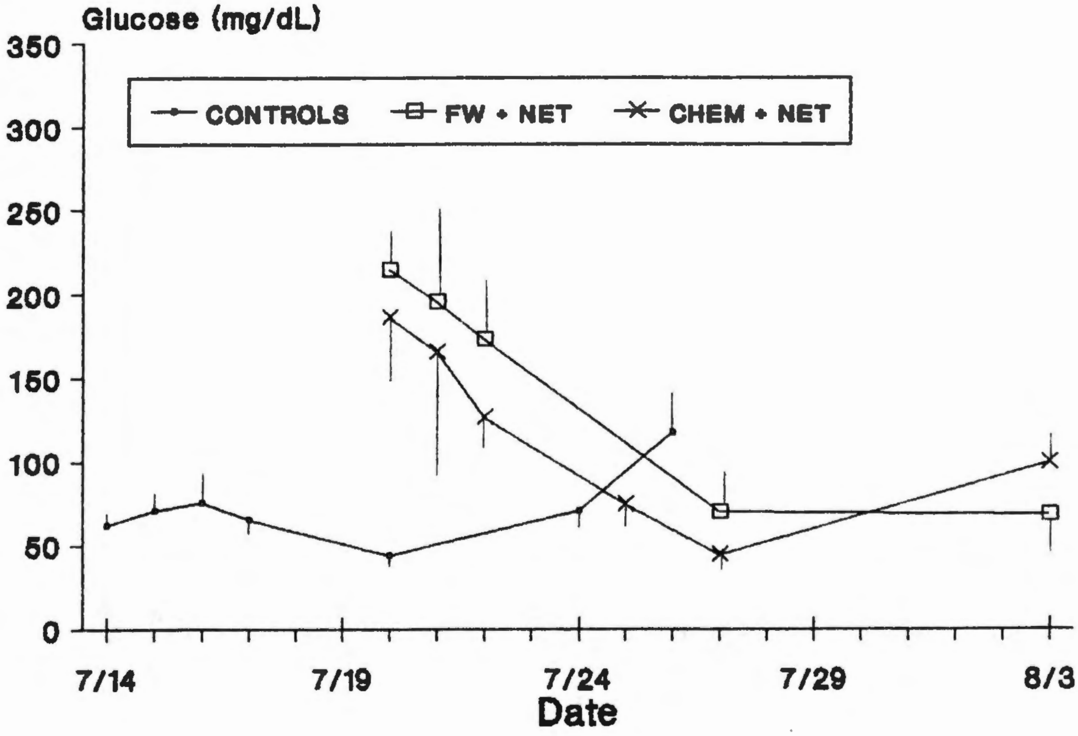

Figure 4. Mean blood plasma glucose levels of juvenile striped bass, acclimated to 26 C, before and after a simulated 6-h transport and release into recovery tanks on July 20, 1984. Treatments were transport in fresh water and net release (FW + NET) or transport in a 1.0% NaCl solution with 25 mg/l of tricaine methanesulfonate, followed by net release (CHEM + QR).

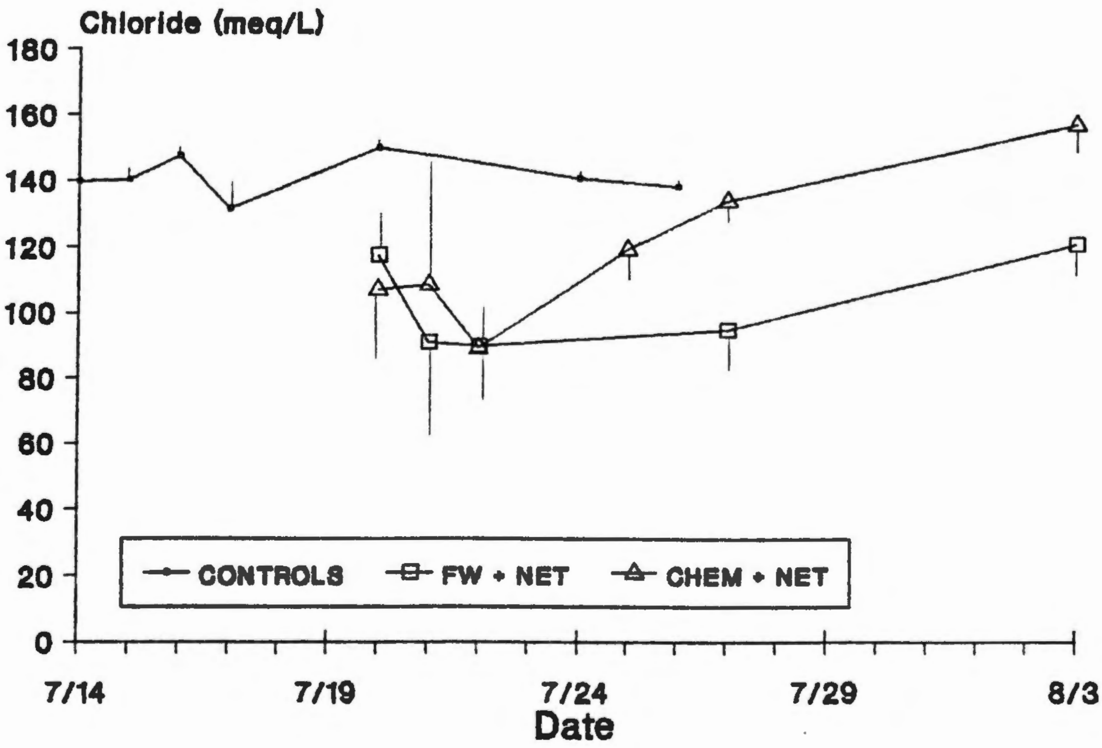

Figure 5. Mean blood plasma chloride levels of juvenile striped bass, acclimated to 26 C, before and after a simulated 6-h transport and release into recovery tanks on July 20, 1984. Treatments were transport in fresh water and net release (FW + NET) or transport in a 1.0% NaCl solution with 25 mg/l of tricaine methanesulfonate, followed by net release (CHEM + QR).

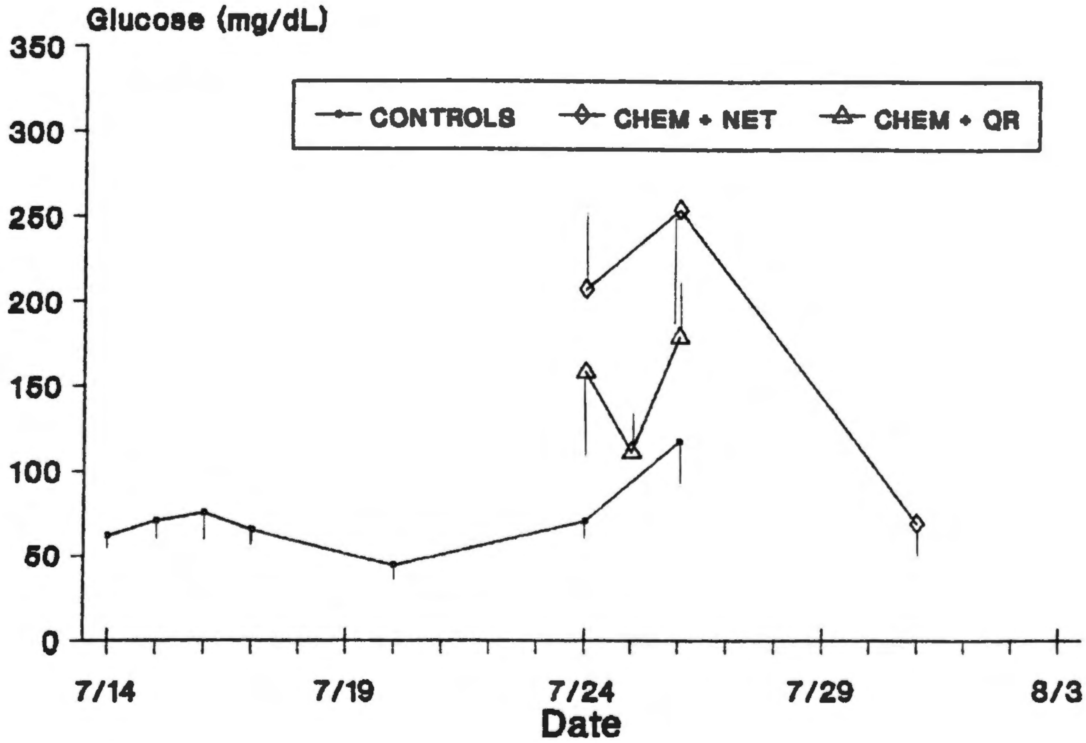

Figure 6. Mean blood plasma glucose levels of juvenile striped bass, acclimated to 26 C, before and after a simulated 6-h transport and release into recovery tanks on July 24, 1984. Treatments were transport in a 1.0% NaCl solution with 25 mg/l of tricaine methanesulfonate, followed by either net release (CHEM + NET) or quick release (CHEM + QR).

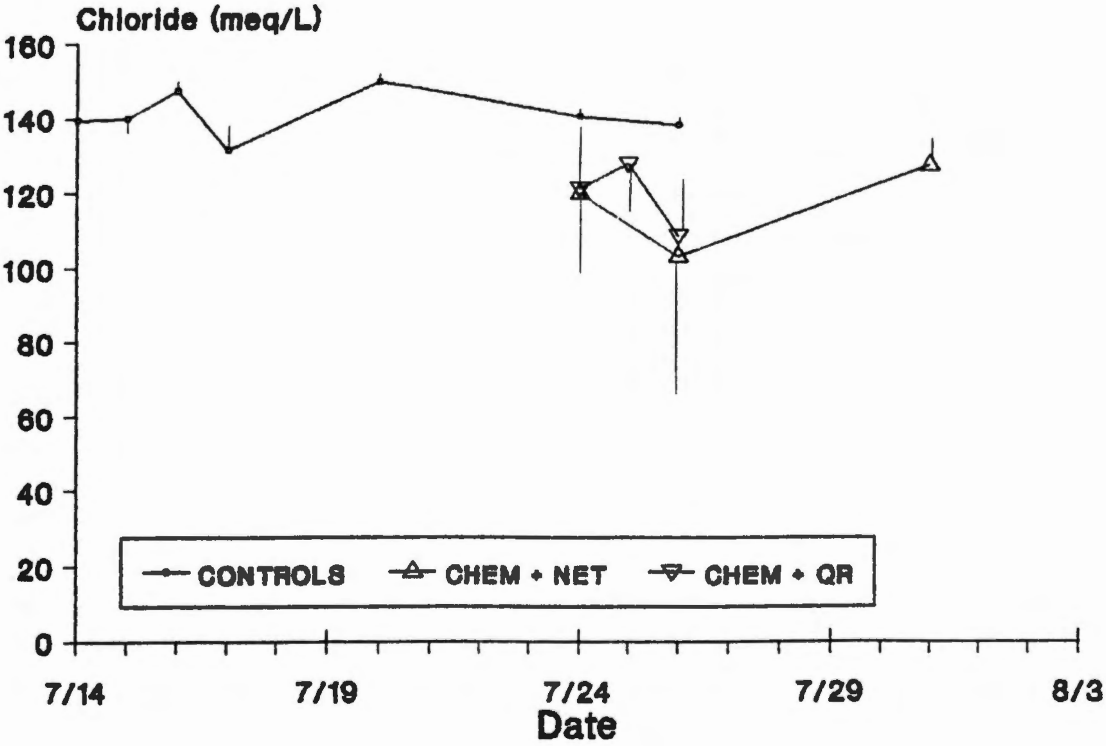

Figure 7. Mean blood plasma chloride levels of juvenile striped bass, acclimated to 26 C, before and after a simulated 6-h transport and release into recovery tanks on July 24, 1984. Treatments were transport in a 1.0% NaCl solution with 25 mg/l of tricaine methanesulfonate, followed by either net release (CHEM + NET) or quick release (CHEM + QR).

The limited data suggested recovery at one day post-haul, a secondary stress response the next day, and recovery within a week following transport. Mortality in this trial was negligible: one fish died in the chemical and quick release treatment, and none in the chemical and net treatment.

Plasma glucose and chloride concentrations were not related to fish length, weight, or condition. In Trial 3, the control mean for plasma glucose at two days post-haul (July 26) was elevated for unknown reasons, possibly an unidentified disturbance near the tank. This control value was significantly higher (PROC GLM; DUNCAN) than remaining control means for all three trials, and was considered an outlier for purposes of comparison.

<u>1984 Transport Simulations</u>

Survival over a 14 day post-transport period ranged from 3 to 100% among the treatments, with considerable variability among trials. In Trial 1, short-term survival was high in both the FW + NET and FW + QR treatments (Figure 8), but the net-released group showed additional mortalities after the eighth day to finish with significantly lower overall survival.

In Trials 2 and 3, the groups hauled in fresh water and netted showed high first-day mortality, 20 and 66%, respectively, and again finished with significantly lower survival than their respective paired treatment. In fact,

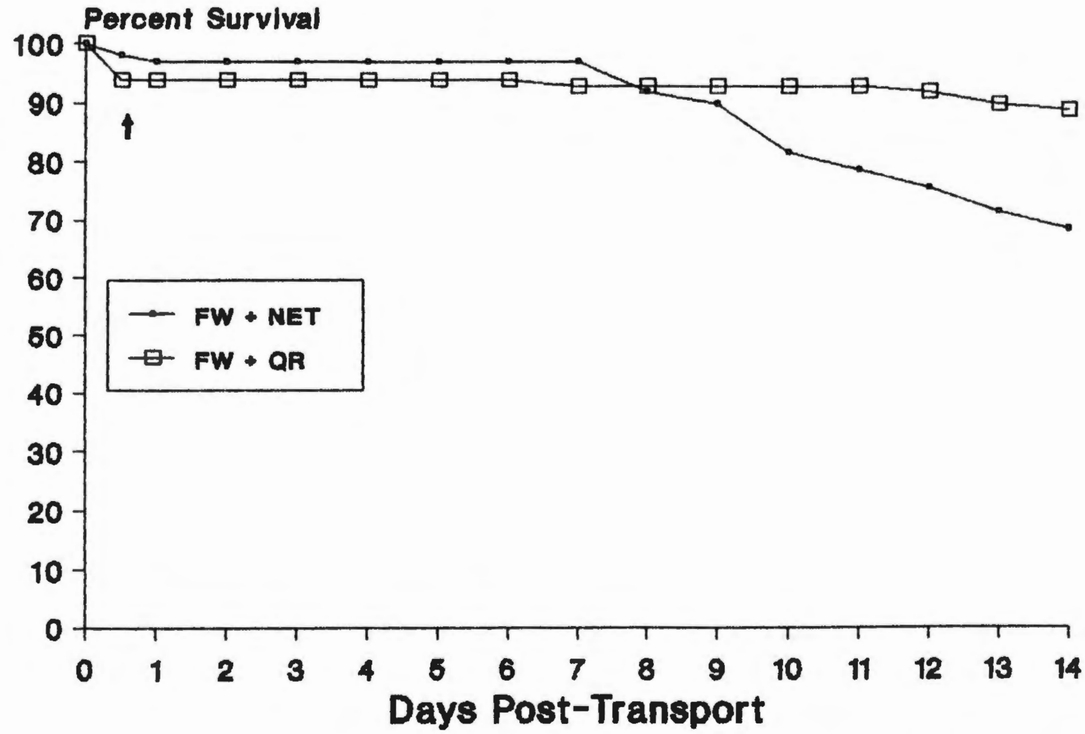

Figure 8. Two-week survival of fingerling striped bass after pond harvest on July 12, 1984 and a 6-h simulated transport and stocking into circular recovery tanks set at 26 C. Treatments were transport in fresh water and either net release (FW + NET; N = 98) or quick release (FW + QR; N = 97). Arrow indicates survival immediately after release from transport tanks into recovery tanks.

final survival figures for the FW + NET treatments in Trial 2 (36%) and Trial 3 (4%) were the lowest recorded for the 14 groups tested (Figures 9, 10).

Trial 4 also showed high immediate mortality in the two treatments, despite the fact that sodium chloride was used in both hauling compartments (Figure 11). First-day mortality was higher in the netted group (32%) than in the quick-released group (19%). Survival remained constant for both treatments between days two and eight, then showed a greater decline in the netted group over the last six days. Final survival for that treatment (46%) was significantly lower than that for the quick-released sample (71%).

Survival equaled or exceeded 93% for all treatments within Trials 5, 6, and 7, and was highest in the CHEM + QR treatment (Figures 12, 13, 14). Alternate treatments produced equally high striped bass survival at least over the first week following transport. Thereafter, mortality increased slightly in the NaCl + NET group within Trial 5 and in the NaCl + QR treatment of Trial 7. For all trials, many of the mortalities observed during the second week after transport showed symptoms of infection by Flexibacter columnaris.

Some of the variablity in survival among trials appeared to be related to fish size. Treatment survival was positively related to mean length of striped bass at the start of the trial (PROC CORR; PROC REG; $P = 0.04$; $R^2 = 0.30$).

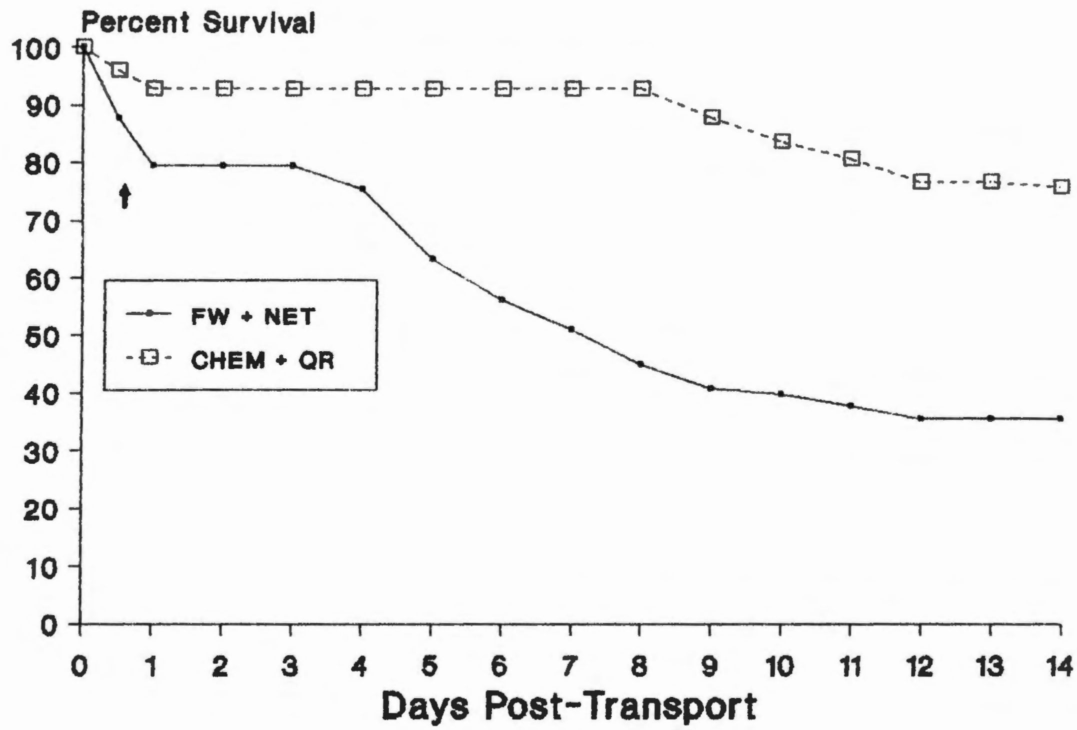

Figure 9. Two-week survival of fingerling striped bass after pond harvest on July 17, 1984 and a 6-h simulated transport and stocking into circular recovery tanks set at 26 C. Treatments were transport in fresh water and net release (FW + NET; N = 98) or transport in a 1.0% NaCl solution with 25 mg/l tricaine methanesulfonate, followed by quick release (CHEM + QR; N = 99). Arrow indicates survival immediately after release from transport tanks into recovery tanks.

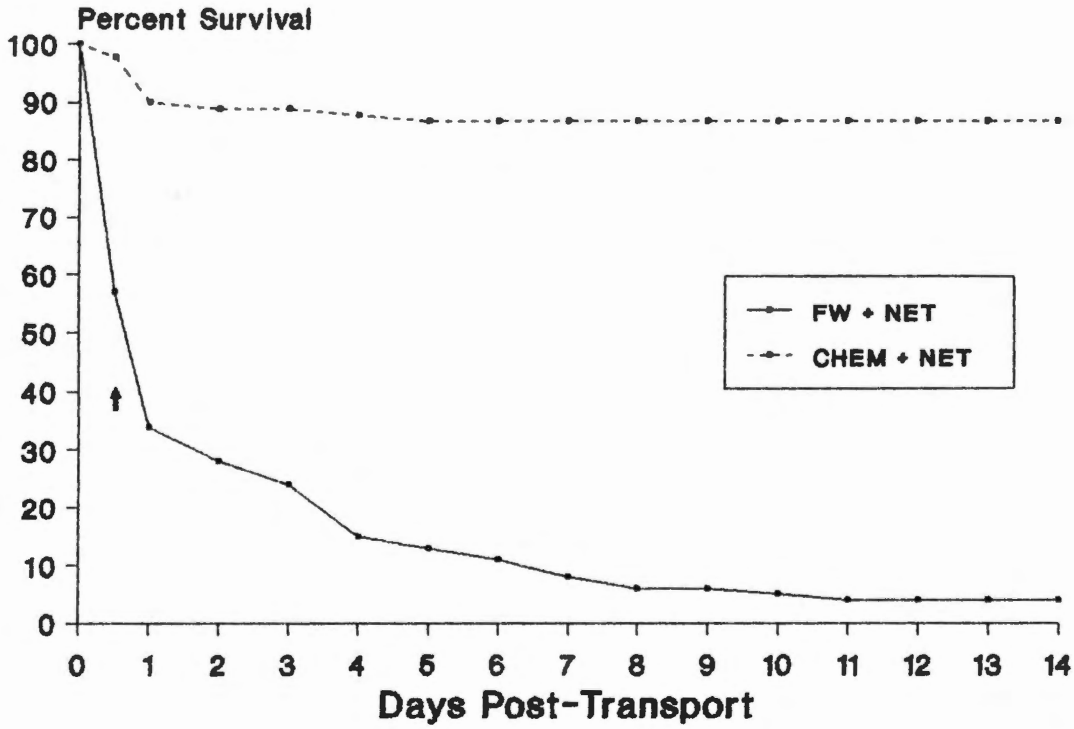

Figure 10. Two-week survival of fingerling striped bass after pond harvest on July 18, 1984 and a 6-h simulated transport and stocking into circular recovery tanks set at 26 C. Treatments were transport in fresh water and net release (FW + NET; N = 100) or transport in a 1.0% NaCl solution with 25 mg/l tricaine methanesulfonate, followed by net release (CHEM + NET; N = 89). Arrow indicates survival immediately after release from transport tanks into recovery tanks.

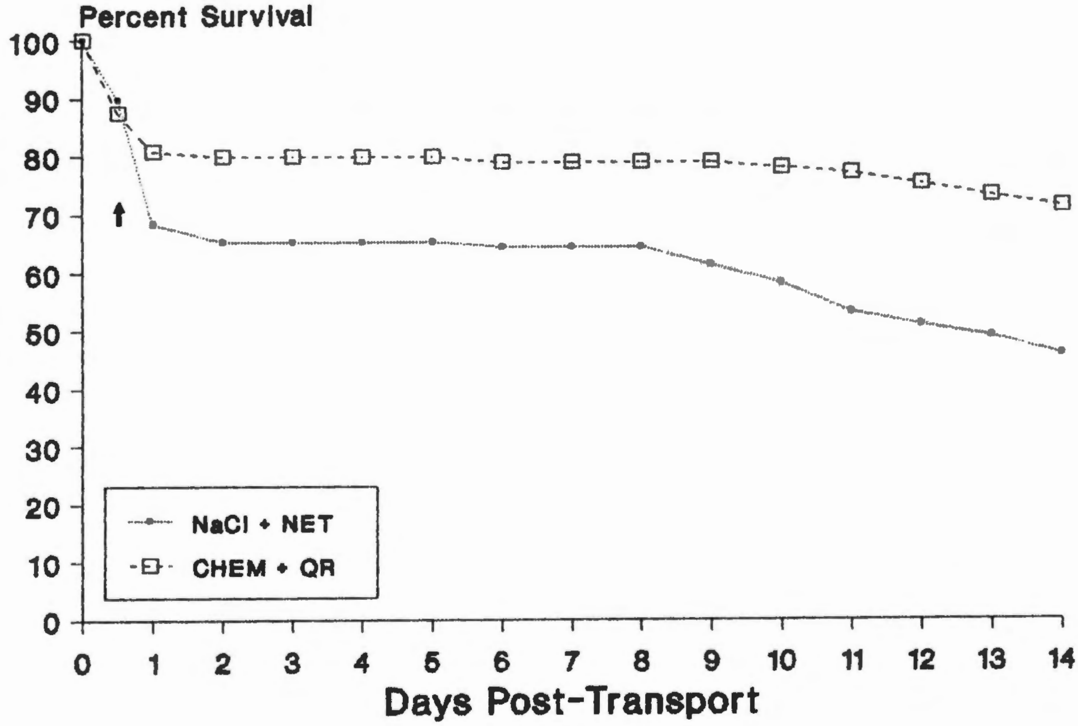

Figure 11. Two-week survival of fingerling striped bass after pond harvest on July 30, 1984 and a 6-h simulated transport and stocking into circular recovery tanks set at 26 C. Treatments were transport in a 1.0% NaCl solution and net release (NaCl + NET; N = 98) or transport in a 1.0% NaCl solution with 25 mg/l tricaine methanesulfonate, followed by quick release (CHEM + QR; N = 104). Arrow indicates survival immediately after release from transport tanks into recovery tanks.

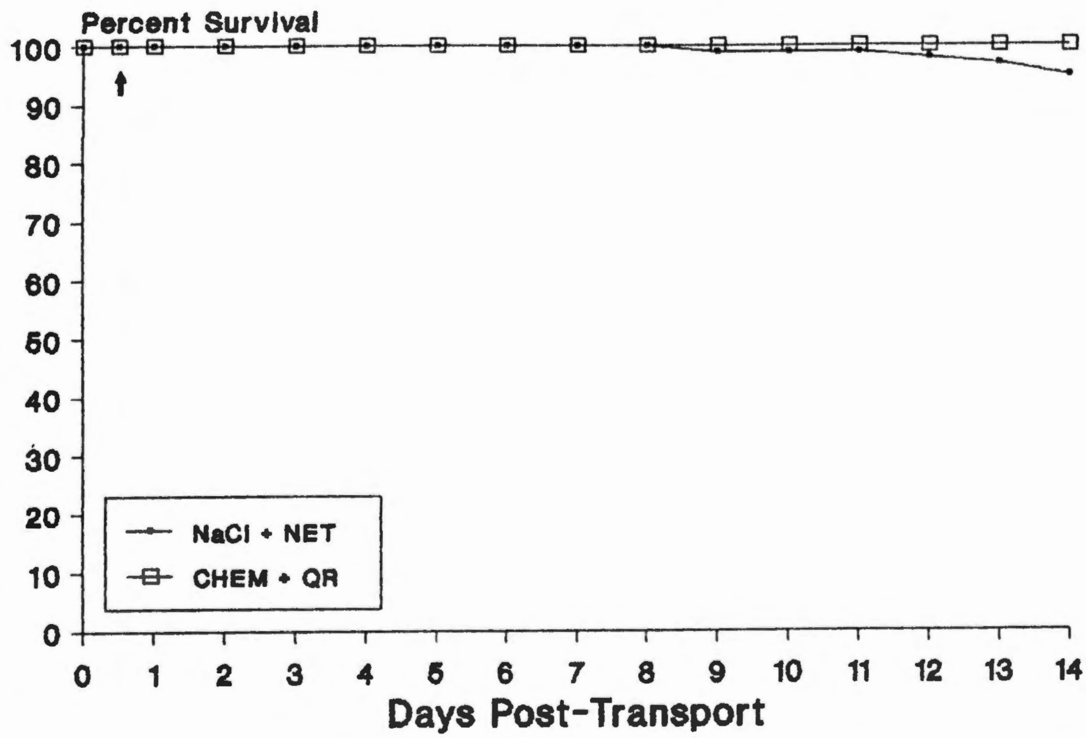

Figure 12. Two-week survival of fingerling striped bass after pond harvest on August 1, 1984 and a 6-h simulated transport and stocking into circular recovery tanks set at 26 C. Treatments were transport in a 1.0% NaCl solution and net release (NaCl + NET; N = 98) or transport in a 1.0% NaCl solution with 25 mg/l tricaine methanesulfonate, followed by quick release (CHEM + QR; N = 97). Arrow indicates survival immediately after release from transport tanks into recovery tanks.

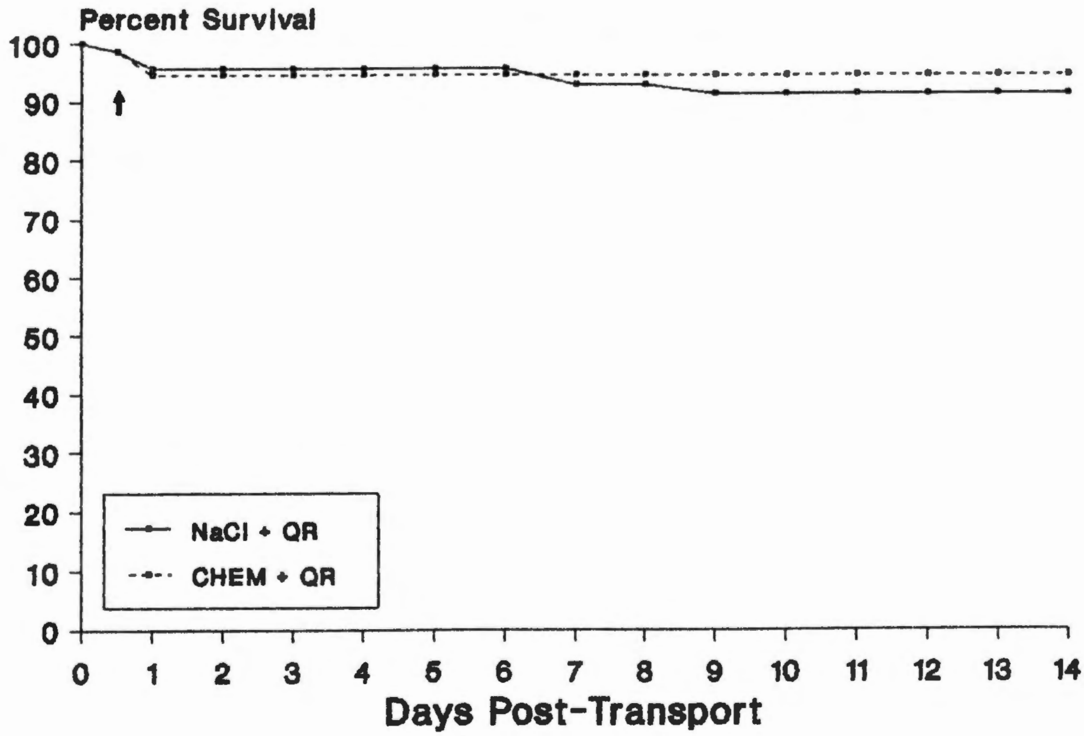

Figure 13. Two-week survival of fingerling striped bass after pond harvest on September 1, 1984 and a 6-h simulated transport and stocking into circular recovery tanks set at 26 C. Treatments were transport in a 1.0% NaCl solution and quick release (NaCl + QR; N = 94) or transport in a 1.0% NaCl solution with 25 mg/l tricaine methanesulfonate, followed by quick release (CHEM + QR; N = 101). Arrow indicates survival immediately after release from transport tanks into recovery tanks.

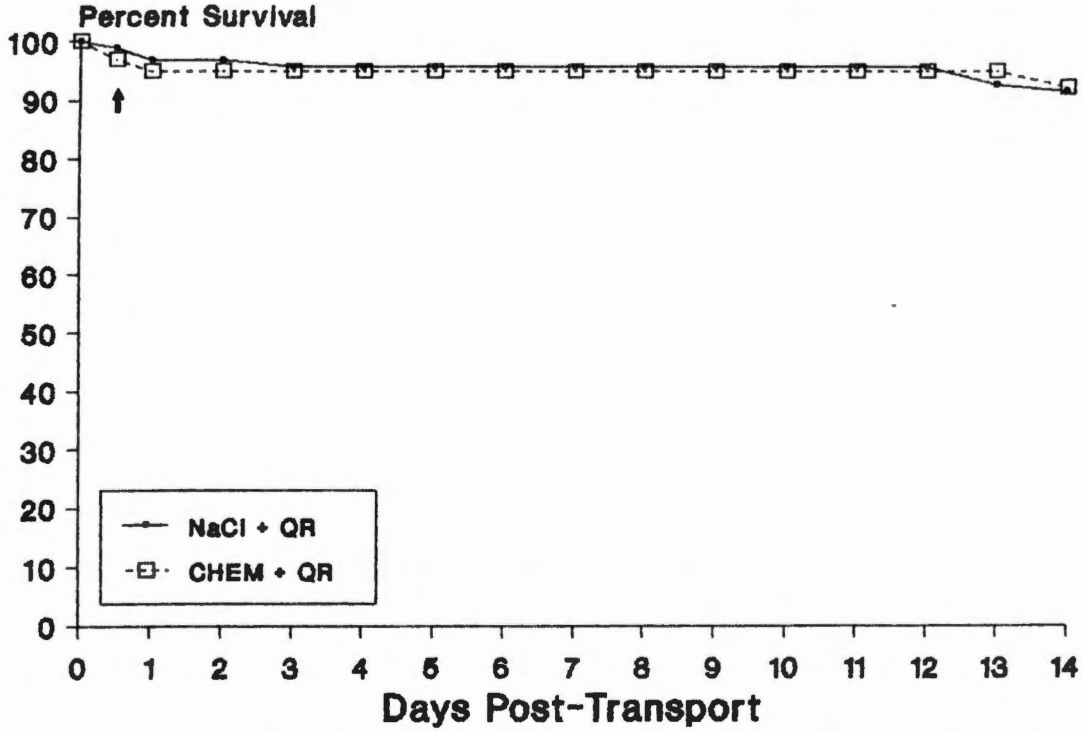

Figure 14. Two-week survival of remaining striped bass from trials 1 through 3 acclimated to 26 C for two weeks and then subjected to a 6-h transport and stocking simulation. Treatments were transport in a 1.0% NaCl solution and quick release (NaCl + QR; N = 70) or transport in a 1.0% NaCl solution with 25 mg/l tricaine methanesulfonate, followed by quick release (CHEM + QR; N = 74). Arrow indicates survival immediately after release from transport tanks into recovery tanks.

A plot of the data suggested that survival increased linearly as mean length increased to about 50 mm, then leveled off at rates between 90 and 100%. With one exception, survival approached or exceeded 90% in Trials 1, 5, 6, and 7, which used fish 50 mm or larger (Table 3). Regardless of treatment, overall survival in the three remaining trials was much lower. Differences in striped bass survival among treatments were not related to water temperature, pH, or ammonia concentrations.

The addition of 10 g/L sodium chloride to the hauling tanks appeared to greatly enhance striped bass survival. Excluding Trial 7, which used previously tested striped bass, mean survival for the eight treatments that employed NaCl was 82% (range, 46-100%), while survival in the four freshwater treatments averaged only 49% (range, 4-89%). In Trials 2-4, which used smaller fish, treatments containing NaCl produced much higher survival of striped bass than treatments without the salt.

CHAPTER 5

DISCUSSION

Kentucky Lake Stocking

The first objective of this study was to assess the effects of transport and stocking on mortality of striped bass fingerlings released into Kentucky Lake. Although a precise mortality estimate could not be determined from the live cage experiment, it appeared that at least 80% of the fish survived the initial trauma of stocking and had resumed normal feeding behavior. Based on the results of later transport simulations, which showed that fish larger than 50 mm hauled in salt-treated water survived well and that most handling- and confinement-induced mortality occurred within two days, there was no reason to expect catastrophic losses of stocked striped bass due to the stocking procedure itself.

Predation of newly stocked striped bass was documented, but intensive predation was seen only within five hours after stocking. Striped bass appeared to disperse rapidly from the Spring Branch boat ramp and probably headed downstream. The majority of fingerlings found were seen in electrofishing and predator gut samples taken downstream from the stocking site, with very few observed above that point. The reservoir at this site had a distinct riverine character with noticeable current, which may have also influenced downstream movement and dispersal of striped bass. Personal observations of downstream movement by striped bass stocked in the headwaters of Cherokee Reservoir support this hypothesis. Although predation effects were not followed over a longer distance or time period, the apparent rapid dispersal of stocked fish and return of caged fish to normal behavior suggested that predation probably did not cause much acute, catastrophic loss of striped bass. A similar decline in predation rates apparently due to dispersal of stocked fish was seen for sockeye salmon in Lake Wenatchee, Washington (Thompson and Tufts 1967).

It is unlikely that harvest, transport, and stocking procedures were limiting the Kentucky Lake striped bass fishery, as the same procedures were used to maintain successful Morone fisheries in other Tennessee impoundments. Field observations showed that fish stocked into Tims Ford Reservoir were subjected to roughly the same degree of confinement, water quality, and handling stress as the Kentucky Lake fish. If stocking procedures were limiting Kentucky Lake striped bass populations, they should have had similar effects on Tims Ford fish. For the period 1979-1983, the estimated annual striped bass harvest from Tims Ford averaged 0.44 fish/ha, compared to 0.03 fish/ha from Kentucky Lake (TWRA, unpublished creel data). Available data strongly suggest that stocking procedures are not the principal factor associated with depressed Kentucky Lake striped bass populations.

Other factors may have limited the Kentucky Lake striped bass fishery. Although invertebrate forage appeared to be comparable to quantities found in other striped bass reservoirs (Saul 1981; Richardson 1982), no forage fish of adequate size were available to the newly-stocked striped bass. Cherokee Reservoir research has shown excellent growth of young striped bass when newly-stocked striped bass could quickly convert to a fish diet (Saul 1981; Humphries 1983). Striped bass stocked in late summer into Kentucky Lake missed the opportunity to forage on larval shad and appeared to have a size disadvantage when compared with competing species (Table 6). Such a predator/prey imbalance may limit striped bass populations in the reservoir.

Kentucky Lake may also lack enough summer habitat to support many adult striped bass. Waddle et al. (1977) and Schaich and Coutant (1980) showed that thermal refuges with water temperatures of 22 C or less and adequate dissolved oxygen levels were critical for summer survival of adults in Cherokee Reservoir. Kentucky Lake is a mainstream reservoir with a mean annual retention time of 22 days (Kentucky Reservoir Water Resources Task Force 1987). During 1979-1983, the mean weight of a striped bass creeled from Kentucky Lake was 3.8 kg, quite smaller than the 5.0, 5.5, and 5.7 kg averages for Percy Priest, Tims Ford, and

Chickamauga reservoirs, respectively (TWRA, unpublished creel data). It is possible that summer striped bass habitat in Kentucky Lake was not consistently available in sufficient quantities to allow for long-term survival of adult fish.

Beginning in 1984, TWRA altered its Morone stocking program for Kentucky Lake (Mike Smith, Eagle Bend Hatchery, personal communication). Both striped bass and hybrids were stocked during the next two years, followed by three years of hybrid stocking exclusively. During the third year of hybrid stocking only (1988), an abundance of young-of-year striped bass was observed in the reservoir. That year-class has since produced a successful fishery in Kentucky Lake, with striped bass ranking third in the creel behind black bass and crappie. Biologists suspect successful reservoir spawning due drought effects on reservoir flows, or migration through locks from populations in the Ohio River. Further Morone stockings have been withheld until the source of those striped bass has been identified. The fish are now reaching 4.5-6.5 kg in weight, and their relative survival as adults over upcoming years should test the theory of limited summer habitat conditions.

Stocking Stress

The second objective of this study was to identify stressful aspects of the striped bass stocking procedure.

Although most striped bass appeared to survive transport and stocking into Kentucky Lake, at least 10-20% was still lost within 48 hours, based on the live cage data. The two shipments of fingerlings sent from Eagle Bend Hatchery to ORNL for the 1983 lab tests suffered mortalities of approximately 17% and 16%, figures close to that seen at the reservoir. The most important potential stressors observed were handling, confinement, and water quality changes (temperature, salinity, ammonia levels). Loading density of transport tanks may have contributed to stress, but similar densities have been used when transporting fingerlings to other reservoirs with successful striped bass fisheries.

The 1983 experiments concentrated on the roles of handling, confinement, and water temperature change in relation to fingerling survival. Overall, the tests suggested that initial netting was probably most detrimental. In Trial 1, fingerlings netted and put into cages suffered 10% mortality within a day even though water quality was equal among stock and test tanks. The effect of handling could not be separated from cage confinement effects. However, mortalities in the stock tank on days following removal of striped bass for cage tests totaled 6, 11, and 18 fish, much higher than the average daily mortality of one fish. Immediate mortality of adult Hudson River striped bass captured in seines and trawls was 16.1 and 17.7%, respectively, before modification of the handling technique (Dunning et al. 1989). Mortality of juvenile striped bass occurred after net confinements of 10 minutes (Tomasso et al. 1980) and 12 minutes (Davis and Parker 1990). Initial capture has been demonstrated to be highly stressful to salmonids (Wedemeyer 1972; Strange and Shreck 1978; Shreck 1981; Pickering et al. 1982).

Trials 1-4 demonstrated cumulative impacts from combined stressors. When combined with handling and confinement, instantaneous temperature change dramatically increased mortality. Mortality was related to the severity of the stressor, in this case the temperature change. Gradual temperature change in the Simulation and No Tempering treatments eliminated the instantaneous temperature change, and striped bass survival was unaffected by temperature over the 15 C test range.

As the stress load was further reduced, mortalities declined. When handling and instantaneous temperature change were combined in Trial 6, mortality increased and feeding behavior decreased slightly over the group that was handled without a temperature change. Based on results from early trials, a somewhat higher mortality rate was expected, especially for handled fish. However, test fish were survivors from the original hatchery shipment that had avoided capture for earlier testing. These larger, stronger fish may have been more resistant to stress than the rest of the lot. Fingerling striped bass in Trial 5 were able to withstand sudden 14 C changes in water temperature with no mortality when handling and confinement stressors were eliminated.

Effective Transport and Stocking

The third objective of this study was to determine the most effective transport and stocking procedure for striped bass. The 1984 experiments were attempts to more accurately define and subsequently reduce stress due to transport and stocking. Both physiological tests and observations of survival showed that transport and stocking caused significant stress in juvenile striped bass, especially when hauled in fresh water. The mean glucose concentration of all control samples, excluding the July 26 outlier, was 64 mg/dL, very similar to the 69 mg/dL reported by Davis and Parker (1990) for resting striped bass acclimated to 25 C. In the current study, post-transport levels usually rose beyond 200 mg/dL, well above the levels seen in response to a 12-min net confinement by Davis and Parker (1990), but much lower than those for striped bass harvested and held 24 h, then transported for 5 h in either fresh water or 0.1% $CaCl_2$ (Mazik et al. 1991). Mean chloride concentrations of control fish were higher in this study (141 meq/L) than in the short confinement study (88 meq/L). Chloride levels of fish hauled in fresh water declined to 65 meq/L in Trial 1 and 90 meq/L in Trial 2, and mortalities were seen in both cases.

Hypochloremia appeared to be a good indicator of osmoregulatory dysfunction caused by transport stress. In fresh water, fish gain water and lose electrolytes (Mazeaud et al. 1977). Minumum chloride levels found in striped bass from the fresh water treatment may have shown the stress limits where osmoregulatory recovery was no longer possible. Under the water quality conditions of this study, it appeared that levels below 90 meq/L signaled mortality. The role of disease in reducing the capability of fish to handle further stress was shown clearly.

Addition of 10 g/L NaCl to the hauling medium reduced mortality and alleviated to some degree both the magnitude and the duration of hypochloremia caused by transport stress. The salt treatment also appeared to slightly reduce hyperglycemia in transported striped bass. The mediation of hyperglycemia by NaCl addition to soft water has been documented previously for salmonids (Wedemeyer 1972) and for striped bass (Mazik et al. 1991). The salt solution was especially important in the transport of diseased fish in Trial 1, where infected fish could not withstand the added stress of fresh water. Generally, fish hauled in the salt solution took about one week to recover normal plasma glucose levels, while a limited number of observations suggested that recovery from freshwater transport was slightly longer. That may, however, be an overestimation of the duration of response. Fish were fed late on the second day after transport, which may have elevated plasma glucose levels. Striped bass surviving the six-hour transport simulation required at least one week to normalize their plasma chloride levels if hauled in 1% salt, and possibly two weeks if hauled in fresh water.

As expected, NaCl additions to the hauling media enhanced 14-day survival of fingerling striped bass after simulated transport. Effects were most pronounced for fish under 50 mm, which appeared to be more sensitive to initial handling stress. The present TWRA practice of adding 10 g/L NaCl to transport tanks filled with Eagle Bend Hatchery water (total hardness, 110 mg/L) is vital to continued stocking success, especially if fish are small or are already stressed from disease or other factors.

Sodium chloride additions probably were beneficial because adequate calcium concentrations for ionic balance were already present in culture ponds and hauling tanks. When added to very soft water (calcium < 15 mg/L), sodium chloride has been shown to decrease fingerling striped bass survival (Grizzle et al. 1990). Mazik et al. (1991), using striped bass reared in relatively soft water (total hardness, 28 mg/L), observed much greater survival of fish hauled in 1.0% NaCl than those hauled in 0.1% $CaCl_2$ or fresh water. It appears that the adequate concentration of dissolved calcium needed for positive effects of NaCl treatment may be between 15 and 28 mg/L.

No clearcut benefits to the use of anesthetic were apparent from the data. MS-222 was used solely in conjunction with NaCl and effects due to mild anesthesia were likely masked. In fact, the addition of MS-222 may have added more stress. Mild doses of MS-222 administered after initial disturbance has been shown to be stressful to chinook salmon (Strange and Shreck 1978), red drum (Robertson et al. 1988), and striped bass (Davis et al. 1982). Only when that anesthetic was administered to undisturbed fish prior to loading was it effective in reducing transport stress (Strange and Shreck 1978; Tomasso et al. 1980).

The present hatchery operation of loading striped bass stocking trucks directly from the ponds precludes the practical use of anesthetics prior to disturbance. If fish are instead transferred to holding vats prior to loading onto trucks, the anesthetization method of Tomasso et al. (1980) could reduce handling and stocking mortality. However, the additional stress from holding and handling twice before transport may offset any gains from anesthetization. If the experimental anesthetic etomidate gains approval for food fish use, it could be applied after initial disturbance and still provide sedation without additional stress (Davis et al. 1982).

Physiology trials indicated that quick release of striped bass into recovery tanks was slightly better than netting, while two of the fingerling transport trials (1,4) showed a distinct survival advantage of quick-released fish. Considering that handling appeared to be the most adverse practice involved with striped bass transport and stocking, and that repeated handling has been shown to produce cumulative stress effects (Barton et al. 1986), handling should be reduced wherever possible. Fitting of all stocking equipment with quick-release valves would reduce the overall stress load on stocked striped bass and improve their chances of reservoir survival.

Lastly, optimum survival of transported striped bass depends on maintenance of low stress levels in fingerlings. Potential adverse conditions in hatchery ponds prior to and during harvest can predispose fish to other stressors that are normally tolerated. Attention should be directed at maintaining high water quality (high dissolved oxygen, low turbidity, moderately cool temperatures) in the pond catch basin during both drawdown and harvest. Development of alternate harvest techniques involving less handling (Dunning et al. 1989) may be the key to increasing the efficiency of striped bass stocking in Tennessee reservoirs.

The optimum harvest, transport, and stocking procedure for striped bass fingerlings would then involve minimal handling and high water quality. Ponds should be drawn down and cool water introduced to allow high dissolved oxygen levels and gradual reduction in pond temperature to within 5 C of the transport temperature. Fingerlings should be harvested with as little handling as is practical. Transport tanks should contain enough NaCl and $CaCl_2$ to reduce the osmotic and ionic gradient between the fish and the transport medium. Anesthetics should not be used if fish have already been disturbed by harvest or loading procedues. FDA-approved bacteriostats can be used to reduce the probability of epizootics. Upon arrival at the stocking site, water should be exchanged between the stocking tanks and the reservoir to reduce the magnitude of instantaneous changes in water quality. Once temperature and osmotic gradients have been minimized, fingerlings should be quick-released from the transport tank into the resevoir. Available habitat and forage conditions should then play a larger role than stocking stress in the success of that striped bass year-class.

CHAPTER 6

SUMMARY

1. Investigation of a Kentucky Lake stocking trip indicated that the majority of newly-stocked striped bass appeared to survive the transport and stocking and dispersed into the reservoir. An estimated 10%-20% of fish in a live cage did suffer transport-related mortality.

2. Laboratory tests showed that handling and confinement mortality was significant in fish tested in fresh water. Temperature change did not significantly affect the stress response to handling if the change was gradual. Acute temperature changes, however, had a cumulative effect, with striped bass mortality dependent on the magnitude of change.

3. Simulated transport trials showed that hauling in fresh water was extremely stressful to striped bass. Adding 10 g/L NaCl to the hauling medium alleviated some of the sublethal stress response and increased subsequent survival.

4. Quick-release of striped bass into recovery tanks appeared to be better than net transfer.

5. A mild concentration of 25 mg/L MS-222 did not show any positive effects on striped bass survival.

6. Recommended stocking procedures included maintenance of water quality in both harvested ponds and

transport tanks, addition of NaCl and $CaCl_2$ to transport tanks to reduce the osmotic and ionic gradient between fish and water, and the use of quick-releases to minimize handling stress on stocked striped bass.

LIST OF REFERENCES

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American Public Health Association (APHA). 1971. Standard methods for the examination of water and wastewater. APHA, 1015 Eighteenth Street,NW, Washington, D.C. 874 pp.

Axon, J.R., and D.K. Whitehurst. 1985. Striped bass management in lakes with emphasis on management problems. Transactions of the American Fisheries Society 114:8-11.

Barton, B.A., and R.E. Peter. 1982. Plasma cortisol stress response in fingerling rainbow trout, (Salmo gairdneri) Richardson, to various transport conditions, anaesthesia, and cold shock. Journal of Fish Biology 20:39-51.

Barton, B.A., C.B. Schreck, and L. Sigismondi. 1986. Multiple acute disturbances evoke cumulative physiological stress responses in juvenile chinook salmon. Transactions of the American Fisheries Society 115:245-251.

Bishop, R.D. 1975. The use of circular tanks for spawning striped bass (Morone saxatilis). Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 28:35-44.

Bonn, E.W., editor. 1976. Guidelines for striped bass culture. Publication of the Striped Bass Comittee, Southern Division of the American Fisheries Society, Bethesda, Maryland. 103 pp.

Braschler, E.W. 1975. Development of pond culture techniques for striped bass (Morone saxatilis) Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 28:44-48.

Caldwell, C.A., and J.R. Tomasso. 1986. Stocking and handling-induced stress in red drum fingerlings. Proceedings of the Annual Conference Southeastern Association of Fish and Wildlife Agencies 39:238-247.

Carmichael, G.J., J.R. Tomasso, B.A. Simco, and K.B. Davis. 1984a. Confinement and water quality-induced stress in largemouth bass. Transactions of the American Fisheries Society 113:767-777.

Carmichael, G.J., J.R. Tomasso, B.A. Simco, and K.B. Davis. 1984b. Characterization and alleviation of stress associated with hauling largemouth bass. Transactions of the American Fisheries Society 113:778-785.

Chittenden, M.E., Jr. 1971a. Transporting and handling young American shad. New York Fish and Game Journal 18:123-128.

Chittenden, M.E., Jr. 1971b. Effects of handling and salinity on oxygen requirements of the striped bass, (Morone saxatilis). Journal of the Fisheries Research Board of Canada 12:1823-1830.

Coutant, C.C., H.M. Ducharme Jr., and J.R. Fisher. 1974. Effects of cold shock on vulnerability of juvenile channel catfish (Ictalurus punctatus) and largemouth bass (Micropterus salmoides) to predation. Journal of the Fisheries Research Board of Canada 31:351-354.

Coutant, C.C., K.L. Zachman, D.K. Cox, and B.L. Pearman. 1984. Temperature selection by juvenile striped bass in laboratory and field. Transactions of the American Fisheries Society 113:666-671.

Cox, D.K. 1978. Acclimation states of juvenile striped bass held in constant and fluctuating temperature regimes. Pages 703-713 in J.H. Thorp and J.W. Gibbons, editors. 1978. Energy and environmental stress in aquatic systems. CONF-771114. National Technical Information Service, Springfield, Virgina.

Cox, D.K., and C.C. Coutant. 1981. Growth dynamics of juvenile striped bass as functions of temperature and ration. Transactions of the American Fisheries Society 110:226-228.

Davies, W.D. 1973. Rates of temperature acclimation for hatchery reared striped bass fry and fingerlings. Progressive Fish Culturist 35:214-217.

Davis, K.B., N.C. Parker, and M.A. Suttle. 1982. Plasma corticosteroids and chlorides in striped bass exposed to tricaine methanesulfonate, quinaldine, etomidate, and salt. Progressive Fish Culturist 44:205-207.

Davis, K.B., and N.C. Parker. 1990. Physiological stress in striped bass: effect of acclimation termperature. Aquaculture 91:349-358.

Dunning, D.J., Q.E. Ross, M.T. Mattson, P. Geoghegan, and J.R. Waldman. 1989. Reducing mortality of striped bass captured in seines and trawls. North American Journal of Fisheries Management 9:171-176.

Elliott, J.M. 1981. Some aspects of thermal stress on freshwater teleosts. Pages 210-245 in A.D. Pickering, editor. Stress and fish. Academic Press, New York, New York.

Emerson, K., R.C. Russo, R.E. Lund, and R.V. Thurston. 1975. Aqueous ammonia equilibrium calculations: effect of pH and temperature. Journal of the Fisheries Research Board of Canada 32:2379-2383.

Geiger, J.G., and N.C. Parker. 1985. Survey of striped bass hatchery management in the southeastern United States. Progressive Fish Culturist 47:1-13.

Grizzle, J.M., A.C. Mauldin II, D. Young, and E. Henderson. 1985. Survival of juvenile striped bass (Morone saxatilis) and Morone hybrid bass (Morone chrysops X Morone saxatilis) increased by addition of calcium to soft water. Aquaculture 46:167-171.

Grizzle, J.M., A.C. Mauldin II, D. Young, and E. Henderson. 1990. Effects of environmental calcium and sodium on postharvest survival of juvenile striped bass. Journal of Aquatic Animal Health 2:104-108.

Hall, L.W., S.L. Margrey, D.T. Burton, and W.C. Graves. 1983. Avoidance behavior of juvenile striped bass, Morone saxatilis, subjected to simultaneous chlorine and elevated temperature conditions. Archives of Environmental Contamination and Toxicology 12:715-720.

Hazel, C.R., W. Thomsen, and S.J. Meith. 1971. Sensitivity of striped bass and stickleback to ammonia in relation to temperature and salinity. California Fish and Game 57:138-153.

Humphries, M. 1983. Effects of forage variations on young-of-year striped bass and other young predators in Cherokee Reservoir, Tennessee. Master's Thesis. University of Tennessee, Knoxville, TN.

Jarman, R., and J.L. Harper. 1969. Production of striped bass fingerlings, Morone saxatilis (Walbaum), on Oklahoma state fish hatcheries. Proceedings of the Annual Conference Southeastern Association of Game and Fish Commissioners 23:571-575.

Johnson, D.L., and M.T. Metcalf. 1982. Causes and controls of freshwater drum mortality during transportation. Transactions of the American Fisheries Society 111:58-62.

Kelley, J.R., Jr. 1969. Investigations on the propagation of striped bass, Morone saxatilis (Walbaum). Doctoral Dissertation. Auburn University, Auburn, Alabama.

Kentucky Reservoir Water Resources Task Force. 1987. Kentucky Reservoir Water Resources Task Force prograss report for the period September 1986 - September 1987. TVA\ONRED\AWR-88\4. Tennessee Valley Authority, Knoxville, Tennessee.

Leitritz, E., and R.C. Lewis. 1980. Trout and Salmon Culture (Hatchery Methods). California Fish Bulletin Publication Number 4100. Agricultural Sciences Publications, University of California, Berkeley, California. 197 pp.

Lewis, W.M., and R.D. Heidinger. 1981. Tank culture of striped bass production manual. Final report, Dingell-Johnson Project F-26-R. Illinois Department of Conservation and Southern Illinois University, Carbondale, Illinois. 115 pp.

Long, C.W., J.R. McComas, and B.H. Monk. 1977. Use of salt (NaCl) water to reduce mortality of chinook salmon smolts (Oncorhynchus tshawytscha) during handling and hauling. Marine Fisheries Review 39:6-9.

Mathur, M.E., and D. H. Wahl 1989. Comparative mortality of three esocids due to stocking stressors. Canadian Journal of Fisheries and Aquatic Sciences 46:214-217.

Maule, A.G., C.B. Shreck, C.S. Bradford, and B.A. Barton. 1988. Physiological effects of collecting and transporting emigrating juvenile chinook salmo past dams on the Columbia River. Transactions of the American Fisheries Society 117:245-261.

Mazeaud, M.M., F. Mazeaud, and E.M. Donaldson. 1977. Primary and secondary effects of stress in fish: some new data with a general review. Transactions of the American Fisheries Society 106:201-212.

Mazik, P.M., B.A. Simco, and N.C. Parker. 1991. Influence of water hardness and salts on survival and physiological characteristics of striped bass during and after transport. Transactions of the American Fisheries Society 120:121-126.

Meldrim, J.W., and J.J. Gift. 1971. Temperature preference, avoidancve and shock experiments qwith estuarine fishes. Ichthyological Associates, Inc. Bulletin 7:2-75.

Meldrim, J.W., J.J. Gift, and B.R. Petrosky. 1974. The effect of temperature and chemical pollutants on the behavior of several estuarine organisms. Ichthyological Associates, Inc. Bulletin 11:2-40.

Miles, H.M., S.M. Loehner, D.T. Michaud, and S.L. Salivar. 1974. Physiological reponses of hatchery reared muskellunge (Esox masquinongy) to handling. Transactions of the American Fisheries Society 103:336-342.

Murai, T., J.W. Andrews, and J.W. Muller. 1979. Fingerling american shad: effect of valium, MS-222, and sodium chloride on handling mortality. Progressive Fish-Culturist 41:27-29.

Nikinmaa, M., A. Soivio, T. Nakari, and S. Lindgren. 1983. Hauling stress in brown trout (Salmo trutta): physiological responses to transport in fresh water or salt water, and recovery in natural brackish water. Aquaculture 34:93-99.

Norris, K.S., F. Brocato, F. Calandrino, and W.N. McFarland. 1960. A survey of fish transportation methods and equipment. California Fish and Game 46:5-33.

Otwell, W.S., and J.V. Merriner. 1975. Survival and growth of juvenile striped bass (Morone saxatilis) in a factorial experiment with temperature, salinity and age. Tranactions of the American Fisheries Society 3:560-566.

Pickering, A.D., T.G. Pottinger, and P. Christie. 1982. Recovery of brown trout, (Salmo trutta L.) from acute handling stress: a time course study. Journal of Fish Biology 20:229-244.

Piper, R. G., I.B. McElwain, L.E. Orme, J.P. McCraren, L.G. Fowler, and J.R. Leonard. 1982. Fish Hatchery Management. U.S. Fish and Wildlife Service. Washington, D.C. 517 pp.

Powell, N.A. 1970. Striped bass in air shipment. Progressive Fish Culturist 32:18.

Redding, J. M., and C.B. Schreck. 1983. Influence of ambient salinity on osmoregulation and cortisol concentration in yearling coho salmon during stress. Tranactions of the American Fisheries Society 112:800-807.

Reeves, W.C. 1973. Effects of feeding regimes and sources of fish on production of advance fingerling striped bass. Proceedings of the Annual Conference Southeastern Association of Game and Fish Commissioners 27:540-547.

Richardson, J.M. 1982. Food habits and growth of young-of-year striped bass in Norris Reservoir, Tennessee. Master's Thesis. University of Tennessee, Knoxville, TN.

Robertson, L., P. Thomas, and C.R. Arnold. 1988. Plasma cortisol and secondary stress responses of cultured drum (Sciaenops ocellatus) to several transportation procedures. Aquaculture 68:115-130.

Robins, C.R., editor. 1980. A list of common and scientific names of fishes from the United Staes and Canada. American Fisheries Society Special Publication 12. American Fisheries Society, Bethesda, Maryland. 174 pp.

SAS (Statistical Analysis System). 1982. SAS users guide: statistics. SAS Institute, Raleigh, NC.

Saul, B.M. Food habits and growth of young-of-year striped bass in Cherokee Reservoir, Tennessee. Master's Thesis. University of Tennessee, Knoxville, TN.

Schaich, B.A., and C.C. Coutant. 1980. A biotelemetry study of spring and summer habitat selection by striped bass in Cherokee Reservoir, Tennessee, 1978. ORNL/TM-7127. Oak RIdge National Laboratory, Oak Ridge, Tennessee. 220 pp.

Schoumacher, R. 1969. Transporation of adult striped bass. Progressive Fish Culturist 31:230.

Schreck, C.B. 1981. Stress and compensation in teleostean fishes: response to social and physical factors. Pages 295-321 in A.D. Pickering, editor. Stress and fish. Academic Press, New York, New York.

Selye, H. 1950. Stress and the general adaptation syndrome. British Medical Journal 1:1383-1392.

Specker, J.L., and C.B. Shreck. 1980. Stress response to transportation and fitness for marine survival in coho salmon (Oncorhynchus kisutch) smolts. Journal of the Fisheries Research Board of Canada 37: 765-769.

Stein, R.A., R.F. Carline, and R.S. Hayward. 1981. Largemouth bass predation on stocked tiger muskellunge. Transactions of the American Fisheries Society 110:604-612.

Stevens, R.E. 1966. Hormone-induced spawning of striped bass for reservoir stocking. Progressive Fish Culturist 28:19-28.

Stevens, R,E. 1984. Historical overview of striped bass culture and management. Pages 1-15 in J.P. McCraren, editor. The aquaculture of striped bass: a proceedings. UM-SG-84-01. Maryland Sea Grant Program, University of Maryland, College Park, Maryland.

Strange, R.J., and C.B. Schreck. 1978. Anesthetic and handling stress on survival and cortisol concentration on yearling chinook salmon (Oncorhynchus tshawytscha). Journal of the Fisheries Research Board of Canada 35:345-349.

Strange, R.J., and C.B. Schreck. 1980. Seawater and confinement alters survival and cortisol concentration in juvenile chinook salmon. Copeia 1980:351-353.

Tagatz, M.E. 1962. Tolerence of striped bass and American shad to changes of temperature and salinity. U. S. Fish and Wildlife Service Special Scientific Report, Fisheries Number 388. 8 pp.

Tennessee Wildlife Resources Agency (TWRA). 1979. Management plan for striped bass in Tennessee. Tennessee Wildlife Resources Agency, Nashville, Tennessee.

Thompson, R.B., and D.F. Tufts. 1967. Predation by Dolly Varden and nothern squawfish on hatchery-reared sockeye salmon in Lake Wenatchee, Washington. Transactions of the American Fisheries Society 96:425-427.

Tisa, M.S., R.J. Strange, and D. Peterson. 1983. Hematology of striped bass in fresh water. Progressive Fish Culturist 45:41-44.

Tomasso, J.R., K.B. Davis, and N.C. Parker. 1980. Plasma corticosteroid and electrolyte dynamics of hybrid striped bass (white bass X striped bass) during netting and hauling. Proceedings of the World Mariculture Society 11:303-310.

U.S. Fish and Wildlife Service. 1978. Manual of fish culture. Section G: fish transportation. U.S. Fish and Wildlife Service, Washington, D.C.

Waddle, H.R., C.C. Coutant, and J.L. Wilson. 1977. Summer habitat selection of striped bass, *Morone saxatilis*, in Cherokee Reservoir, Tennessee, 1977. ORNL/TM-6927. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Wedemeyer, G. A. 1972. Some physiological consequences of handling stress in the juvenile coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*Salmo gairdneri*). Journal of the Fisheries Research Board of Canada 29:1780-1783.

Wedemeyer, G.A., and W.T. Yasutake. 1977. Clinical methods for the assessment of the effects of environmental stress on fish health. U.S. Fish and Wildlife Service Technical Paper 89.

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