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CONTAMINANTS DATA FOR YELLOW
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FINAL DRAFT

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A SYNTHESIS OF WATER QUALITY AND CONTAMINANTS DATA FOR
YELLOW PERCH, PERCA FLAVESCENS

Steven A. Fischer
Lenwood W. Hall, Jr.
and
John A. Sullivan

The Johns Hopkins University
Applied Physics Laboratory
Aquatic Ecology Section
Shady Side, Maryland

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INTRODUCTION

The unique physical, chemical and biological parameters of the Chesapeake Bay create a suitable environment for numerous fish species. The abundance and distribution of resident and migratory fish species which utilize the Bay, as well as the recruitment potential of estuarine-reared oceanic fish species, are influenced by variables such as climate, reproductive potential, parasites, disease, natural population cycles, food availability and suitable habitat. Overharvesting of commercial and recreational fish species and habitat destruction (water quality and contaminants) are the primary factors resulting in dramatic and prolonged fish stock declines (Wohlfarth, 1986; Setzler-Hamilton, 1987; Speir, 1987). Habitat degradation resulting from adverse water quality and chemical contaminants have been suspected recently of reducing several Chesapeake Bay fish species populations (Hendrey, 1987; Klauda and Bender, 1987).

The extent and degree of spawning and nursery habitat degradation resulting from deleterious contaminant and water quality conditions within the Chesapeake Bay and related tributaries are major considerations when attempting to manage particular fish species. Populations of anadromous and resident fish species, including the yellow perch (Perca flavescens), have recently declined within the Chesapeake Bay (Hendrey, 1987; Klauda and Bender, 1987). Due to such drastically low yellow

perch stocks in the Chesapeake Bay, the state of Maryland instituted a partial ban effective in 1989. The ban prevents the collection of yellow perch by any method from 11 river systems around the Bay. The new regulation also prohibits the sale of yellow perch during the entire month of February. In addition, a creel limit of 5 yellow perch per person per day with a minimum length limit of 216 mm was implemented.

Yellow perch are residents of the Bay and spawn within the poorly buffered coastal plain freshwater tributaries. Yellow perch eggs and larvae are exposed to potentially detrimental acidic pulses. More definitive data concerning water quality and contaminant effects on the early life history stages of yellow perch are required if adequate management plans are to be implemented. Synthesis of the data can also be used to identify suitable habitat requirements.

This document was developed to provide a compilation and review of both water quality and contaminants data on various life stages of yellow perch. Data contained in this document will be useful in the Toxics Reduction Strategy for the Chesapeake Bay Program effort. A life history and ecology section on yellow perch will be prepared by other investigators and merged with this document to provide a complete review of the species.

TOXIC WATER QUALITY CONDITIONS

Toxic water quality conditions adversely affecting various life stages of yellow perch are presented in Table 1. Each parameter is discussed separately in the following sections.

Temperature

Temperature effects on yellow perch embryos, larvae, juveniles and adults were evaluated in 19 different studies. Hokanson (1977a) reported that yellow perch require increased temperatures during early ontogenetic development. Hokanson and Kleiner (1974) and Hokanson (1977b) indicated minimum and maximum median tolerance limits (TL50) for yellow perch egg stages were 6.8 and 19.9 C, respectively. Hatching varied from 2 d at 18.2 C to 30.5 d at 3.3 C according to Hokanson and Kleiner (1974). Hardy (1978) indicated that hatching occurred in 11 - 13 d at 15 C in freshwater, while 13 - 15 d were required at 15 C in 5.8 ppt salinity.

Yellow perch larvae exhibited a temperature preference of 21.7 - 24.3 C when acclimated at 20 - 25 C (Ross et al. 1977). Hale and Carlson (1972) reported a 63% survival rate for larvae fed at 20 - 21 C, which is similar to the preference range reported by Ross et al. (1977). A temperature tolerance range of 10 - 30 C for feeding larvae was reported by Hokanson (1977b), while Hubbs (1971) reported that larvae fed when temperatures

were as low as 9.5 C. Significant mortality to larvae, acclimated between 13.5 - 17 C, occurred only as a result of a 15 C temperature increase in an experiment designed to simulate primary entrainment with pressure-temperature shock (PSE&G, 1978). They also reported no significant difference in mortality between control and treatment groups when larvae, acclimated at 16.5 C, were exposed to test temperatures of 19.0 - 24.5 C for 0.5 - 4 h.

McCauley and Read (1973) and Cherry et al. (1977) reported juvenile yellow perch selected a temperature range of 19 - 23 C when acclimated at 24 C and 15 - 24 C, respectively. Neill and Magnuson (1974) reported young-of-the-year (YOY) perch selected a similar temperature (23 C) during a laboratory thermal preference experiment. Reynolds and Casterlin (1979) reported that age-0 yellow perch exhibited a diel rhythm of preferred temperature, with a predawn minimum of 16.7 C and a dusk maximum of 23.8 C. Optimum growth conditions for juvenile yellow perch were approximately equal to the preferred temperature (22 C) with 16 h of light (Huh et al., 1976). Conversely, McCormick (1976) reported significantly greater growth rates at 26 - 30 C when held at constant temperatures. He also reported little to no growth at 8 C and total mortality within 7 d at 34 C. Growth of juvenile yellow perch occurred within a temperature range of 6 - 31 C (Hokanson, 1977b). Barans and Tubb (1973) collected YOY and adult yellow perch seasonally to compare temperature preference ranges between the two life stages. They reported that YOY

yellow perch selected temperature ranges 4 C greater than those selected by adults during spring, summer, and fall, but YOY selected a temperature range 2 C lower than adults during the winter. Hokanson and Kleiner (1974) also reported the juvenile stage was more thermally tolerant than the adult stage.

Hokanson and Kleiner (1974) reported that 24.7 C was the physiological optimum temperature for adult yellow perch. Ross and Siniff (1982) reported that adult yellow perch preferred a median temperature of 6.3 C when exposed to a winter thermal effluent of 0 - 15 C. This winter temperature preference differs from that of Barans and Tubb (1973) who collected adult yellow perch during the winter in the range of 12 - 16 C. Meldrim and Gift (1971) reported that adult perch acclimated at 15 C (6 ppt salinity) and 25 C (freshwater) preferred 23.5 C and 22.5 C, respectively. Thermal avoidance tests were also conducted by Meldrim and Gift (1971). Two groups of adult yellow perch acclimated at 25 C and different light levels avoided temperatures greater than 33 C. PSE&G (1978) reported a similar avoidance range (31 - 34 C) when acclimated at 25 C in freshwater. PSE&G (1978) data also indicated that saltwater increased the upper avoidance temperature in adult yellow perch. Avoidance temperatures of 14 - 18 C and 27 C were reported when adult yellow perch were acclimated at 6 C in freshwater and saltwater (1.5 ppt salinity) environments, respectively. Two investigators reported that rheotactic responses were the cause of behavioral changes exhibited by adult yellow perch

encountering heated thermal effluent (Kelso, 1976; MacLean, 1982).

Salinity

Salinity effects on yellow perch eggs, larvae, YOY and adults were evaluated in four studies. Muncy (1962) reported that spawning occurred in freshwater and in brackish areas with less than 2.5 ppt salinity. Hatching success of yellow perch eggs decreased with increased salinity ranging from 0 - 11.7 ppt (Muncy, 1962). He also reported a 2 d hatching delay in saltwater (5.8 ppt) versus freshwater at 15 C. Muncy (1962) also reported hatching success ranged from 65 - 42% when salinity conditions varied from 0 - 2.43 ppt.

Klauda et al. (1988) conducted a preliminary salinity tolerance laboratory experiment of 8 and 26 d old yellow perch larvae. Mortality estimates for 8 and 26 d old larvae at 3 ppt salinity were 40% and 28%, respectively. Mortality estimates for 8 and 26 d old larvae at 6 ppt salinity were 25% and 18%, respectively. Neither age-group survived longer than 48 h in 12 and 24 ppt salinity.

Muncy (1962) reported that YOY perch were collected in salinities ranging from 0.5 - 9.5 ppt. Seine hauls from the Severn River (Annapolis, MD) indicated that YOY yellow perch were most abundant in 5 - 7 ppt salinity (Muncy 1962).

Actual field data represents the only salinity information regarding adult yellow perch since no laboratory salinity

preference experiments have been conducted. Driver and Garside (1966) and Muncy (1962) both reported that adult yellow perch inhabit salinities ranging from 0.0 - 10.3 ppt, while Hardy (1978) reported that adult yellow perch were collected from waters with salinities up to 15 ppt.

Dissolved Oxygen

The effects of low dissolved oxygen (D.O.) on larval and juvenile yellow perch were examined in two studies. Petit (1973) reported a lethal D.O. concentration of 0.84 mg O₂/L for yellow perch larvae at 23 C. This D.O. concentration was not lethal for YOY tested at 15.1 C, which may have been the result of a lowered metabolic rate. Carlson et al. (1980) indicated that growth of juvenile yellow perch was not significantly affected when mean D.O. concentrations were \geq 3.5 mg O₂/L, while growth was significantly reduced when D.O. concentrations were \leq 2.0 mg O₂/L.

pH

Eight studies were conducted to evaluate the effects of pH on various life history stages of yellow perch. Yellow perch eggs were exposed to four pH levels (5.0 - 7.0) and five nominal aluminum concentrations (0 - 400 ug/L) during a series of flow-

through experiments (Janicki and Greening, 1988). They reported that mean egg mortality (62%) was significantly greater at pH 5.0 with no aluminum during a 15 d exposure than in the less acidic test conditions (40 -45%). The addition of aluminum did not significantly influence mortality rates.

Klauda et al. (1988) reported that yellow perch larvae could tolerate 12 - 24 h acidic pulses of pH 5.0. These investigators also reported that 17 d old feeding larvae were more sensitive to acid pulses of pH 4.0 than were pre-feeding larvae. They concluded that yellow perch is a relatively acid tolerant species that can sustain reproducing populations when mean pH is 5.0. Correll et al. (1987) indicated that significant differences in the survival of newly hatched (12 h old) yellow perch larvae existed between pH 5 and 7 even though greater than 50% of the larvae survived at pH 5.0. The addition of 100 ug/L of nominal inorganic monomeric aluminum at pH 5.0 reduced survival of yellow perch larvae from > 50% (pH 5.0 with no aluminum) to 5% (Swenson et al. 1989). Klauda (1989) proposed that critical acidic conditions for early life history stages of yellow perch occur between pH 4.5 - 5.5, and includes inorganic monomeric aluminum concentrations between 50 - 150 ug/L with dissolved calcium levels at least 2 mg/L.

The acid tolerance of YOY and adult yellow perch collected from lakes with ambient pH > 6.0 was tested under laboratory conditions (Rahel and Magnuson, 1983). It was reported that both YOY and adults survived longer than 10 d at pH 3.05 in 19 C

water. Lyons (1982) examined blood sodium concentrations in adult yellow perch from a naturally acidic (pH 4.6) and a naturally alkaline lake (pH 7.9). He reported that exposure to lethal acidity (pH 3.2) for 48 h resulted in significant but similar decreases in plasma sodium levels in both populations. Factors other than significant decreases in blood sodium levels were assumed responsible for mortality in the yellow perch populations. Rahel (1983) reported that adult yellow perch from acidic lakes (pH 4.5) survived longer than adults from alkaline lakes (pH 7.6) when exposed to pH 3.2 for 21 d. This suggests possible genetic adaptations to low pH conditions. The survival of adult yellow perch at pH 10.4 was similar for organisms previously exposed to acidic and alkaline lakes (Rahel, 1983).

Suspended Sediment

Several studies designed to evaluate the effects of suspended solids on yellow perch eggs and larvae in the Chesapeake Bay have been conducted. Schubel and Wang (1973) reported fine-grained suspended sediment in concentrations \leq 500 mg/L had no significant effect on hatching success of yellow perch eggs. However, they did report a 6 - 12 h delay in hatching at 100 and 500 mg/L suspensions. Schubel et al. (1973) conducted additional tests and reported that a 1000 mg/L suspension significantly reduced hatching success of yellow perch eggs. Conversely, Auld and Schubel (1974) exposed eggs to the

same conditions and found no significant reduction in hatching success.

Minimal information exists concerning the effect of suspended solids on yellow perch larvae. Survival was significantly reduced when yellow perch larvae were exposed for 96 h to concentrations of suspended solids \geq 500 mg/L (Auld and Schubel, 1974).

TOXICITY TO SINGLE CHEMICALS

Acute toxicity data for larval and juvenile yellow perch exposed to 56 single chemicals are presented in Tables 2 and 3, respectively. The majority of the acute toxicity research for yellow perch was conducted at the Columbia National Fisheries Research Laboratory (Mayer and Ellersieck, 1986).

The deleterious effects of total residual chlorine (TRC) to yellow perch larvae were greatly enhanced in saltwater versus freshwater. PSE&G (1978) reported 50% mortality when larvae were exposed to 0.55 mg/L TRC for 0.5 h in 3.5 ppt salinity at 16 C. Seegert et al. (1977) reported a 24 h LC50 value of 4.0 mg/L TRC when larvae were exposed for 0.5 h in a freshwater environment at 15 C. The acute toxicity of one inorganic compound on yellow perch larvae was investigated by Fung and Bewick (1980). They reported 1 h LC50 values of 1.55 and 0.046 mg/L hydrogen sulfide at 10 and 20 C, respectively. Acute toxicity data for larvae exposed to 42 organic compounds are presented in Table 2. The

most toxic substances (expressed as 96 h LC50's) were the pesticides Antimycin A (0.040 ug/L), S-bioallethrin (7.8 ug/L), DDT (9.0 ug/L) and toxaphene (12 ug/L) (Mauck et al., 1976; Mayer and Ellersieck, 1986).

Toxicity data for yellow perch juveniles were available from six studies (Table 3). Brooks and Seegert (1977) reported 24 h LC50 values of TRC for YOY yellow perch were inversely related to temperature. A study by Marking and Olsen (1975) indicated 3-trifluoromethyl-4-nitrophenol (TFM) was more toxic to juvenile yellow perch than to older age-0 yellow perch. Toxicity data from three inorganic compounds (hydrogen cyanide, hydrogen sulfide and potassium permanganate) are listed in Table 3. Hydrogen sulfide was the most toxic to juvenile yellow perch with a 96 h LC50 value of 8 ug/L (Fung and Bewick, 1980). Acute toxicity data for juveniles exposed to 7 organic compounds are presented in Table 3. The most toxic chemicals (expressed as 96 h LC50's) were RU-11679 (0.06 ug/L), endrin (0.15 ug/L) and resmethrin (0.51 ug/L) (Mayer and Ellersieck, 1986).

TOXICITY TO CHEMICAL MIXTURES

One acute toxicity chemical mixture experiment was conducted with juvenile yellow perch. Seeyle et al. (1988) graphically presented 24 h LC25 values for numerous combinations of the piscicides TFM and Bayer-73 at 33 different alkalinities (40 -

200 mg/L CaCO₃). Juvenile yellow perch sensitivity to TFM and mixtures of TFM and Bayer-73 decreased as alkalinity increased.

IN-SITU STUDIES

Four in-situ contaminant studies have been conducted with yellow perch eggs, larvae, YOY and adults (Table 4). Schofield and Driscoll (1987) reported that only 3.8% of the yellow perch eggs collected in a near-neutral lake (pH 6.6), with 0 - 30 ug/L total monomeric aluminum, hatched when placed in an acidic lake (pH 5.0 with 190 - 230 ug/L total monomeric aluminum). Hatching success for eggs spawned and hatched in the neutral lake was 86.2%. A hatching success rate of 43.5% was reported for eggs deposited and hatched in the acidic lake (pH 5.0) (Schofield and Driscoll, 1987). Similar to Rahel (1983), Schofield and Driscoll (1987) concluded that yellow perch exhibited genetic adaptation to acid stress. In-situ tests were also conducted in two Maryland coastal plain streams by Janicki and Greening (1988). They reported an 8.4% egg mortality rate as pH decreased to 6.0 and total monomeric aluminum peaked at 55 ug/L during a 4 d storm event in Mattawoman Creek. In Bacon Ridge Creek, egg mortality rates ranged from 0.3 - 50.0% as pH decreased to 6.4 and total monomeric aluminum peaked at 20 ug/L. Janicki and Greening (1988) did not offer any suggestions as to why higher mortalities were observed in the less acidic system, although Klauda (1989) suggested that suspended sediments, turbulence, and

current velocity may have affected the mortality rates. Greening et al. (1989) reported that yellow perch eggs were relatively insensitive to chemical changes during four storm events in the same two streams studied by Janicki and Greening (1988). They recorded egg mortality rates of 0 - 23.7% in Mattawoman Creek at pH minimums of 5.8 - 6.0, dissolved calcium concentrations of 3.1 - 5.6 mg/L, and total monomeric aluminum maxima of 69 ug/L. Mortality rates ranged from 2.5 - 12.5 % in Bacon Ridge Creek as pH ranged from 5.8 - 6.0, dissolved calcium concentrations were 5.7 - 8.2 mg/L, and total monomeric aluminum peaked at 52 ug/L.

Greening et al. (1988) also examined mortality rates of larval yellow perch. They reported that larvae were more sensitive than eggs when exposed to acidic storm events. Mortality rates for yellow perch larvae in Mattawoman Creek ranged from 51.5 - 100% as pH minima ranged from 5.8 - 6.3, with total monomeric aluminum maxima at 69 ug/L and dissolved calcium between 3.1 - 7.3 mg/L. At Bacon Ridge Creek, a 92.3% larval mortality rate was recorded at a pH minima of 5.8, with total monomeric aluminum of 52 ug/L and dissolved calcium between 5.7 - 8.2 mg/L.

Schofield and Driscoll (1987) reported a 72% survival rate when YOY perch were transferred from a neutral lake (pH 6.9) to an acidic lake (pH 4.6) for a 28 d in-situ experiment. They concluded that non-native species (yellow perch) exhibited greater acid tolerance than native cyprinids.

Adult yellow perch were placed into wire mesh cages in the Hudson River (below a suspected contaminant source) for 14 d to show the rapid bioaccumulation of the polychlorinated biphenyl (PCB), Aroclor 1016 (Skea et al., 1979). Control groups were located upstream of the suspected contaminant source. The PCB concentration was calculated daily from the river water below the contaminant source. Concentrations of Aroclor 1016 found within the exposed adult yellow perch were greater than 10,000 times the concentrations present in the water.

CONCLUSIONS

1. Yellow perch populations within the Chesapeake Bay have declined in recent years. Spawning occurs in poorly buffered coastal plain freshwater tributaries of the Chesapeake Bay. Eggs and larvae are thus exposed to potentially deleterious acidic pulses.
2. Hatching occurred in 2 d at 18.2 C, while 30.5 d were required at 3.3 C. Median thermal tolerance limits for yellow perch eggs were 7 - 20 C. Feeding larvae tolerated a temperature range of 10 - 30 C, while 20 - 24 C appears to be the optimum range. Optimum growth conditions for juveniles occurred at 22 C with 16 h of light. A diel temperature preference was reported for age-0 yellow perch; maximum

preferred temperature occurred at dusk. The physiological optimum temperature for adult yellow perch is 24.7 C.

3. Spawning occurs in freshwater and brackish water with less than 2.5 ppt salinity. Hatching success of yellow perch decreased as salinity increased from 0 - 2.4 ppt salinity. Larvae survived for 72 h at salinities \leq 6 ppt, but no survival was observed after 48 h exposure to salinities \geq 12 ppt. Adults have been collected in salinities ranging from 0 - 15 ppt.
4. A dissolved oxygen (D.O.) concentration of 0.84 mg/L was lethal to larval yellow perch exposed at 23 C, but was not lethal after exposure at 15 C. Growth of age-0 yellow perch was significantly reduced when D.O. concentrations were \leq 2.0 mg/L.
5. Yellow perch is considered a relatively acid tolerant species, however, the data suggests adults can survive and spawn in acidic waters that are potentially detrimental to fertilized eggs. Mortality of yellow perch eggs was significantly greater at pH 5.0 than at other less acidic conditions. Larvae tolerated a 12 - 24 h exposure to an acid pulse of \geq pH 5.0, while survival decreased from $>$ 50% to 5% with the addition of 100 ug/L aluminum at pH 5.0. A proposed critical acidic condition exists for early life stages of

yellow perch exposed to pH 4.5 - 5.5, with inorganic monomeric aluminum concentrations between 50 - 150 ug/L and dissolved calcium levels at least 2 mg/L. Adult yellow perch collected from naturally acidic waters (pH 4.5) exhibit a possible genetic adaptation to low pH conditions over adults from alkaline lakes (pH 7.6).

6. Concentrations of 100 - 500 mg/L suspended solids caused a 6 - 12 h delay in hatching of yellow perch eggs. Survival of larvae was significantly reduced when exposed for 96 h to concentrations \geq 500 mg/L suspended solids.
7. Acute toxicity data for larval yellow perch exposed to 44 single chemicals indicated that the pesticides Antimycin A, S-bioallethrin, DDT and toxaphene were most toxic. Toxicity data for juveniles exposed to 13 single chemicals indicated the insecticides RU-11679, endrin, and resmethrin were most toxic.
8. An inverse relationship existed between alkalinity and the sensitivity of juvenile yellow perch to 3-trifluoromethyl-4-nitrophenol (TFM) and mixtures of TFM and Bayer-73.
9. Field studies revealed that less than 50% of the eggs hatched from a yellow perch population indigenous to an acidic lake (pH 5.0). In-situ tests also indicated that yellow perch

larvae are more sensitive than egg stages when exposed to critical acidic storm events.

10. An in-situ experiment demonstrated the rapid (14 d) bioaccumulation of the PCB Aroclor 1016 in adult yellow perch from the Hudson River.

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Table 1. Toxic water quality parameters adversely affecting various life stages of yellow perch.

Parameter	Life Stage	Data	Reference
Temperature	Egg	Tolerance range of 7 - 20C	Hokanson, 1977
Temperature	Egg	LC50 range of 6.8 - 19.9C	Hokanson and Kleiner, 1974
Temperature	Larvae	Primary entrainment was simulated. Significant mortality occurred only as the result of a 15C temperature increase when acclimated between 13.5 - 17C.	PSE&G, 1978
Temperature	Larvae	A preference range of 21.7 - 24.3C was reported when acclimated between 20 - 25C.	Ross et al, 1977
Temperature	Larvae	No significant difference occurred in mortality between controls and experimental treatments when exposed to a 2.5 - 8.0C temperature increase for 0.5 - 4h. Acclimation was 16.5C.	PSE&G, 1978
Temperature	Larvae	63% survival occurred during a feeding study after 3 weeks at 20 - 21C.	Hale and Carlson, 1972

Table 1. (Continued)

Parameter	Life Stage	Data	Reference
Temperature	Larvae	At 12.5C three of seven groups fed, while one of nine fed at 9.5C.	Hubbs, 1971
Temperature	Larvae	Tolerance range for feeding larvae was 10 - 30C.	Hokanson, 1977
Temperature	Juvenile	Temperature preference ranged from 19.2 - 22.4C when acclimated at 15, 18, 21, and 24C.	Cherry et al, 1977
Temperature	Juvenile	Growth tolerance range was 6 - 31C.	Hokanson, 1977
Temperature	Juvenile	A temperature range of 20 - 23.3C was selected when acclimated at 24.	McCauley and Road, 1973
Temperature	Juvenile	Greatest weight gain occurred at 22C with 16h of light. Data suggests photoperiod influences growth much more than temperature.	Huh et al, 1976
Temperature	Age-0	Diel preferred temperatures of 16.7C (predawn) and 23.8C (dusk) were exhibited when acclimated at 20C.	Reynolds and Casterlin, 1979

Table 1. (Continued)

Parameter	Life Stage	Data	Reference
Temperature	Age-0 and Adults	Fish were collected seasonally from Lake Erie. Age-0 fish preferred temperatures 4C or greater than those preferred by adults during spring, summer and fall, but preferred water 2C lower than adults during winter.	Hokanson and Kleiner, 1974
Temperature	Adults	A temperature of 6.3C was preferred when exposed to a winter thermal plume consisting of a 0 - 15C thermal gradient.	Ross and Siniff, 1982
Temperature	Adults	Selected a temperature range of 17.6 - 20.1C when acclimated to 24C.	McCauley and Reed, 1973
Temperature	Adults	Preferred 23.5C when acclimated at 15C in 6 ppt salinity. Preferred 22.5C when acclimated at 25C in freshwater. Similar avoidance temperatures (33.3 - 33.9C) were selected when acclimated at 25C but different light levels (2 and 20 ft. - candles).	Meldrim and Gift, 1971

Table 1. (Continued)

Parameter	Life Stage	Data	Reference
Temperature	Adults	Fish acclimated in freshwater to 25C avoided areas 31 - 34C, while those acclimated to 6C avoided 14 - 18C. Fish acclimated to 6C in 1.5 ppt salinity avoided 27C.	PSE&G, 1978
Salinity	Egg	Hatching success was: 65-68% in freshwater 56% in 0.47 - 2.43 ppt salinity 42% in 0.1 - 0.94 ppt salinity 55% in 5.8 ppt salinity 0% in 11.7 ppt salinity	Muncy, 1962
Salinity	Larvae	8 and 26d old larvae were exposed to 3, 6, 12 and 24 ppt salinity for 72h. No survival occurred in either group after 48h exposure in 12 - 24 ppt salinity. Mortality for 8d old larvae ranged from 40 - 25% after 72h exposure to 3 - 6 ppt salinity. Mortality of 26d old larvae ranged from 28 - 18% after 72h exposure to 3 - 6 ppt salinity.	Klauda et al, 1988

Table 1. (Continued)

Parameter	Life Stage	Data	Reference
Dissolved Oxygen	Juvenile	Exposed for 67d to five concentrations of dissolved oxygen (2.0 - 6.5 mg/L). Growth was not reduced when mean constant dissolved oxygen level was \geq 3.5mg/L. Growth was not affected at fluctuations of 1.4 - 3.8 mg/L.	Carlson et al, 1980
Dissolved Oxygen	Age-0	Fish at 22.95C were exposed to dissolved oxygen concentrations between 1 - 5 mg/L. At 5 mg/L opercular movements increased; 4 mg/L there was loss of normal coloration; 2 mg/L cessation of feeding; loss of equilibrium at 1 mg/L. Lethal level occurred at 0.895 mg/L for individuals and 0.839 mg/L for groups of four. No lethal level found when acclimated at 15.1C.	Petit, 1973
pH	Egg	Exposed to pH 5, 5.5, 6 and 7 and nominal aluminum (0 - 400 μ g/L). 62% mortality after 15d exposure to pH 5.0 with no aluminum. Mortality in less acidic conditions (40 - 45%) was significantly less than at pH 5.0. Addition of aluminum did not significantly affect mortality. Temp = 12 - 15C.	Janicki and Greening, 1988

Table 1. (Continued)

Parameter	Life Stage	Data	Reference
pH	Larvae	At pH 5.0 with 100 µg/L aluminum (Al) survival declined significantly to 5% compared to > 50% survival in the other pH 5.0 treatments. The addition of 100 µg/L Al at pH 4.5 resulted in total mortality.	Swenson et al, 1989
pH	Larvae	17d old feeding larvae were more sensitive to acid pulses of pH 4.0 than pre-feeding larvae. Mean mortalities of feeding larvae during a 12h pulse were 98% at pH 4, 4% at pH 5 and 8% at pH 6. Mean mortalities of pre-feeding larvae during a 12h pulse were 22% at pH 4, 2% at pH 5 and 0% at pH 6. Pulse durations did not affect larval mortality at pH 5 or 6.	Klauda et al, 1988
pH	Larvae	>50% survival occurred at pH 5.0. Significant difference in survival occurred between pH 5 and 7, while both significantly reduced overall survivability.	Correll et al, 1987

Table 1. (Continued)

Parameter	Life Stage	Data	Reference
pH	Adult	Exposure to lethal acidity (pH 3.2) for 48h resulted in significant but similar decreases in blood plasma sodium levels in both populations. Fish were from a naturally acidic lake (pH 4.6) and a naturally alkaline lake (pH 7.9).	Lyons, 1982
pH	Adult	Fish from acidic lakes (pH 4.5) survived longer than fish from alkaline lakes (pH 7.6) when exposed to pH 3.2 at 18 - 20C in a laboratory. Acclimation to sublethal pH (4.6) for 21d did not affect acid tolerance. Susceptibility to lethal high pH (10.4) was similar for acidic and alkaline acclimated fish.	Rahel, 1983
pH	Adult	Survived longer than 10d in a lab experiment at pH 3.05 and 19C. Collected from wild in lakes with ambient pH > 6.0.	Rahel and Magnuson, 1983
Suspended Solids	Egg	Exposures of 50, 100, 500 and 1000 mg/L were used. A significant decrease in hatching success occurred when exposed to 1000 mg/L	Schubel et al, 1973

Table 1. (Continued)

Parameter	Life Stage	Data	Reference
Suspended Solids	Egg	Hatching success was not affected by concentrations \leq 500 mg/L. A 6 - 12h hatching delay occurred at 100 and 500 mg/L suspensions.	Schubel and Wang, 1973
Suspended Solids	Egg	Exposures of 50, 100, 500 and 1000 mg/L were used. No significant reduction in hatching success was reported.	Auld and Schubel, 1974
Suspended Solids	Larval	Suspensions \geq 500 mg/L significantly reduced survival when exposed for 96h.	Auld and Schubel, 1974

Table 2. Toxicity data for yellow perch larvae exposed to various single chemicals. All studies were static unless otherwise noted. (FT = flow through)

Chemical	Water Type	Water Quality			Data	References
		Temp. (C°)	pH	Hardness (mg/L) (CaCO ₃)		
Acephate (Insecticide)						
94% Tech material	Fresh	12	7.5	42	96h LC50 > 50000 µg/L	Mayer and Ellersieck, 1986
75% Wettable powder		12	7.5	42	96h LC50 > 100000 µg/L	
75% Wettable powder		12	6.5	42	96h LC50 > 100000 µg/L	
75% Wettable powder		12	9.0	42	96h LC50 > 100000 µg/L	
75% Wettable powder		12	8.0	12	96h LC50 > 100000 µg/L	
75% Wettable powder		12	8.0	44	96h LC50 > 100000 µg/L	
75% Wettable powder		12	8.0	300	96h LC50 > 100000 µg/L	
Aminocarb (Herbicide)						
98% Tech	Fresh	12	7.5	40	96h LC50 = 6400 µg/L	
98% Tech		12	7.5	40	96h LC50 = 230 µg/L	
17% Oil soluble		12	7.5	40	96h LC50 = 11700 µg/L	
98% Tech		7	7.5	40	96h LC50 = 5600 µg/L	
98% Tech		12	7.5	40	96h LC50 = 4700 µg/L	
98% Tech		17	7.5	40	96h LC50 = 1700 µg/L	
98% Tech		22	6.5	40	96h LC50 = 6400 µg/L	
98% Tech		12	7.5	40	96h LC50 = 7000 µg/L	
98% Tech		12	8.5	40	96h LC50 = 1430 µg/L	
98% Tech		12	9.0	40	96h LC50 = 425 µg/L	
98% Tech		12	8.0	40	96h LC50 = 5400 µg/L	
98% Tech		12	8.0	40	96h LC50 = 6200 µg/L	
98% Tech		12	8.0	160	96h LC50 = 7400 µg/L	
98% Tech		12	8.0	280	96h LC50 = 5600 µg/L	
Antimycin A (Piscicide)						
95.5% Tech	Fresh	12	7.4	44	96h LC50 = 0.040 µg/L	

Table 2. (Continued)

Chemical	Water Type	Water Quality			Data	References
		Temp. (C°)	pH	Hardness (mg/L) (CaCO ₃)		
Azinphos-methyl (Insecticide)	Fresh					
93% Tech		18	7.1	44	96h LC50 = 15 µg/L	
93% Tech		7	7.5	44	96h LC50 = 40 µg/L	
93% Tech		17	7.5	44	96h LC50 = 5.6 µg/L	
93% Tech		22	7.5	44	96h LC50 = 2.4 µg/L	
93% Tech		12	6.5	44	96h LC50 = 17 µg/L	
93% Tech		12	7.5	44	96h LC50 = 29 µg/L	
93% Tech		12	8.5	44	96h LC50 = 8.5 µg/L	
93% Tech		12	9.0	44	96h LC50 = 29 µg/L	
93% Tech		12	8.0	12	96h LC50 = 18 µg/L	
93% Tech		12	8.0	44	96h LC50 = 36 µg/L	
93% Tech		12	8.0	170	96h LC50 = 11 µg/L	
93% Tech		12	8.0	300	96h LC50 = 27 µg/L	
93% Tech	(FT)	12	7.5	314	96h LC50 = 6.5 µg/L	
Captan (Fungicide)	Fresh					
90%	(FT)	17	7.5	314	96h LC50 = 120 µg/L	
Carbaryl (Insecticide)	Fresh					
99.5% Tech		18	7.1	40	96h LC50 = 745 µg/L	
99.5% Tech		12	7.5	42	96h LC50 = 5100 µg/L	
99.5% Tech		7	7.5	42	96h LC50 = 13900 µg/L	
99.5% Tech		12	7.5	42	96h LC50 = 5400 µg/L	
99.5% Tech		17	7.5	42	96h LC50 = 3400 µg/L	
99.5% Tech		22	7.5	42	96h LC50 = 1200 µg/L	
99.5% Tech		12	6.5	42	96h LC50 = 4000 µg/L	
99.5% Tec		12	7.5	42	96h LC50 = 4200 µg/L	
99.5% Tech		12	8.5	42	96h LC50 = 480 µg/L	
99.5% Tech		12	9.0	42	96h LC50 = 350 µg/L	
99.5% Tech		12	8.0	42	96h LC50 = 3800 µg/L	
99.5% Tech		12	8.0	170	96h LC50 = 5000 µg/L	
99.5% Tech		12	8.0	300	96h LC50 = 3750 µg/L	

Table 2. (Continued)

Chemical	Water Type	Water Quality			Data	References
		Temp. (C°)	pH	Hardness (mg/L) (CaCO ₃)		
Carbaryl (Insecticide) 99% Tech 99% Tech 99% Tech	Fresh	12	7.5	44	96h LC50 = 240 µg/L	
		12	9.5	42	96h LC50 = 120 µg/L	
		12	7.5	44	96h LC50 = 400 µg/L	
Chlordane (Insecticide) 100% Tech	Fresh (FT)	12	7.1	44	96h LC50 = 9.6 µg/L	
		18	7.1	44	96h LC50 = 9.0 µg/L	
DDT (Insecticide) 99% Tech	Fresh	12	7.4	44	96h LC50 > 50000 µg/L	
		12	7.4	40	96h LC50 > 25000 µg/L	
Diflubenzuron (Insecticide) 95% Tech 95% Tech	Fresh	12	7.5	44	96h LC50 = 28 µg/L	
		12	7.5	314	96h LC50 = 1000 µg/L	
Dimethrin (Insecticide) 100% Tech	Fresh	12	7.5	44	96h LC50 = 780 µg/L	
		12	7.5	44	96h LC50 = 60000 µg/L	
Dinitramine (Herbicide) 99.2% Tech 99.2% Tech	Fresh (FT)	12	7.5	44	96h LC50 = 23500 µg/L	
		12	9.5	44	96h LC50 = 23500 µg/L	
Diquat (Herbicide) 35.3% Liquid Concentrate 35.3% Liquid Concentrate	Fresh	12	7.5	44	96h LC50 = 60000 µg/L	
		12	9.5	44	96h LC50 = 23500 µg/L	

Table 2. (Continued)

Chemical	Water Type	Water Quality			Data	References
		Temp. (C°)	pH	Hardness (mg/L) (CaCO ₃)		
Fenitrothion (Insecticide)	Fresh					
95% Tech		12	7.5	40	96h LC50 =	5800 µg/L
40% Wettable Powder		12	7.5	42	96h LC50 =	2700 µg/L
40% Wettable Powder		12	7.5	42	96h LC50 =	4700 µg/L
40% Wettable Powder		7	7.5	42	96h LC50 =	2600 µg/L
40% Wettable Powder		12	7.5	42	96h LC50 =	3500 µg/L
40% Wettable Powder		17	7.5	42	96h LC50 =	3000 µg/L
40% Wettable Powder		12	6.5	42	96h LC50 =	4800 µg/L
40% Wettable Powder		12	7.5	42	96h LC50 =	2900 µg/L
40% Wettable Powder		12	8.5	42	96h LC50 =	3500 µg/L
40% Wettable Powder		12	9.0	42	96h LC50 =	3200 µg/L
40% Wettable Powder		12	8.0	44	96h LC50 =	3900 µg/L
40% Wettable Powder		12	8.0	170	96h LC50 =	2000 µg/L
40% Wettable Powder		12	8.0	300	96h LC50 =	3700 µg/L
Fenthion (Insecticide)	Fresh					
46% spray concentrate		18	7.1	44	96h LC50 =	1650 µg/L
Folpet (Fungicide)	Fresh					
88% Tech		12	7.5	44	96h LC50 =	177 µg/L
Houghto - Safe 1120 (Hydraulic fluid)						
100% liquid		12	7.5	314	96h LC50 =	500 µg/L

Table 2. (Continued)

Chemical	Water Type	Water Quality			Data	References
		Temp. (C°)	pH	Hardness (mg/L) (CaCO ₃)		
Leptophos (Insecticide)	Fresh					
87.2% Tech		12	7.4	44	96h LC50 = 2000 µg/L	
87.2% Tech		12	7.4	44	96h LC50 = 1320 µg/L	
87.2% Tech		7	7.4	44	96h LC50 = 3750 µg/L	
87.2% Tech		12	7.4	44	96h LC50 < 500 µg/L	
87.2% Tech		22	7.4	44	96h LC50 < 25 µg/L	
87.2% Tech		12	9.0	44	96h LC50 = 680 µg/L	
87.2% Tech		12	8.5	44	96h LC50 = 150 µg/L	
87.2% Tech		12	7.5	44	96h LC50 = 690 µg/L	
87.2% Tech		12	6.5	44	96h LC50 = 140 µg/L	
87.2% Tech		12	8.0	12	96h LC50 = 270 µg/L	
87.2% Tech		12	8.0	44	96h LC50 = 2500 µg/L	
87.2% Tech		12	8.0	170	96h LC50 = 950 µg/L	
87.2% Tech		12	8.0	300	96h LC50 = 880 µg/L	
87.2% Tech		12	8.0	44	96h LC50 = 2050 µg/L	
87.2% Tech	(FT)	12	7.6	314	96h LC50 = 7.0 µg/L	
Malathion (Insecticide)	Fresh					
95% Tech		18	7.1	44	96h LC50 = 263 µg/L	
Methoxychlor (Insecticide)	Fresh					
98% Tech		12	7.5	40	96h LC50 = 30.0 µg/L	
50% Granular		12	7.5	40	96h LC50 = 17.5 µg/L	
98% Tech		12	7.5	42	96h LC50 > 50 µg/L	
98% Tech	(FT)	12	7.5	314	96h LC50 > 20 µg/L	
Methyl Parathion (Insecticide)	Fresh					
90% Tech		18	7.1	44	96h LC50 = 3060 µg/L	

Table 2. (Continued)

Chemical	Water Type	Temp. (C°)	Water Quality			Data	References
			pH	Hardness (mg/L) (CaCO ₃)			
Mexacarbate (Insecticide) 90% Tech 90% Tech 90% Tech	Fresh	12	7.5	44	96h LC50 = 16200 µg/L		
	(FT)	17	7.5	44	96h LC50 = 16900 µg/L		
		12	7.5	314	96h LC50 = 8300 µg/L		
Mirex (Insecticide) 98% Tech	Fresh	15	7.4	40	96h LC50 > 100000 µg/L		
Paroill 1032 (Plasticizer) 100% liquid	Fresh	12	7.5	314	96h LC50 > 5000 µg/L		
	(FT)						
Paroill 1048 (Plasticizer) 100% liquid	Fresh	12	7.5	314	96h LC50 > 10000 µg/L		
	(FT)						
Paroill 160 (Coolant) 100% liquid	Fresh	12	7.5	314	96h LC50 > 10700 µg/L		
	(FT)						
PCB Arochlor (Industrial) 1016 100% Tech 1242 100% Tech 1248 100% Tech 1254 100% Tech 1260 100% Tech	Fresh	12	7.4	44	96h LC50 = 240 µg/L		
	(FT)	17	7.6	314	96h LC50 > 150 µg/L		
	(FT)	17	7.6	314	96h LC50 > 100 µg/L		
	(FT)	17	7.6	314	96h LC50 > 150 µg/L		
	(FT)	17	7.6	314	96h LC50 > 200 µg/L		
Phthalate Dibutyl (Plasticizer) 100% liquid	Fresh	12	7.6	314	96h LC50 = 350 µg/L		
	(FT)						
Pydraul 50E (Hydraulic fluid) 100% liquid	Fresh	12	7.8	300	96h LC50 = 540 µg/L		
	(FT)						

Table 2. (Continued)

Chemical	Water Type	Temp. (C°)	Water Quality		Data	References
			pH	Hardness (mg/L) (CaCO ₃)		
S-Bioallethrin (Insecticide) 98% Tech	Fresh	12	7.5	44	96h LC50 = 7.8 µg/L	
Toxaphene (Insecticide) 100% Tech	Fresh	18	7.4	44	96h LC50 = 12 µg/L	
Trichlorfon (Insecticide) 98% Tech	Fresh	12	7.5	40	96h LC50 > 10000 µg/L	
Tricresyl Phosphate (Industrial) 100% Tech	Fresh (FT)	12	7.4	242	96h LC50 = 500 µg/L	
Xylenol Dimethylamino (metabolite) 99% Tech	Fresh	12	7.5	44	96h LC50 = 3400 µg/L	
		12	9.5	44	96h LC50 = 100 µg/L	
Dinitramine (Herbicide)	Fresh	12	7.5	42	96h LC50 = 1000 µg/L	Olson et al, 1975
Pyrethrum extract 20%	Fresh (FT)	12			96h LC50 = 44.5 µg/L	Mauck et al, 1976
Dimethrin 96% Tech	Fresh	12			96h LC50 = 28 µg/L	
d-Trans allethrin 90% Tech	Fresh (FT)	12			96h LC50 = 9.9 µg/L	
RU-11679	Fresh	12			96h LC50 = 0.06 µg/L	

Table 2. (Continued)

Chemical	Water Type	Water Temp. (C°)	Water Quality		Data	References
			pH	Hardness (mg/L) (CaCO ₃)		
S-bioallethrin	Fresh	12			96h LC50 = 7.8 µg/L	
SBP-1382 89% Tech	Fresh (FT)	12			96h LC50 = 0.5 µg/L	
Total Residual Chlorine (TRC)	Saline (3.5°/oo)	16			Approximately 50% mortality after 0.5h exposure to 550 µg/L TRC. No survival after 0.5h exposure to 2300 µg/L TRC.	PSE&G, 1978
TRC	Fresh	10			24h LC50 = 7700 µg/L	Seegert et al, 1977
		15			24h LC50 = 4000 µg/L	
		20			96h LC50 = 1100 µg/L	
		25			96h LC50 = 1100 µg/L	
Hydrogen Sulfide	Fresh	10	7.5		96h LC50 = 2 µg/L	Fung and Bewick, 1980
		20	8.0		96h LC50 < 2 µg/L	

Table 3. Toxicity data for juvenile yellow perch exposed to various single chemicals. All studies were static unless otherwise noted. (FT = flow through)

Chemical	Water Type	Water Quality			Data	References
		Temp. (C°)	pH	Hardness (mg/L) (CaCO ₃)		
Carbaryl (Insecticide) 99.5% Tech	Fresh (FT)	12	7.5	314	96h LC50 = 1420 µg/L	Mayer and Ellersieck, 1986
D-trans Allethrin (Insecticide) 90% Tech	Fresh (FT)	12	7.5	314	96h LC50 = 9.9 µg/L	
Endrin (Insecticide) 99.8% Tech	Fresh (FT)	12	7.6	314	96h LC50 = 0.15 µg/L	
Phoxim (Insecticide) 89% Tech	Fresh	12	7.5	44	96h LC50 = 605 µg/L	
89% Tech		17	7.5	44	96h LC50 = 563 µg/L	
89% Tech	(FT)	12	7.5	314	96h LC50 = 710 µg/L	
Pyrethrum (Insecticide) 20% liquid	Fresh (FT)	12	7.6	314	96h LC50 = 33 µg/L	
Resmethrin (Insecticide) 84% Tech	Fresh (FT)	12	7.6	314	96h LC50 = 0.51 µg/L	
RU-11679 (Insecticide) 96% Tech	Fresh (FT)	12	7.6	314	96h LC50 = 0.06 µg/L	

Table 3. (Continued)

Chemical	Water Type	Temp. (C°)	Water Quality		Data	References
			Hardness (mg/L) (CaCO ₃)	pH		
TRC	Fresh	10			Effects of one 0.5h exposure	Brooks and Seegert, 1977
		15			24h LC50 = 8000 µg/L	
		20			24h LC50 = 3900 µg/L	
		25			24h LC50 = 1100 µg/L	
		30			24h LC50 = 1000 µg/L 24h LC50 = 700 µg/L	
Hydrogen sulfide	Fresh	10			Effects of three 5 min. exposures 3 h apart	Fung and Bewick, 1980
		20			24h LC50 = 22600 µg/L	
		20			24h LC50 = 9000 µg/L	
Hydrogen Cyanide (HCN)	Fresh	10	7.5		96h LC50 = 36 µg/L	Smith, 1978
		20	8.0		96h LC50 = 8 µg/L	
Potassium Permanganate	Fresh	12	7.5	44	96h LC50 = 90.4 µg/L 96h LC50 = 108 µg/L	Marking and Bills, 1975
		12			An inverse relationship existed between organism sensitivity to HCN and dissolved oxygen concentration at 21C.	
3-trifluoromethyl-4-nitrophenol (TFM)	Fresh (FT)	12			96h LC50 = 9400 µg/L	Marking and Olsen, 1975
		12			96h LC50 = 4400 µg/L	

Table 4. In-situ water quality and contaminant studies conducted with various life stages of yellow perch.

Parameter	Life Stage	Data	Reference									
pH	Egg	Temp = 10.3 - 10.9C. Poor hatching success occurred as a result of alterations in egg membrane structure inhibiting process. This suggests possible genetic adaptation to acid stress.	Schofield and Driscoll, 1987									
		<u>Mortality rates:</u> Egg Source										
		<table border="1"> <thead> <tr> <th>Incubation Site</th> <th>Moose (pH 5.0)</th> <th>Moss (pH 6.6)</th> </tr> </thead> <tbody> <tr> <td>Moose</td> <td>43.5%</td> <td>3.8</td> </tr> <tr> <td>MOSS</td> <td>77.0%</td> <td>86.2</td> </tr> </tbody> </table>	Incubation Site	Moose (pH 5.0)	Moss (pH 6.6)	Moose	43.5%	3.8	MOSS	77.0%	86.2	
Incubation Site	Moose (pH 5.0)	Moss (pH 6.6)										
Moose	43.5%	3.8										
MOSS	77.0%	86.2										
pH	YOY	YOY were transferred from an alkaline lake (pH 6.9) to an acidic lake (pH 4.6) where cages were monitored for 28 d. 72% survival rate was recorded.	Schofield and Driscoll, 1987									

Table 4. (Continued)

Parameter	Life Stage	Data	Reference
pH and Aluminum (Al)	Egg	<p><u>Mattawoman Creek:</u> egg mortality = 8.4% pH minima = 5.8 - 6.0 Total monomeric Al maxima = 55 µg/L Dissolved calcium ≥ 4.8 mg/L</p>	Janicki and Greening, 1988
		<p><u>Bacon Ridge Creek:</u> egg mortality = 50% pH minima = 5.8 - 6.0 Total monomeric Al maxima = 52 µg/L Dissolved calcium = 5.7 - 8.2 mg/L</p>	
pH and Al	Larvae	<p><u>Mattawoman Creek:</u> Larval mortality = 51.5 - 100% pH minima = 5.8 - 6.3 Total monomeric Al maxima = 69 µg/L Dissolved calcium = 3.1 - 7.3 mg/L</p>	Greening et al., 1989
		<p><u>Bacon Ridge Creek:</u> Larval mortality = 92.3% pH minima = 5.8 Total monomeric Al maxima = 52 µg/L Dissolved calcium ≥ 5.7 mg/L</p>	

Table 4. (Continued)

Parameter	Life Stage	Data	Reference
Arochlor 1016 (PCB)	Adult	<p>Fish were collected from a nearby lake and exposed for 14d to Hudson River water. Fish had bioaccumulated 1.8 µg/g of Arochlor 1016. While controls (up river) had residues < 0.02 µg/g. Perch bioaccumulated approximately 10400 times the concentration present within the water (0.17 µg/L).</p>	Skea et al., 1979



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