Ohio Sea Grant

DELAYED MORTALITY FOLLOWING TRANSPORT OF LAKE ERIE FRESHWATER DRUM CAPTURED IN SHORE SEINES

by
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PREFACE

The following report was prepared by Michael Thomas Metcalf as partial fulfillment for a Master of Science Degree in the School of Natural Resources at The Ohio State University. Research conducted on this thesis was part of a project coordinated by the Division of Fisheries and Wildlife Management at The Ohio State University and was in part sponsored by the National Marine Fisheries Service and the Ohio Division of Wildlife, project number 04-7-043-447. Dr. David L. Johnson, Division of Fisheries and Wildlife Management, served as advisor. Other members of the reading committee were Dr. James Triplett and Dr. Joseph Kasile.

On behalf of the Ohio Sea Grant Extension Program, I am pleased that we are able to reproduce copies of this research effort and make it available to other scientists.

Jeffrey M. Reutter
Program Leader

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

LIST OF TABLES

LIST OF FIGURES

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ABSTRACT

Freshwater drum, (*Aplodinotus grunniens*) obtained from seines operated by commercial fishermen in Sandusky Bay, Lake Erie, were transported to ponds during the summers of 1976 and 1977, and delayed mortality (1-2 weeks after transport) was monitored. Fish were transported in several treatment combinations added to hauling water. The following treatments significantly reduced delayed mortality: 5 g/liter NaCl ($\underline{P} \leq 0.05$); low fish hauling density (1 fish/9.1 liters), and late summer transport ($\underline{P} \leq 0.01$). Immediate mortality (end of 6-h transport) was low (3.8% ± 0.2SD) and delayed mortality (1-2 weeks after transport) was high (93.7% ± 11.1SD) and variable in experiments that tested hauling water treatments. Other groups of fish were transported and caged to determine which stressor (capture, transport, or stocking in ponds) had the greatest effect on delayed mortality. Fish transported (6 h) or stocked in ponds survived significantly ($\underline{P} \leq 0.01$) better than fish caged immediately in waters from which they originated. Capture was the most important stressor. Delayed mortality of tagged fish in hauling water experiments (mean 91.7%) was significantly higher ($\underline{P} \leq 0.05$) than untagged fish from stressor experiments (mean 35.4%). Delayed mortality was most severe 1-3 days after stocking and nearly complete after 1 week.

INTRODUCTION

A considerable demand exists for freshwater drum and other rough fish available from Lake Erie commercial fishermen (Mountz and Hackney, unpublished data). This species is currently underutilized in Lake Erie and Van Meter (1969) has shown that 13,712 lb of 39,408 lb of drum captured in trap nets were discarded for lack of suitable market. He estimated the potential harvest of drum to be 1.534 times (2,664,765 lb) that which was taken (1,891,786 lb) in U. S. waters of Lake Eries western basin in 1969. These figures are based primarily on ratio of marketed to discarded drum captured incidental to fishing for other species. It is unknown how many pounds of freshwater drum could be captured if increased fishing effort for this species was profitable.

One market for drum has been the live sale and transport of Lake Erie fish to stock private pay-fishing ponds. However, commercial fish transporters have indicated that mortality of drum is high during the summer months (normally June, July, August, and September). Although this is a seasonal market (April to June), due to high summer mortality (Harman 1978), commercial fishermen receive 25 cents per fish or about 15 to 20 cents per pound for live drum. Mountz (1974) studied the economics and patrons of the pay-pond fishery in Ohio and found that availability of large, inexpensive, and easily caught species was one of the most important factors for success. The freshwater drum is known by anglers for its ease of catchability and sporting fight.

At the request of commercial fishermen and transporters this study was initiated to determine the relationship between capture, transport, and the resultant delayed mortality of freshwater drum. The objectives of the study were (1) to determine if improved hauling techniques could be expected to increase survival of drum transported to ponds; and (2) to determine which stressor -- capture, transport or introduction into new waters (pond stocking) -- had the greatest effect on delayed mortality. The approach used in the study was to employ methods similar to commercial fish transporters but to develop simple treatments and procedure that would improve survival.

Transport or transfer of live fish is involved in many facets of fisheries including aquaculture, stocking, and research studies. Norris et al. (1960:6) reviewed the history, equipment, methodology, and problems of fish transportation and stated: "In general, all wish to carry as many fish as possible in as little water as possible with a minimum of mortality." Recently, successful transportation techniques have been discussed by Long et al. (1977) for chinook salmon (*Oncorhyncus tshawytscha*), Clupidae (Collins and Hulsey 1963; Chittenden 1971), and various African freshwater fish (Hattingh et al. 1975).

Fish often die during transportation or after some delay following transport. Stresses that result from handling and transporting fish cause distressed physical conditions that can remain unapparent for some time but eventually are fatal (Bouck and Ball 1966). Love (1970:39-59) discusses stress and the importance of considering its effect on the biochemistry of fish. Mazeaud et al. (1977) reviewed the impact of stress on fish and classified the effects as primary or secondary. Primary effects are rapid changes in catecholamine and corticosteroid concentration in blood that can result from capture (Bouck and Ball 1966), transport (Hattingh et al. 1974; Fraser and Beamish 1969), handling (Wedemeyer 1972; Soivio and Oikari 1976), struggling (Mazeaud et al. 1977), hypoxia (Chavin and Young 1970; Mazeaud et al. 1977), and thermal shock

(Mazeaud et al. 1977; Strange et al. 1977). Secondary effects of stress are metabolic disturbances (Black 1955; Chavin and Young 1970) and osmotic imbalances (Stevens 1968; Maetz 1974). Both primary and secondary effects of stress can cause mortality directly because physiological limitations are exceeded or indirectly because susceptibility to disease is increased (Wedemeyer 1970; Roth 1972).

LITERATURE REVIEW

Nomenclature and Discription

The freshwater drum, Aplodinotus grunniens Rafinesque, (Bailey et al. 1970) was originally described by Rafinesque (1819) in the Ohio River. This fish is the only freshwater member of the predominately marine family Sciaenidae. The nomenclature is somewhat complex with several generic and specific synonyms (Jordan and Eigenmann 1889; Trautman 1957; Cross 1967; Scott and Crossman 1973). Table 1 lists the scientific and common names associated with this species. Scott and Crossman (1973) give the etymology of the scientific name as "Aplodinotus - simple or single; back; grunniens - grunting." The ability of the fish to produce an audible croaking or grunting sound by action of muscles which oscillate the swim bladder has accounted for the specific name and many of the common names.

The freshwater drum is generally quite recognizable among other species because of the high arched back and the extension of the lateral line onto the caudal fin. (Fig. 1) Trautman (1957) lists only Morone chrysops, white bass, and certain carpsuckers, as superficially similar. Descriptions of the species are given in Forbes and Richardson (1920), Nichols (1942), Trautman (1957), Cross (1967), Brown (1971), and Scott and Crossman (1973). The species was found to display remarkable stability in meristic data since early post glacial times (Hubbs 1940) and for recent specimens from Kentucky to Wisconsin (Krumholz and Cavanah 1968). The skeletal morphology is also unique among freshwater fishes. The fused pharyngeal arches with crushing teeth, the large sagitta or saccular otoliths, and the heavily strutted skull are all characteristic features. The skeletal system was first

TABLE 1

COMMON AND SCIENTIFIC NAMES[1]

Common Names	Scientific Names
Buffalo-fish Buffalo perch Bubbler Bubbling fish Casse-gurgo Croaker Crocus Drum Drumfish Freshwater drum Gaspagie Gaspergou Gray bass Gray perch Grunter Grunting bubbler Grunting perch Jewell head Lake sheepshead Lake Drum Malashogany Mussel eater Perch Red River bass Sheepshead Silver bass Sunfish Thunder-pumper White bass White perch	*Aplodinotus grunniens* (Rafinesque 1819) *Amblodon grunniens* (Rafinesque 1820) *Sciaena oscula* (Lesueur 1822) *Sciaena grisea* (Lesueur 1822) *Sciaena* (*Corvina*) *oscula* (Lesueur)(Richardson 1836) *Corvina oscula* (Cuv. and Val. 1836) *Corvina richardsoni* (Cuv. and Val. 1836) *Catostomus oscula* (Kirtland 1841) *Corvina grisea* (DeKay 1842) *Amblodon concinnus* (Agassiz 1854) *Amblodon lineatus* (Agassiz 1855) *Corvina Richardsonii* (Forelle 1857) *Amblodon neglectus* (Girard 1858) *Haploidonotus grunniens* (Gill 1861) *Haploidonotus richardsoni* (Gill 1861) *Haploidonotus concinnus* (Gill 1861) *Haploidonotus lineatus* (Gill 1861) *Haploidonotus neglectus* (Gill 1861) *Corvina* (*Amblodon*) *neglecta* (Steindachner 1867) *Eutychelithus richardsoni* (Jordan (1876) *Aplidonotus grunniens* (Graham 1885) *Aplodonatus grunniens* (Graham 1885) *Corvina oscula* DeKay (Bean 1903)

[1] Adopted from Foell (1974)

studied in detail by Green (1941) and compared to that of carp, Cyprinus carpio, then common in laboratory anatomical studies. The labyrinth and associated hearing apparatus containing the large otoliths were described by Schneider (1962). Schneider and Hasler (1960) concluded that the animals may be capable of acoustic signaling in connection with spawning behavior. The otoliths are popular as curiosities and often termed "lucky stones" (probably because of the "L" shaped pattern on the medial surface of the otolith where the sacculus lies). Wirth (1958), Witt (1960), and Priegel (1965) have commented on the frequency of drum otoliths in Indian kitchen middens. They suggest that freshwater drum may have provided both food and sources of jewelry or trinkets. Degens (1969) found the composition of all fish otoliths including freshwater drum to be nearly identical, consisting mineralogically of aragonite. He further suggested that the crystal ultrastructures of otoliths may function as piezoelectric bodies which physiologically are linked to depth and sound perception. The occurence of bones of freshwater drum as fossils was first recorded by Smith (1954) in northwestern Oklahoma from the Illinoian Glacial stage of Pleistocene times.

Distribution

The freshwater drum has probably the greatest latitudinal range of any North American freshwater fish (Barney 1926). Its wide range stretches from the northern limit at the Nelson River, Manitoba (Scott and Kooyman 1952) , south to the Rio Usumacinta basin of Guatemala, the Rockies in the west and Appalachians in the east (Barney 1926). Barney (1926) believes the species originated in the Gulf of Mexico and was isolated some time prior to the last glaciation of the Northern U.S. during the Pleistocene Age. He believes the species was probably not limited by climate or temperature but instead, by geographical limits to migration. The species is very common in Lake Erie, especially the shallow western basin, and is found in most of the Great Lakes except Superior. Generally freshwater drum are found in lakes and larger, low-gradient streams (Daiber 1950). Many authors have associated this species with turbid conditions, but Trautman (1957) disputes this belief and cites the much larger populations in the clearer Muskingum River of Ohio than the turbid Scioto as evidence. Although this fish is generally considered benthipelagic and often associated with the bottom, Cady (1945) found them vertically distributed primarily between 20-50 ft with a maximum of about 95 ft in stratified Norris Reservior, (200 ft maximum depth) Tennessee. In shallower areas of the same reservior Hasbauer (1945) found 70% of all drum were captured in the bottom third of 8-ft deep gill nets set on the bottom. Bryan and Howell (1946) found that in unstratified mainstem reserviors (Wheeler Reservior, Alabama) they were found between 11-30 ft and most often in 16-20-ft depths. Eley et al. (1967) found the drum's vertical distribution in Keystone Reservior, Oklahoma, to be unrelated to all physicochemical factors measured (temperature, conductivity, pH, alkalinity, carbon dioxide, specific gravity, oxygen, turbidity, and light penetration); whereas, most fishes vertical distributions were highly correlated with temperature.

Spawning and Early Life History

The life history of A. grunniens is incompletely known because spawning has not been observed and documented. Based on condition factor, gonadisomatic index, and overall condition and number of eggs in ovaries, the spawning period has been placed from early June to mid September and at temperatures from 64-78 F (Daiber 1950, 1953; McLeod 1953; Wirth 1958; Butler 1965; Edsall 1967; Nelson et al. 1967; Wrenn 1968; Swedberg and Walburg 1970). Pelagic, planktonic, bouyant eggs found in Lake Erie were not identified as those of freshwater drum until Davis (1959) hatched and reared them. The marine relatives were known to be pelagic spawners with planktonic eggs, and Daiber (1950, 1953) and Langlois (1954) suspected this was also true for freshwater drum but did not confirm it by rearing. Spawning in Lake Erie is thought to occur in diverse habitats including bays, lower portions of rivers, and in the open lake over sand or mud bottoms to a depth of about 6 ft (Daiber 1953). As previously mentioned, Schnieder and Hasler (1960) believe the "drumming" noise of this fish to be connected with communication during spawning. Commercial fishermen in Sandusky Bay, Lake Erie catch tremendous numbers (up to 80 T in a single seine haul) during the known spawning period.

The age at sexual maturity varies for populations of freshwater drum having different growth rates. Total length, however, is much more importantly related to sexual maturity than age and Butler and Smith (1950), Daiber (1953), and Edsall (1967) found this to be especially true for female drum. In general, males mature a year earlier than females. Daiber (1953) found 79% of Lake Erie males to be mature at an average length of 302 mm (Age group V) and 84% of females mature at 365 mm (Age group VI). Edsall (1967) found mature males as early as Age group II and females as early as Age group III; however, 79% of males were mature at 285 mm and 72% of females at 355 mm. Wrenn (1968) and Swedberg (1970) found similarly that males were first to mature.

Fecundity is high for this species and ranges from 34,00 to 686,000 eggs with averages from 200,000 to 300,000 (Daiber 1953; Edsall 1967; Wrenn 1968; Swedberg and Walburg 1970). There appears to be a positive relationship between the number of eggs and the age of fish. Three distinct sizes of eggs (.54-.84 mm) can be found in ovaries prior to spawning and two sizes of residual eggs remain for the next season (Daiber 1953). Davis (1959) measured extruded eggs and found them to be 1.15-1.70 mm in diameter with a large oil globule 0.64-0.72 mm in diameter. The eggs float at the surface or may be churned to a depth of 3 m by waves (Swedberg and Walburg 1970). They found that hatching occurs in about 24 hours and embryonic development is remarkably rapid for temperate freshwater fish. Prolarval development (4.0 mm long) is complete in about 48 hours, feeding commences at 5 mm, and adult characteristics develop in 108 hours at 15 mm. Butler (1965) noted that eggs and larvae of drum are not heavily preyed upon by pelagic predator fish. Priegel (1966) has shown that scale development is complete on young drum at 22 mm.

There is evidence that the extended spawning period from early June to late September arises from sub-groups in the spawning population. These sub-groups give rise to definite growth modalitites amongst young-of-the-year fishes. Daiber (1950, 1953) explained such modalities in terms of either (a) interrupted or repeated spawning by females during a given season, or (b) differentials in time of spawning between females of various year classes. Swedberg and Walburg (1970) found year class strength was positively correlated with above average summer (June-August) temperatures and that year class strength was determined before fish reached 25 mm in length. They estimated instantaneous mortality rates of

.32 to .44 for 25-84-mm fish from 1966 through 1968 in Lewis and Clark Lake, Missouri. Nelson et al. (1967) also found year class to be determined early and calculated mortality rates from catch-effort indices for different lengths without regard to collection date. Juveniles are rarely consumed as prey except they make up about 1% of the diet of Lake Erie walleyes (Stizostedion vitreum) (Doan 1942; Parsons 1971), and one and two year olds are eaten by burbot, Lota lota (Clemens 1951). A definite migration pattern of young-of-the-year fish in reservoirs was observed as a shift from old river channels to flood plains (presumably associated with diet change from zooplankton to benthic macroinvertebrates) at about 20 mm (Nelson et al. 1967; Swedberg and Walburg 1970).

Age and Growth

Numerous age and growth studies have been published for freshwater drum from many locations throughout its wide geographical range. These studies include those of Eddy and Carlander (1942) in Minnesota; Ricker and Lagler (1942) in Indiana; Shoffman (1941, 1969) in Tennessee; Butler and Smith (1950), in the upper Mississippi River impoundments; Wrenn (1968) in Alabama; Priegel (1969) in Wisconsin; Purkett (1958) in Missouri streams; Houser (1960) in Oklahoma; Swedberg (1965, 1968), Nelson (1974), and Gabel (1974) in South Dakota; Benson (1968) reviewed growth studies on Missouri River main stem reservoirs; and Van Oosten (1938), Daiber (1950, 1953), Larmoyeux (1951), Edsall (1967), and Foell (1974) studied Lake Erie growth. Additional studies include growth information on young-of-the-year fish (Nelson et al. 1967; Swedberg and

Walburg 1970). Besides conventional scale aging techniques, freshwater drum growth has also been determined from otoliths (Witt 1960; Priegel 1965) and the eye lens (Burkett and Jackson 1971). Typically, growth is greater for drum in the southern part of its range and is usually highly variable for different habitats within the same general geographical area. Priegel (1969) used the time interval required to attain a total length of 356 mm (14 inches) as a standard of comparison. Table 2 presents growth data from the above studies with this method of comparison. It can be seen that the best known growth is in Oklahoma Lakes under 500 acres while the slowest growth is from Lake Erie's central basin. Table 3 demonstrates what appears to be a decreasing growth rate in the Western basin of Lake Erie, perhaps indicative of an expanding, underexploited population. Most authors have noted that it is considerably difficult to age fish once they are sexually mature, and there is normally a great deal of overlap in length classes for a given age. Butler and Smith (1950) presented criteria for scale-age validation for the species, but no one has apparently validated scale-aged fish by comparing them with known-age specimens from the same population. Most age and growth studies report the oldest age in samples as 10 to 15 years which corresponds approximately to 450-600 mm (17-20 inches) and weights of 1.5-3.0 kg (3-6 lb). However, most authors who have described the species list maximum weights as high as 50-60 lb. Cross (1967) lists the largest Kansas specimen as 37 in and 27 lb, and Trautman (1957) lists the largest specimen from Ohio as 35-39 in and 36 lb. Priegel (1965) and Witt (1960) have shown that the maximum size of ancient freshwater drum was similar to recent specimens. Young-of-the-year growth is probably impossible to

TABLE 2

NUMBER OF YEARS REQUIRED BY DRUM IN VARIOUS LOCATIONS TO ATTAIN A TOTAL LENGTH OF 356 mm (14 inches)[1]

Site and Author(s) of Study	Time Required by the Average Drum to Reach a Total Length of 356 mm (14 in)
Oklahoma lakes under 500 acres	
Houser, 1960	2 - 3 years
Oklahoma reservoirs over 500 acres	
Houser, 1960	3 - 4 years
Reelfoot Lake, Tennessee	
Schoffman, 1941	3 - 4 years
Upper Mississippi River navigation pools	
Butler & Smith, 1950	4 - 5 years
Salt River, Missouri	
Purkett, 1958	5 - 6 years
Lake Winnebago, Wisconsin	
Priegel, 1969	6 years
Wheeler Reservoir, Alabama	
Wrenn, 1968	6 - 7 years

TABLE 2
(Continued)

Site and Author(s) of Study	Time Required by the Average Drum to Reach a Total Length of 356 mm (14 in)
Missouri River Main Stem Reservoirs South Dakota	
Nelson, 1964	5 - 6 years
Swedberg, 1965, 1968	6 - 7 years
Missouri River Main Stem Reserviors North Dakota	
Benson, 1968	5 - 6 years
Lake Erie Western Basin	
Van Oosten, 1938	5 - 6 years
Larmoyeux, 1951	5 - 6 years
Edsall, 1967	6 - 7 years
Busch Unpublished Data 1974	6 - 7 years
Barickman Unpublished Data 1977	7 - 8 years
Lake Erie Central Basin	
Foell, 1974	7 - 8 years

[1] Adapted from Foell (1974)

TABLE 3

TOTAL LENGTH (mm) OF FRESHWATER DRUM FROM WESTERN LAKE ERIE AT THE END OF GIVEN YEARS OF LIFE[1]

Study	Years of Life Completed				
	3	4	5	6	7
Barickman (1977)[2]	219	254	284	314	345
Busch (1974)[2]	243.4	280.8	318.9	352.0	375.4
Edsall (1967)	255.4	290.7	329.3	352.2	382.9
Larmoyeux (1951)	266.7	307.3	340.4	373.4	401.3
Van Oosten (1938)	276.9	317.5	348.0	381.0	403.9

[1] Adapted from Foell (1974)

[2] Unpublished data

describe by linear regression because of the multi-modal distribution produced by extended spawning.

Food and Feeding Habits

One might suspect, based on many of the common names (Table 1) and the specialized anatomical features such as the subterminal mouth and large moliform pharyngeal teeth, that the freshwater drum is a bottom feeding carnivore which utilizes mollusks and benthic crustaceans as a major portion of its diet. Early studies of freshwater drum food habits (summarized by Daiber 1950) have supported that the major portion of the diet of adults was mollusks, supplemented by crustaceans and fish. Young drum fed mainly on benthic invertebrates, especially insects.

Recent food studies in western Lake Erie seem to indicate that mollusks are rarely a major part of the adult diet and that benthic insects and crustaceans are far more important (Daiber 1950, 1952). Price (1963) states that the species is notably omniverous in Lake Erie. In western Lake Erie the larger drum fed primarily on mayflies (Hexagenia) and amphipods, while young-of-the-year fish (up to 30 mm) fed mainly on copepods (Cyclops and Diaptomus) and amphipods (Gammarus) (Daiber 1952). More recently, in Lake Erie, the midge larvae (Chironomidae) and sludge worms (Oligochaetae) have become important in the diet (Price 1963). This shift in the diet from Hexagenia to midges and oligochaetes is not suprising in light of the near disappearance of mayflies in Lake Erie reported by Britt (1955) and Carr and Hiltunen (1965). Griswold and Tubb (1977) noted that the food habits of freshwater drum in Sandusky Bay, Lake Erie have seasonal trends based on availability of food. They noted a large percentage of fish in the diet in the fall when large numbers of juvenile gizzard shad (Dorosoma cepedianum) were available. During my thesis research, I observed a high degree of cannibalism in Sandusky Bay when many juvenile drum were available. I also observed that large drum (> 450 mm) often contained large snails, (Viviparus japonicus), in the late summer (one 728-mm specimen contained 14 operculae with soft parts attached). Although both Price (1963) and Griswold and Tubb (1977) allude to the importance of food availability in relation to food habits, it is unfortunate that no researcher has determined electivity indices (Ivlev 1961) which equate food preferences with respect to available prey. Recent food habit studies in lakes or reservoirs (Moen 1955; Dendy 1946; Priegel 1967; Swedberg 1966, 1968) and rivers (Whitaker 1975) in other geographical areas parallel the findings for Lake Erie.

A description of the feeding methods of freshwater drum, based on aquaria observation when fed minnows and crayfish, was given by Daiber (1950). Prey were seized by a sudden and forceful suction of the extended mouth. When bottom feeding, drum have been observed to possess a mechanism for straining; such that, suitable bottom materials are sucked into the mouth and expelled through the opercles in a constant stream as the fish moves over the substrate. This mechanism likely explains the absence of large amounts of inorganic ooze in stomachs even when benthic invertebrates are common food items (Foell 1974). In light of their omnivorous food habits, it is likely that drum represent a serious competitor to other species when they are numerous, such as in western Lake Erie (Price 1963) and Lake Winnebago, Wisconsin (Priegel 1967).

Parasites

Bangham and Hunter (1939), in studying the parasites of Lake Erie fishes, reported that the freshwater drum displayed a high degree of parasitic infestation with all but 4 of 48 individuals examined showing some degree of parasitism. A diverse fauna of parasites were identified including trematodes, cestodes, nematodes, acanthocephalons, and myxosporidians. Vendeland (1968) surveyed freshly killed specimens of freshwater drum from Lake Erie and included Hirudinea, aquatic insect larvae and Ectoprocta as additional parasites of this species. Vendeland (1968) also reviewed the literature associated with parasitism of freshwater drum. Hoffman (1967) lists the parasites of this species in North American waters. Bangham (1972) resurveyed the Lake Erie fish parasites and found a much higher incidence of parasitism in all fishes than the 1939 survey (98.5% vs 58.3%). He found 100% of 88 freshwater drum examined were parasitized by one or more of 23 parasite species. He contributed most of this increased incidence of parasitism to improved techniques of recognizing many smaller and encysted forms rather than an increased infestation. Bangham (1972) discussed parasite species of economic importance to Lake Erie fish. Of these species, freshwater drum contained five: Philometra cylindracea, a filiform nematode responsible for parasitism of the eye sockets; Eustrongylides sp., a flesh invading nematode; metacercariae of the larval genus Diplostomulum, often found parasitizing the eye lens; the fluke, Posthodiplostomum minimum, as a liver and mesentary cyst; Proteocephalus ambloplitis, the so called bass cestode, frequently invading the liver, mesenteries, and gonads, often responsible for sterility. Crites (1975) was the first to demonstrate the

Philometra sp. to be the cause of the "pop-eyed" condition of many freshwater drum, especially those under 200 mm, but not young-of-the-year. Many authors have described additional parasites or noted their occurence in freshwater drum from Lake Erie and other areas: the trematode, *Cotylogaster occidentalis* Nickerson, (Dickerman 1948; Frederickson 1972); the crustacean, *Lernaea cyprinacea*, (Whitaker and Schlueter 1975); the piscicolid leeches (Branson 1961; Nagel 1976); and the nematodes *Contracaecum* sp., *Spinitectus carolini*, *Rhabdochona decaturensis*, (Spall 1968).

Response to Physical Environment

The freshwater drum apparently is able to withstand rather low oxygen conditions (less than 2 ppm) based on catch data from southern reservoirs where fish distribution was determined with respect to physicochemical factors (Dendy 1945; Eley et al. 1967). The final temperature preferendum (Fry 1947) and heat and cold shock limits of many Lake Erie fish including freshwater drum were reported by Reutter and Herdendorf (1975, 1976). They found the final temperature preferendum of drum was 26.5 C for adults and 31.3 C for young-of-the-year during the summer (21.2 C ambient temperature). All species tested were found to follow this pattern for preference of temperatures higher than ambient. Heat and cold shock tests with drum showed the lethal CTM (Critical Temperature Maximum) to be 34.0 C during the summer. Similarly, Cvanvora et al. (1977) found an LD50 value for lethal temperature of young-of-the-year freshwater drum of 32.8 C. Cold shock was not a problem during any season. However, Reutter and Herdendorf's (1975, 1976) tests used 11.1 C drops or increases from ambient temperature and Sisk (1968 unpublished data) found that a sudden drop from 22.2 C to 8.3 C(13.9 C drop) produced about 90% mortality within 5 hours. McCarraher (1971) studied the ability of different fishes to tolerate alkalinity in natural lakes in Nebraska. He found that drum were not especially tolerant to high alkalinity and recommended stocking in ponds with less than 900 ppm total alkalinity. Apparently the drum is not particularly effected by turbidity although Trautman (1957) believes that it prefers clear waters. The pelagic spawning habits and planktonic eggs should be a definite reproductive advantage under turbid conditions.

Economic Importance

The freshwater drum has traditionally been a fish of rather low esteem both to commercial and sport fishermen in Lake Erie. Yet, commercial fishing annually removes 10 million pounds of the species valued at $300,000 from the Great Lakes and Mississippi River watersheds (Foell 1974). Table 4 summarizes the commercial catch of this species for the Great Lakes.

Summarizing the data of Baldwin and Saalfield (1962) and Anonymous (1970) for the 21 year period from 1948 to 1968, the average catch of freshwater drum for the Great Lakes is 4,334,000 lb. This catch is proportioned between the U. S. and Canada as follows: Ohio 3,232,000 (74.6%); New York, Pennsylvania, and Michigan combined 83,000 (1.9%); Ontario 1,019,000 (23.5%). It can be seen that the majority of the Great Lakes catch comes from Ohio, especially from Lake Erie's western basin (Daiber, 1950). Fig. 2 summarizes the Ohio catch from 1915 to 1977. The 1977 Ohio catch was 805,000 lbs valued at $21,900 (06 cents/pound average).

TABLE 4

DISTRIBUTION OF GREAT LAKES FRESHWATER DRUM CATCH

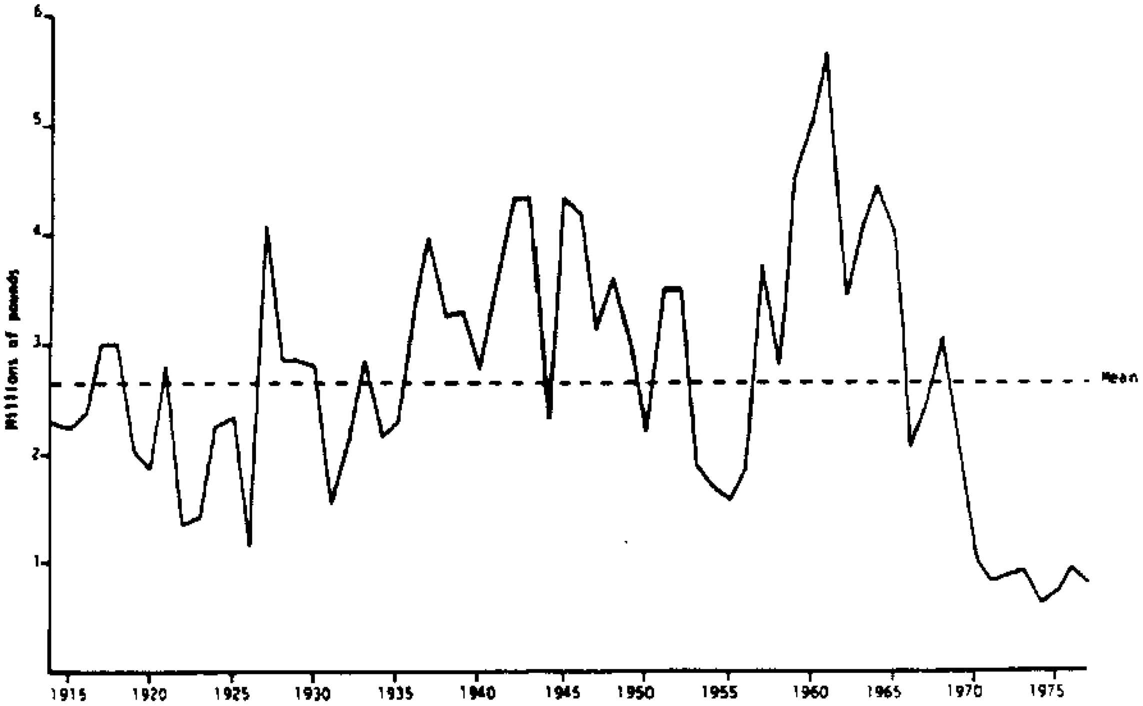
(AVERAGE THOUSANDS OF POUNDS FOR 5 YR PERIODS

FROM 1899-1977)

Year	Lake Huron	Lake Michigan	Lake Erie	Total Great Lakes	% Lake Erie
1899, 1903, 1908, 1913[1]	-	-	-	945	-
1914-1919[1]	-	-	-	2,504	-
1920-1924[1]	-	-	-	2,032	-
1925-1929[1]	-	-	-	2,798	-
1930-1934[1]	-	-	-	2,391	-
1948-1952[2]	4	37	4,037	4,078	99%
1953-1957[2]	27	8	2,964	2,999	99%
1958-1962[2]	66	3	5,697	5,766	99%
1963-1967[2]	86	1	4,394	4,480	98%
1968-1972[2,3]	52	1	1,977	2,029	97%
1973[4]	-	-	1,506	-	-
1974[4]	-	-	1,054	-	-
1975[5]	-	-	1,264	-	-

[1] Baldwin and Saalfield 1962
[2] Anonymous 1970
[3] Anonymous 1971, 1972, 1973, 1974
[4] Anonymous 1975
[5] Anonymous 1976

Figure 2. Ohio freshwater drum landings Lake Erie 1914-1977.[1]



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[1] Anonymous 1978

The Mississippi River system has the greatest commerical harvest of drum. The catch in the Mississippi River system for 1931 was 3,905,000 lb valued at $143,000 (Van Oosten 1938). The 1974 production in the Mississippi River system was 6,089,000 lb valued at $738,000 (Anonymous 1977). Mississippi River drum sold for about 12 cents per pound prior to 1950 (Butler and Smith 1950). The third most extensive commercial fishery for drum is in Lake Winnebago, Wisconsin. About ½ million pounds were harvested annually as part of rough fish removal programs for 25 years prior to 1953 (Wirth 1958). In 1953 an intensified rough fish removal program was initiated in Lake Winnepeg with a peak catch in 1957 of about 4.3 million pounds (Priegel 1971). Benson (1968) noted that a small commerical fishery amounting to 4,000 lb exists in Missouri River main stem reservoirs. The drum is more highly prized as a food fish in Lousiana (Gowanlock 1933). In Alabama, market demand is low and drum bring only about 5 cents/lb (Wrenn 1968). As Foell (1974) so aptly stated:

> "It is important to note that these figures represent only a portion of the drum that are actually taken by commercial fishing. In order to not flood the market, and to protect an already meager profit margin, many fish distributors purchase only a limited amount of the species from commercial fishermen who return the excess catch to the water."

The evident downward trend in Ohio commerical catch (Fig. 2) is likely an artifact produced by the reporting procedures; drum are possibly being included with "other" rough fish, as "animal food", or as "scrap" for rendering to oil and fishmeal. The abundance of drum is most likely as high as in previous years. Edsall (1967) reported that drum were the second most abundant species in Lake Erie bottom trawl explorations in 1958, comprising 21% of the catch by weight. Bowman (1974) reported that drum were the 4th most abundant species (7.7% by weight) in Lake Erie bottom trawl explorations from 1962 to 1966. Only the tremendous increases in alewives and smelt lessened its importance. Van Meter (1973) estimated the total commercial catch of freshwater drum captured by both trap nets and haul seines to be the greatest poundage of all commercial species in Lake Erie. Catch in this instance refers to actual capture by commercial gear rather than removal from waters as harvest. Wolfert et al. (1978) found freshwater drum to be one of the most common species in an inshore area (out to 10-m depth) of southcentral Lake Erie.

The importance of drum in the sport catch was noted by Jackson (1957) and Houser and Heard (1958) in Oklahoma reservoirs where only moderate populations existed. The contribution of drum to the sport fishery of Lake Erie is demonstrated by Keller (1964) and Baker et al. (1976). Keller (1964) found that drum were the second or third most harvested species in Lake Erie, representing about 2-4% of the total catch and having a catch rate of about .15 fish/hr from 1958 to 1960. Baker et al. (1976) found quite similar results: catch per angler hour 0.12, and an estimated harvest of 295,521 fish (410,137 lb), exceeded only by yellow perch and white bass. It sould be noted that these creel figures represent harvest rather than catch. Many more drum are caught and released than are kept by anglers. Scott and Crossman (1973) gave testimony to the game fish qualities of drum through their informative discussion of an 11 pound, 8 ounce drum which won the Ontario, Canada big fish contest as a misidentified smallmouth bass (Micropterus dolomieui), a record which was still in existence in 1970.

The flesh of freshwater drum from Lake Erie has long been refuted as being poorer in quality than that of Ohio River fish (Trautman 1957). This, however, may be a local prejudice against drum due to the long history of availability of more renowned food fishes such as trout, whitefish, Stizostedion sp. and yellow perch (Perca flavescens) in Lake Erie. Baldwin et al. (1969, 1970) studied the palatability of freshwater drum flesh with regard to the size of fish, portion of body, and relationship to Mississippi River pollution sources. They found the drum flesh to be effected more than other species tested with regard to water quality changes, that size was insignificant to flavor, but a possible preference for the posterior portion of flesh did exist. Other workers (Anonymous 1952a, 1952b, 1953; Karrick et al. 1956; Thurston et al. 1958; Krzeczkowski 1970) have determined the composition of drum flesh (moisture, oil, ash, protein, fillet yield) in hopes of development of new commercial markets for drum. One fact noted by these authors was that drum oil content was highly variable but significantly lower (2%) in the spring. Stone (1975) researched the development of food products for human consumption from freshwater drum. He found through taste panel tests that an acceptable fish stick could be produced from this underutilized species.

Although a portion of the market demand is for human consumption as whole fish or fillets, the majority of drum are used for the animal food industry (Edsall 1967; Scott and Crossman 1973; Stone 1975). Foell (1974) suggested, and I wholeheartedly agree, that the common practice of discarding tons of dead and dying drum from commercial gear for lack of suitable market is extremely wasteful in view of the demand for and high cost of fish meal. Presently, one manufacturer of fish meal in the Cleveland, Ohio area has accepted a supply of one million pounds of rough fish (about 70% drum) for processing. This amount was provided by a single haul-seine operator in about a three week period during May and June (Lee Stinson, personal communication). A possible problem with the marketing of drum pet food, fish meal, and oil is the contamination by pesticides. Dugal (1968) and Kleinert et al. (1968) stated however, that the levels of chlorinated hydrocarbons in Lake Erie freshwater drum were below the allowable standards for human consumption as well as animals.

METHODS AND MATERIALS

Transport System

A transportation system was developed to transport fish under controlled conditions during experiments. Project constraints dictated that the system be portable, inexpensive, and simple to operate and maintain. Eight transport tanks were constructed of 3/4-in marine plywood and waterproofed both exteriorly and interiorly with epoxy resin. Tank dimensions were 61 cm X 91 cm X 69 cm and had a working capacity of 227 liters. The tanks were mounted on a 3.5-T flatbed truck with a 14-ft bed. Oxygen was supplied to these tanks either by 12-V DC agitators (Minnowsaver Model 9A) mounted individually in tank lids or by commercial bottled oxygen (33-cu ft cylinders). The bottled oxygen delivery system was controlled by a regulator and oxygen was bubbled through 0.64-cm OD latex tubing which had been perforated on a sewing machine. Even distribution of oxygen in tanks was assured by weaving the tubing through a rigid "H" structure constructed of 3/4-in PVC pipe and brass rod. The transport system is shown in Fig. 3.

Transport Water Experiments

Site Descriptions. The first season of field work was completed during the summer of 1976. Fish were obtained from commercial seiners located along Sandusky Bay in the western basin of Lake Erie (Fig. 4). The majority of the fish were provided by the Port Clinton Fish Co. (site A) after operations of other fishermen ceased in mid-June. Fish were transported 135 km from the seine sites to the Ohio Department of Natural Resources District Three Headquarters near Akron, Ohio, where they were placed in hatchery ponds. Hatchery ponds #6 and #8 were used to hold fish and monitor delayed mortality. Both ponds were drainable and surface water was pumped continuously from nearby North Reservoir for water exchange. Both ponds were about 0.25 ha with a mean depth of 1.0 m and maximum of 1.5 m. *Chara* sp. grew on the bottom of both ponds and pond #6 had a moderate growth of *Ceratophyllum demersum* throughout.

In the 1977 field season, fish were transported exclusively from the Port Clinton Fish Company seine site. Fish were similarly transported to the Ohio Department of Natural Resources (ODNR) Akron facility; however, only one pond, #4 was utilized for the experiment. This pond was quite similar to those previously described.

Experimental Design. The purpose of the transport water experiments was to test the effects of various treatments, added to the water in transport tanks, on delayed mortality of freshwater drum.

In 1976, a 2^6 completely crossed factorial design was used. The experimental design with 64 possible combinations of the 6 treatments is given in Fig. 5. The null hypothesis was that none of the treatment main effects or two level interactions would have a significant effect ($\alpha = 0.05$) on delayed mortality. Each treatment with the exception of temperature control was either present in or absent from transport tanks. The two levels of the variable, temperature control, were ambient temperature or addition of ice to cool transport tank water to 21 C. The treatments were randomly assigned to individual transport tanks. Two blocks of 32 treatment combinations each were transported to complete one replication of this experiment. Replicates were confounded or separated into blocks to ensure that all treatment combinations could be transported within a two week period. Confounding resulted in block

Figure 5. The 1976 transport water experimental design and listing of treatments. The randomized 2^6 completely crossed factorial experiment confounded into blocks is shown.

Block 1

O_2 A ICE F	S A ICE F	O_2 ICE F B	ICE B
O_2 S ICE F	O_2 S A ICE	S ICE F B	S ICE
S A F B	O_2 F	S A ICE B	O_2 S ICE B
A ICE F B	ICE F	A F	F B
O_2 S	O_2 A	O_2 A F B	S A
O_2 S ICE B	O_2 B	O_2 S A F	O_2 S A ICE F B
O_2 ICE	Control	A B	A ICE
O_2 A ICE F	O_2 S F B	S F	S B

Block 2

S ICE B	F	O_2 A B	O_2 A F
O_2 S B	A ICE B	ICE F B	A ICE F
O_2 S A F B	O_2	S ICE F	O_2 ICE B
ICE	O_2 A ICE	S A ICE F B	O_2 A ICE F B
A F B	O_2 S F	O_2 S A ICE B	O_2 s A
O_2 F B	O_2 S ICE F B	S	O_2 ICE F
S A B	S A F	S A ICE	A
S F B	B	O_2 S A ICE F B	O_2 S ICE

Treatments

bottled oxygen (O_2)
5 g/liter NaCl (S)
1 mg/liter MS-222 (A)
temperature control (ICE)
1 mg/liter Malachite green (F)
1 mg/liter terramycin (B)

effects becoming inseparable from the highest level interactions. It was assumed that highest level interactions would be insignificant and only main effects and 2-level interactions were tested. Two replications of the entire experiment were performed on the following dates for each block: 23 May-5 June, 24 June-14 July; 8-18 August, and 13 September - 1 October.

In 1977, a randomized block 6 X 2^3 factorial design was used to test a new set of treatment variables. This design and a listing of variables is given in Fig. 6. The main effects and two level interactions of these variables were tested for significant effects on delayed mortality at an α level of 0.05. Treatments were assigned to tanks at random. Two blocks of the experiment were performed 27 July-3 August; and 24-31 August. Each treatment combination was represented in both blocks and each block was regarded as a fixed main effect, "season". Season was excluded from interactions in analysis to provide more degrees of freedom for the error term and, therefore, a more powerful F-test of main effects (Joseph Kasile, personal communication).

Experimental Procedures. In 1976, treatments were added to each tank and agitation was begun prior to loading fish into tanks. The transport water source was Sandusky Bay. Individual fish (> 250 mm) were captured by gloved hands from the suspended commercial seine bag (Fig. 7) and placed in #3 galvanized wash tubs containing about a 1/3 volume of treated water from transport tanks. Fish were loaded 25/tub and two tubs were placed in each transport tank. Transport tanks were loaded in sequential order, tanks on the front of the truck first, rear tanks last.

Figure 6. The 1977 transport water experimental design and listing of treatments. The 6 x 2^3 factorial experiment is divided into blocks by season.

Block 1

1 A 60	1 60	1 A 120	1 120
2 A 60	2 60	2 A 120	2 120
3 A 60	3 60	3 A 120	3 120
4 A 60	4 60	4 A 120	4 120
5 A 60	5 60	5 A 120	5 120
6 A 60	6 60	6 A 120	6 120

Block 2

1 A 60	1 60	1 A 120	1 120
2 A 60	2 60	2 A 120	2 120
3 A 60	3 60	3 A 120	3 120
4 A 60	4 60	4 A 120	4 120
5 A 60	5 60	5 A 120	5 120
6 A 60	6 60	6 A 120	6 120

Treatments	Levels
"salts"	1 control
	2 NaCl (5g/L)
	3 $CaCl_2$ (1g/L)
	4 Na_2HPO_4 (1g/L)
	5 $CaCl_2$ plus Na_2HPO_4 (1g/L each)
	6 Malachite green plus terramycin (1mg/L each)
Agitation (A)	present or absent
Fish loading density	120g/L or 60g/L
Season	Block 1 (B1) Block 2 (B2)

Fish were then transported 6 h to the experimental ponds. The 6-h transport included 3 h of actual travel and 3 h of simulated transport on the parked truck. Water in all tanks was agitated during the entire transport period.

Following transport, fish were stocked in the ponds. Twenty fish were selected for tagging and stocking from each tank. Fish which were obviously dead or distressed were excluded from stocking. Selected fish were caught by hand or dip net and a numbered monel metal tag (chick wing band size #3) was inserted in the tissue between the premaxillary and maxillary bones of the upper jaw. Tagged fish were transferred 3-4/dip net directly from tanks to ponds. Ten fish were placed in each pond from each treatment. All untagged fish from each tank were measured (± 2 mm) and weighed (± 2 g).

The fish were held in the ponds at least 2 weeks after the last group of treatment combinations in a block had been stocked to determine delayed mortality. During the holding period, the surface, bottom, and perimeter of ponds were monitored daily for dead fish, which were removed and tag numbers recorded. At the completion of the holding period, ponds were drained; surviving fish were counted and tag numbers were noted.

Dissolved oxygen, temperature, pH, and CO_2 were monitored in transport tanks prior to fish loading, after arrival at experimental ponds and at the completion of transport. Each day of fish transport, temperature,disolved O_2, pH, and CO_2 were measured in Sandusky Bay. Once during each experimental block, total alkalinity, total hardness,and total chlorine were determined. Similarly, each experimental pond was monitored on transport days for dissolved oxygen, temperature, and pH. Twice during each block total alkalinity, total hardness, and total chlorine were determined. All O_2 and temperature measurements were taken with a YSI Model 54 temperature-oxygen meter and other water quality measurements were done with a Hach DR-EL portable water engineering laboratory.

In 1977, procedures were modified somewhat from those of 1976. Oxyen was introduced as a constant and agitation became a treatment. Agitation was introduced as a variable because it was feared that currents produced in transport tanks could be causing stress to fish and possibly contributing to greater mortality. Transport water was obtained from a Sandusky municipal water supply and allowed to stand overnight for chlorine dissipation prior to fish transport. Treatments were randomly assigned to transport tanks and added along with O_2 prior to fish loading. Tanks were loaded with fish as previously described except loading was random rather than sequential. Oxygen was bubbled to tanks throughout the 6 h transport; otherwise, transport remained unchanged. Tagging procedures were changed as follows: all fish (25) were tagged from tanks at the low density level, and 25 healthy-looking fish were randomly selected for tagging from tanks at high loading density. If transport water temperature differed from pond water temperature more than 5 C tanks were tempered by exchanging about 1/3 of the tank's water for pond water, ½ h before stocking ponds. The municipal water quality was measured once to determine its overall character. Transport tank water quality was not measured, and pond dissolved oxygen and temperature were checked irregularly.

Analysis. A data management system was designed to aid in accurate compilation and storage of data. Field data was transferred to IBM key-punch cards in a sturctured data tree format. Programs were developed to read and error check data which were stored on magnetic tape. In 1976, an analysis of variance of water treatment data was done utilizing an IBM 370 computer and a package analysis routine, CANOVA (Poor, 1973). The % delayed mortality was the dependent variable. The 1977 water treatment data was handled similarly except the analysis of variance was accomplished with the statistical package SAS 76, GLM procedure (Barr et al. 1976). The dependent variable, % delayed mortality, was transformed with a square root transformation (Steel and Torrie 1960) to correct for skewedness of distribution toward 100%. A Tukey's test (Steel and Torrie 1960) was done on the 6 levels of the treatment, "salt", to compare mean mortalities for significant ($\alpha = 0.05$) differences.

Stressor Experiment

Site Description. This experiment was performed during the summer of 1977. Fish were obtained from the Port Clinton Fish Co. (Fig. 4). Fish were held in 6.1-m^3 nylon nets in two locations. One location was approximately 100 m west and 50 m off shore from the Port Clinton Fish Co. seine site in Sandusky Bay. The second location was a 3-ha pond located near Bayview, Ohio, by the junction of Ohio Rt. 269 and Ohio Rt. 6. This pond was formerly operated as a pay-fishing pond (Bayview Fish Farm) and had a mean depth of about 1.8 m and a maximum depth of about 2.5 m. The pond was void of higher aquatic plants.

Experimental Design. The purpose of the stressor experiment was to recognize which stressor, capture, transport, or stocking in ponds, contributed significantly to delayed mortality of freshwater drum. Fish were transported 6 h or transferred immediately to either Sandusky Bay or Bayview Pond where they were kept one week in nylon holding nets to determine delayed mortality. The design used was a 2 X 2 factorial experiment with the two treatments, "location" and "transport" completely crossed. The treatment "location" had two levels, Sandusky Bay and Bayview Pond and the treatment "transport" had two levels, 6-h transport or immediate transfer. Each treatment combination was replicated (two groups of fish treated identically) within one experimental trial. The null hypotheses were that delayed mortality would not be greater in the Bayview Pond and also no greater for fish transported 6 h. This experiment was repeated 4 times: 6 July-13 July, 18 July-25 July, 26 July-2 August, 26 August-2 September.

Experimental Procedures. Fish holding structures were constructed at each location (4/location). Metal conduit stakes were used to support the square nylon nets. Nylon nets were 1.8 m on a side (6.1 m^3) with 0.4-cm mesh. The nets also had covers of the same material with a 60-cm opening along one side for fish stocking. A rigid pipe framework was erected above the nets so that they might be raised with a rope and pulley system. Fig. 8 shows the arrangement of nylon holding nets. The ability to raise nets made it easier to view fish with a minimum of handling.

Fish were obtained from the Port Clinton Fish Co. seine site (Fig. 4) and loaded into the transport tanks 25 fish/tank as previously described; except that two tubs of fish (25/tub) were transferred immediately by rowboat to the Sandusky Bay holding nets. These tubs were oxygenated by 12-V-DC agitators. Fish were placed in nets, one tub/net. All transport tanks contained 5 g/L NaCl and compressed oxygen was bubbled into tanks. Two tanks of fish were transported to the nearby Bayview pond (20 min) and transferred immediately into the holding nets. The remaining 4 tanks of fish were transported 6 h, and two tanks of fish were placed in the remaining holding nets at each location, the pond and the bay.

All fish were held in the nets 1 wk, and Bayview pond nets were raised daily to monitor mortality. After the 1 week holding period, nets were removed and surviving fish enumerated. Dissolved oxygen and temperature were monitored daily in Bayview pond and occasionally in Sandusky Bay. Addition water quality measurements were taken to characterize Bayview pond water.

Analysis. A computer assisted analysis of variance (ANOVA) was done to determine significant effects ($\alpha = 0.05$) of treatment on delayed mortality. The % delayed mortality was used as the dependent variable. The statistical analysis package SAS 76, procedure ANOVA (Barr et al. 1976), was used to analyze the data.

Tag Effect Experiment

Site Description. The experiment was performed at two locations which have been previously described. These locations were the Bayview pond and the ODNR Akron hatchery pond #4.

Experimental Design. The purpose of this experiment was to determine if tagging fish had a significant effect on delayed mortality. Percent delayed mortality was the dependent variable. The null hypothesis was that tagged fish would not experience significantly ($\alpha = 0.05$) different delayed mortality than would untagged controls. Each experimental group (tagged fish and untagged control) was replicated (2 identically treated groups) within one experiment. The experiment was done once at the Akron Hatchery Pond and once at Bayview Pond.

Experimental Procedures. In each experiment, 4 tubs of fish (25 fish/tub) were randomly loaded in transport tanks (1 tub/tank) that contained 5 g/liter NaCl and received bubbled O_2. Fish were transported

6 h, 50 fish were tagged as described in the transport water experiment, and the 4 tanks of fish were placed one tank/net in the holding nets. Fish were held 1 week and nets were emptied to determine survival.

<u>Analysis</u>. The mean % delayed mortalities were calculated from the 2 replicates of each experimental group. These means were compared for significant differences ($\alpha = 0.05$) by an unpaired *t*-test.

RESULTS AND DISCUSSION

Transport water experiments. In general, % delayed mortality was quite high (93.7 ± 11.1SD) and variable when compared to the % mortality at the conclusion of the 6-h transport (3.8 ± 0.2SD). Harman (1978) reported transport mortality averaged 5.1% and ranged from 0-56% in experiments run concurrently with this experiment. Bouch and Ball (1966) reported high delayed mortality (85%) in rainbow trout (Salmo gairdneri) caught by angling and held 10 days in live boxes. Capture of muskellunge (Esox masquinongy) by seine from a pond (21 C) was found to produce a greater physiological response than marking by fin-clip and transport by truck (Miles et al. 1974). The intense struggling of fish "played" to exhaustion by anglers may be closely compared to the stresses involved in commercial seining operations. Commercially seined fish have been actively swimming to avoid the seine for 3-4 hours, and ultimately fish are confined to a small area where hyperactivity and hypoxia cause rapid exhaustion. Harman (1978) found that loss of equilibrium and a uniform hemmoraging in the skin were distress symptoms of drum held in commercial seine bags, and the onset of these symptoms was most rapid during May through July when spawning populations of drum in Sandusky Bay produce abnormally large catches of fish (10-30 metric tons), primarily drum.

The analysis of variance of data from treatment water experiments is given in table 5 . Because delayed mortality was high and not randomly distributed it was necessary to transform the data using the formula, square root of (100 - % delayed mortality + $\frac{1}{2}$), (Steel and Torrie 1960). In 1976, the only treatment which significantly ($\underline{P}=0.013$) reduced delayed mortality was the addition of 5 g/liter NaCl. Similar beneficial effects of NaCl to transported fish have been reported for salmonids (Long et al. 1977; Wedemeyer 1972), clupeids (Collins and Hulsey 1963), and African freshwater fish (Hattingh et al. 1975). Wedemeyer (1972) demonstrated that some blood parameters of coho salmon (*Oncorhychus kisutch*) and steelhead trout (*Salmo gairdneri*) fingerlings remained more "normal" if placed in 3 ppt saltwater prior to handling. However, Kirk (1976) found that blood lactate levels were not significantly different for channel catfish (*Ictalurus punctatus*) recovering from hypoxia in fresh water and 3% NaCl solution. Miles et al. (1974) similarly reported that muskellunge (*Esox masquinongy*) recovering from handling stress in fresh water and 7% NaCl solution did not differ in blood lactate. One possible beneficial effect of 5 g/liter NaCl may be an increase in osmotic pressure to a level nearly isotonic with fish blood, which lessens the osmoregulatory imbalances caused by stress.

In 1977, analysis of variance of data from the second factorial experiment that incorporated new treatments (Fig. 6) indicated that reduction in density of hauled fish, addition of salts, and season of capture significantly ($\underline{P} \leq 0.05$) affected mortality (table 5). Reduction of density of fish hauled to 60 g/liter and late season transport (August vs June) decreased delayed mortality. The treatment "salts", though significant, required additional statistical treatment to determine which of the 6 levels significantly affected mortality. A Tukey's all possible pair-wise comparison (Steel and Torrie 1960) revealed that a combination of NaCl and $CaCl_2$ had caused significantly ($\underline{P} \leq 0.05$) greater mortality, whereas NaCl alone was not different from controls. Fish which were exposed to the combined treatment of NaCl and $CaCl_2$ were lacking in mucous and represented the majority of all mortalities in

TABLE 5

RESULTS OF ANALYSIS OF VARIANCE ON THE EFFECTS OF SEVERAL TREATMENTS, ADDED TO TRANSPORT TANKS, ON THE DELAYED MORTALITY OF FRESHWATER DRUM TRANSPORTED FROM SANDUSKY BAY, LAKE ERIE, TO HATCHERY PONDS IN AKRON, OHIO, SUMMERS OF 1976 and 1977[1].

1976		1977	
Treatment	Signif. Level	Treatment	Signif. Level
NaCl	P=0.013	Salts[2]	P=0.002
O_2	P=0.554	Agitation	P=0.664
MS-222	P=0.128	Density	P=0.001
Temperature control	P=0.344	Season	P=0.001
Malachite green	P=0.974		
Terramycin	P=0.288		

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[1] % delayed mortality was dependent variable.

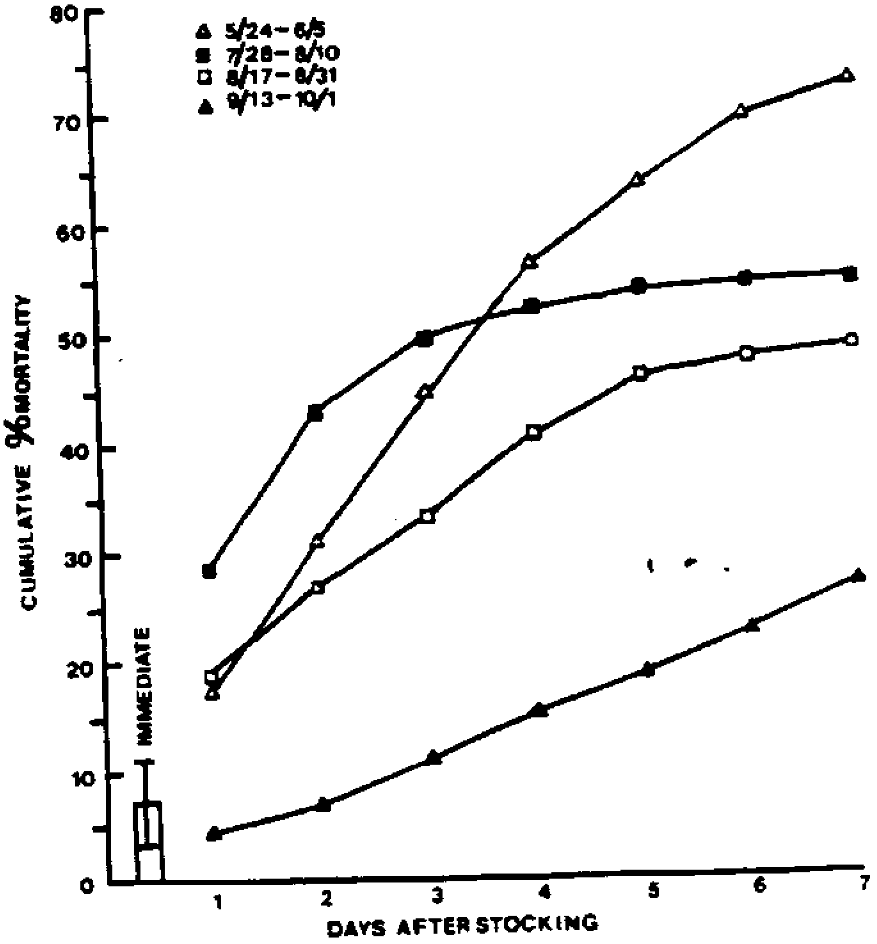
[2] Complex variable having 6 levels: no salt, NaCl, $CaCl_2$, Na_2HPO_4, $CaCl_2$, and Na_2HPO_4 combined, and Malachite green and terramycin combined.

this experiment. Apparently, this combination produces some type of detergent reaction which dissolves the fishes skin mucous layer and probably perpetuates osmoregulatory imbalance.

Because the majority of mortalities were associated with the "salt" treatment, it would be less likely that significant differences would be recognized between other treatments and controls. The effect of season was most likely associated with observed decreases in the seine catch rather than temporal effects. Fewer fish crowded in the seine bag and later in the transport tanks would create less stress from muscular activity and hypoxia, thereby increasing survival. Harman (1978) measured variables associated with the seine capture process and found that the time drum spent in the commercial seine bag after it had been beached was the most important variable. This elapsed time had a highly significant effect on later delayed mortality. The delayed mortality from these experiments was reported as 27.5 ± 2.9% (Harman 1978). Similarly, Mitzner (1969) found that net density was the most relevant factor contributing to mortality of crappie (Pomoxis sp.) captured in pound nets. The failure of NaCl to improve survival may have resulted from an overriding tag effect which masked treatment effect (See tagging experiment). Delayed mortality of drum observed daily in ponds was greatest in the first 3 days after stocking and was nearly total in 1 week (Fig. 9). A similar delayed mortality pattern was reported for chinook salmon smolts (Oncorhyncus tshawytscha), by Long et al. (1977).

The water quality measurements taken in the transport tanks before and after fish hauls and the measurements of pond water quality did not reveal any changes or conditions which would be detrimental to fish survival. Fish commonly encounter wide variations in water quality in the natural environment.

Figure 9. Mean % immediate mortality and cumulative daily delayed mortality of freshwater drum transported from Sandusky Bay, Lake Erie, to hatchery ponds at Akron, Ohio, summer 1977. Fish from individual treatments were combined.



There were definite problems associated with the delayed mortality observations in this experiment. Typically, less than half of all the drum which died floated to the surface and aquatic vegetation or algal growth in the experimental ponds interferred with visual inspection and recovery. Animals also carried off carcasses from the pond edge. A typical recovery rate is demonstrated by the September 13 - October 1, 1976 fish transportation experiments. A total of 640 drum were tagged and stocked in the two hatchery ponds, and only 346 or 54.1% were recovered in daily mortality observations, 205 (32.03%) were unaccounted losses, and the remainder (89 fish) were fish surviving the two week holding period.

Stressor experiment. Results of the experiment to determine which stressor had the greatest effect on delayed mortality are presented in Table o and Fig. 10. Fish that were transported for 6 h and fish held in ponds survived significantly ($\underline{P} \leq 0.01$) better than fish transferred immediately to holding nets at the capture location. Capture is the most important stressor affecting delayed mortality.

Harman (1978) found that 63.8% of the variation in delayed mortality could be explained by the two capture variables, elapsed time in the seine bag and season (catch size). Blood analysis revealed significantly higher lactic acid levels, lower pH, and in vivo hemolysis of blood cells for drum which underwent simulated capture conditions (Harman 1978). Other authors (Bouck and Ball 1966; Hattingh et al. 1974) support the importance of capture as a stressing agent associated with mortality. It was not anticipated that fish which were transported and those fish which were stocked in ponds would survive significantly better than fish returned immediately to holding nets near the capture site. It is quite possible in light of the beneficial effects of NaCl, that variable

TABLE

PERCENT IMMEDIATE AND DELAYED MORTALITY OF FRESHWATER DRUM AFTER TRANSPORT OR TRANSFER TO 1.8-m^2 NYLON NETS IN SANDUSKY BAY AND BAYVIEW POND, ERIE COUNTY, OHIO, SUMMER 1977

Treatment	Dates	Immediate[c]		Delayed[d]	
		Rep. 1	Rep. 2	Rep. 1	Rep.[b] 2
Bay - not transported	7/6-7/13	4.3	4.5	90.9	95.2
Bay - transported		0.0	0.0	50.0	83.3
Pond - not transported		4.8	10.0	70.0	55.6
Pond - transported		10.0	a	55.6	a
Bay - not transported	7/18-7/25	0.0	0.0	76.0	92.0
Bay - transported		0.0	0.0	48.0	70.4
Pond - not transported		0.0	0.0	73.7	40.9
Pond - transported		4.3	4.2	45.5	43.5
Bay - not transported	7/26-8/2	0.0	0.0	32.0	44.4
Bay - transported		0.0	0.0	8.0	15.4
Pond - not transported		0.0	0.0	9.1	26.1
Pond - transported		0.0	0.0	33.0	11.5
Bay - not transported		0.0	0.0	27.3	33.3
Bay - transported		0.0	0.0	27.3	29.6
Pond - not transported		0.0	0.0	57.7	53.8
Pond - transported		0.0	0.0	8.3	11.5

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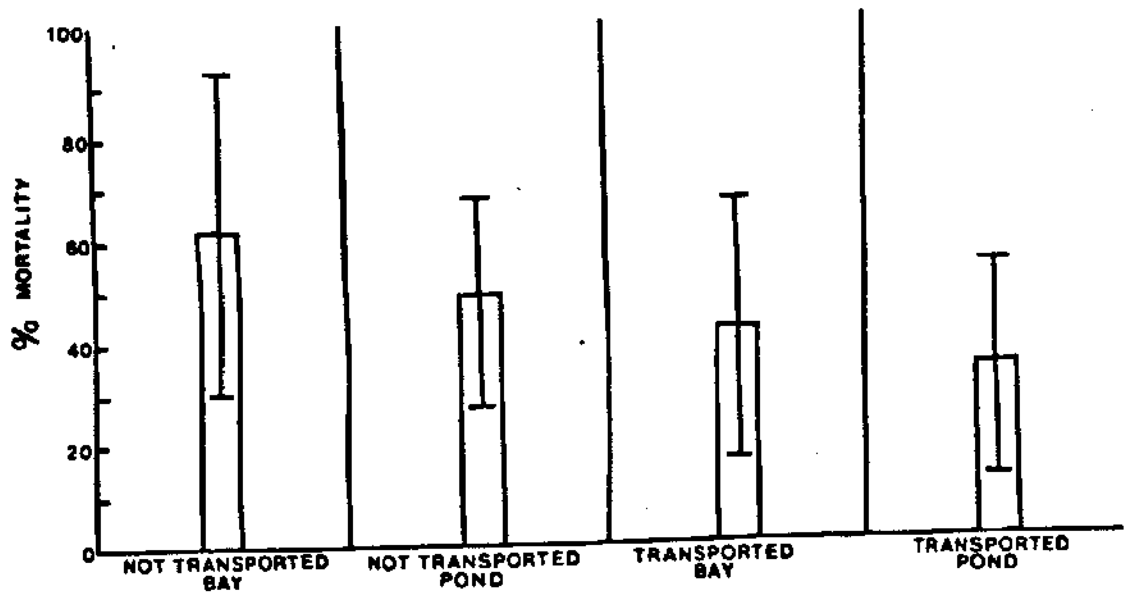
[a] 100% mortality due to failure of oxygen delivery system.
[b] Replicate nets.
[c] Immediate mortality 6 h after capture.
[d] Delayed mortality after one week.

Figure 10. Mean % delayed mortalities of freshwater drum held in nylon holding nets in Sandusky Bay and Bayview Pond, summer 1977. Means are represented by bars, and standard deviations are shown as vertical lines within bars. Fish that were not transported were transferred immediately to holding nets, and transported fish were hauled 6 h and then held. All fish were held 1 week in nets.



exposure periods of fish to the 0.05% NaCl treatment used for these experiments was responsible, in part, for better survival of transported fish and fish stocked in the Bayview pond. Drum which had been transported (6-h exposure) and drum transported to the Bayview pond (1-h exposure) apparently received more benefit from treatment than fish exposed only 20 minutes during transfer to holding nets near the capture site. The mean % delayed mortality for these experiments was 43.5 ± 15.3SD. As shown by Harman (1978) mortality decreased significantly from July 6 to August 26, which is believed to be associated with the reduced seine catches in the later season.

<u>Tagging experiment</u>. Lower delayed mortality was observed for drum held in nets during stressor experiments than for drum tagged during water treatment experiments. Table 7 presents data from the experiment to test for tag effect on delayed mortality. Tagged drum had significantly ($\underline{P} \leq 0.05$) higher delayed mortality than did untagged controls. It is hypothesized that the increased handling during tagging is the cause of the mortality rather than physical damage due to the tag itself. Parker et al. (1963) reviewed the long and short term effects of fish marking on the mortality of fishes in particular salmonids. They recommended that violent exercise should be minimized in the catching and landing process and that exercise after capture, especially exposure to air should be avoided. They suggested that "...additional mortality may be due, in the short term, to the combined effects of wounding and fatigue". Since all fish were tagged in the transport water experiments, the significantly greater mortality of marked fish compared to unmarked fish, should be somewhat randomly distributed as an overriding mortality factor. It would seem that the effect of this overriding mortality factor

TABLE 7

DELAYED MORTALITY OF TAGGED AND UNTAGGED FRESHWATER DRUM TRANSPORTED FROM SANDUSKY BAY, LAKE ERIE, TO HATCHERY PONDS AT AKRON, OHIO, AND HELD 1 WEEK IN 1.8-m^2 NYLON NETS, AUGUST 1977.

		Untagged			Tagged		
	Rep	Alive	Dead	%Mortality	Alive	Dead	%Mortality
Bayview	1	27	0	0.0	23	3	11.54
	2	25	0	0.0	19	10	34.48
Akron	1	25	5	16.67	14	11	44.00*
	2	25	2	3.85	13	10	43.48*

*Significantly higher mortality, $\underline{P} \leq 0.05$.

would be to render small differences in treatment effect on mortality unrecognizable. Treatments which were significantly different under such conditions would likely have been more highly significant had it not been for unwanted tagging effects on mortality. It was not anticipated that the handling involved in tagging drum to recognize treatment would significantly increase short term mortality rates in light of such stressful conditions encountered in the seine capture process. Apparently the additional stress of tagging further aggravates physiological imbalances initiated during capture prior to return to "normal" levels, often exceeding physiological limitations which eventually cause death.

CONCLUSIONS AND RECOMMENDATIONS

Delayed mortality of freshwater drum in stocked ponds could be held to a minimum (below 45%) if commercial fish transporters utilize the following simple methods and treatments:

1. Adequate oxygenation; agitators, compressed air or bottled oxygen.
2. Dechlorinated municipal water for transport.
3. A tank loading density of less than 120 g/L of fish, preferrably about 60 g/L.
4. Addition of common salt (NaCl) at the rate of 0.5% by weight to transport water.
5. Handling of drum should be kept to a minimum and fish with redness in the skin should not be selected for transport (Harman 1978).

Commerical fishermen supplying drum for transport could employ the following procedures to provide drum which will exhibit lower delayed mortality rates as stocked fish:

1. Reduce catch size during the peak catch periods of mid June - mid August by fishing the seine without lead ropes or with short lead ropes attached to the seine wings.
2. Close the diameter of the beached seine bag only as necessary to hand capture fish, remove fish from the seine bag as rapidly as possible, and minimize fish handling.
3. Use as much well-aereated and salt-treated water as possible in transfer tubs from the seine to hauling tanks.
4. Pump fresh water (portable submersible pump) from outside the enclosure of the beached seine bag into the bag enclosure to provide better oxygen levels through increased water circulation.
5. Hold fish in large aereated holding tanks treated with NaCl for 24-48 hr prior to sale to commercial fish transporters which would allow removal of a great percentage of fish experiencing delayed mortality.

Recommendations #4 and #5 are predictions based on the findings of this research and their feasibility for application by commercial fishermen should be further investigated. It is fully realized that some of these recommendations to commercial fishermen such as pumping water into the seine bag and holding fish in tanks for 24-48 hr would increase costs and manpower requirements. However, the end result of such practices could be a substantial increase in length of the present seasonal market for live drum transport and a possible improvement in the quality and quantity of surviving drum in stocked pay-ponds. It is quite possible that the cost-benefit of such procedures would be such that an economic gain could be realized by commercial fishermen, commercial fish transporters, and private pay-pond owners alike. If so, this would be one positive step toward increased usage of this currently underutilized species.

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