A SYNTHESIS OF WATER QUALITY AND
CONTAMINANTS DATA FOR WHITE
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FINAL DRAFT

Sep, 1989

Maryland . Coastal Zone Management Program

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A SYNTHESIS OF WATER QUALITY AND CONTAMINANTS DATA FOR WHITE PERCH, MORONE AMERICANA

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September, 1989

Preparation of this report was funded by the Coastal Resources Division, Tidewater Administration, Maryland Department of Natural Resources, through a CZM Program Implementation Grant from the Office of Ocean and Coastal Resource Management, NOAA.

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INTRODUCTION

The Chesapeake Bay, with its' unique physical, chemical and biological characteristics, creates 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. Habitat degradation (water quality and contaminant) and overharvesting of prized commercial and recreational fish species are the primary causes of dramatic and prolonged fish stock declines (Wohlfarth, 1986; Setzler-Hamilton, 1987; Speir, 1987). Habitat loss, resulting from adverse water quality and chemical contaminants, has recently been suspected in reducing several Chesapeake Bay fish species populations (Hendrey, 1987; Klauda and Bender, 1987).

Deterioration of spawning and nursery habitats of fish species in Chesapeake Bay is a serious consideration when attempting to manage a species. Populations of anadromous and resident fish species, including the white perch (*Morone americana*), have drastically declined in recent years (Hendrey, 1987; Klauda and Bender, 1987; Speir, 1987). White perch are classified as freshwater to oligohaline (0.0 - 4.0 ppt) spawners within tributaries of the Bay (Hardy 1978). Larval and juvenile white perch are also inhabitants of freshwater and oligohaline

DRAFT

environments. The early life history of white perch results in the exposure of eggs, larvae and juveniles to potentially toxic conditions present within the Chesapeake Bay and associated tributaries. Efforts should be increased in an attempt to identify adverse conditions associated with the reduction of white perch if adequate management plans are to be implemented in the future. 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 white 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 white perch will be prepared by other investigators and merged with this document to provide a complete review on the species.

TOXIC WATER QUALITY CONDITIONS

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

Temperature

The effects of temperature on white perch eggs were examined in five different studies. The optimum temperature for white perch egg hatching was 14.1 C at a salinity of 0 ppt (Morgan and Rasin, 1982). Hardy (1978) indicated that hatching occurred in 24 h between 16 - 20 C, while 144 h were required between 11 - 16 C. Hardy (1978) also reported ambient water temperatures below 10 C caused significant mortality, while Ecological Analysts (1978) reported normal hatching occurred at 30.5 C. AuClair (1960) and Hardy (1978) reported that temperature drops of 4 - 5 C were lethal to developing eggs, while sudden drops of 2 - 3 C were sufficient to cause egg mortality. No significant effect on hatching success was observed when white perch eggs, acclimated at 13.5 - 14.5 C, were exposed to temperature increases of 6 - 10 C for $\leq$ 1 h (Schubel, 1974).

Two studies have evaluated the effects of temperature on larval white perch. Maximum length of white perch larva at hatch occurred at 18 C when acclimated over a temperature range of 8 - 26 C (Morgan and Rasin, 1982). Ecological Analysts (1978) reported a 24 h TL50 range of 30.2 - 31.8 C when acclimated at 24 C.

Temperature effects on juvenile white perch were examined in four different studies. Ecological Analysts (1978) reported that YOY white perch exhibited a preferred temperature of 31.2 C when acclimated at 24 C. Hall et al. (1979) reported that juveniles acclimated between 6 - 33 C exhibited final temperature preferences between 15.2 - 31.0 C. A 14 d TL50 temperature of 33.8 C, and a 96 h TL50 temperature range of 32.4 - 34.7 C, were reported for early juveniles acclimated to 24 C (Ecological Analysts, 1978). Dorfman and Westman (1970) indicated 80% survival of juveniles exposed to 30.6 C for 24 h after exposure for three days to increasing temperatures beginning at 20 C. They also reported a critical thermal maximum (CTM) temperature of 36.4 C, which was dependent upon acclimation temperature. Marcy (1976) collected young-of-the-year (YOY) white perch in water ranging from 5.7 - 40 C.

Ten studies have examined the effects of temperature on adult white perch. Terpin et al. (1977) utilizied vertical temperature preference studies to determine final temperature preferences of adult white perch. They reported that adults acclimated at 5, 8 and 10 C in 26.5 - 27 ppt salinity preferred 23, 22.8 and 21.5 C, respectively. A summer maximum preferred temperature of 32.2 C for adult perch in 4 - 9 ppt salinity from the Delaware River was reported by Meldrim and Gift (1971). A preferred temperature of 27.8 C was exhibited by adult white perch from the Hudson River (Ecological Analysts, 1978). Hall et al. (1978) reported that significant differences existed in final temperature preferenda amoung age-0 white perch populations from North Carolina, Maryland, and New Jersey. Adult white perch from the Hudson River avoided temperatures < 9.5C and > 34.5 C (Texas Instruments, 1976), while an upper avoidance temperature of 32 C was reported for adult perch in New Jersey Bay (Gift and Westman, 1971). McErlean and Brinkley (1971), Meldrim and Gift (1971), Meldrim et al. (1974) and PSE&G (1978) reported that upper lethal temperatures varied as a result of acclimation temperatures. Texas Instruments (1976) and Ecological Analysts (1978) reported a 96 h LC50 range of 32 - 35 C for adult white perch. Gift and Westman (1971) reported a CTM temperature of 37.6 C. Exposure to a temperature increase of ≥ 9 C for ≥ 15 min caused mortality in adult white perch acclimated to temperatures between 15.5 - 26.7 C (Meldrim and Gift, 1971), while a 20 C decrease in temperature resulted in total mortality for adults acclimated to 26 C (PSE&G, 1978). Burton (1979) indicated adult white perch ventilation rates increased with increased ambient temperature. Meldrim et al. (1974) determined that temperature, and not salinity or body length, contributed significantly to estimates of active and inactive metabolism in adult white perch.

Salinity

Few studies have examined the effects of salinity on various life stages of white perch. Only one experiment examined the effect of salinity on white perch eggs. Morgan and Rasin (1982) indicated that mean egg diameter was inversely related to salinity. They also reported eggs tolerate a salinity range of 0 - 10 ppt when exposed to temperatures of 8 - 26 C.

White perch larvae and juveniles inhabited a salinity range of 0 - 8 ppt, while the majority of larvae and juveniles preferred salinities < 1.5 ppt and < 3 ppt, respectively (Stanley and Danie, 1983). Both larval and juvenile white perch life

DRAFT

stages have been collected in waters with up to 13 ppt salinity (Stanley and Danie, 1983).

A normal salinity range for adults of 5 - 18 ppt was reported in Stanley and Danie (1983). It was also reported that spawning occurs at salinities < 4.2 ppt (Hardy, 1978).

Dissolved Oxygen

Only two studies have examined the effects of low dissolved oxygen (D.O.) on white perch YOY and adults. Dorfman and Westman (1970) reported 60% survival for YOY white perch when exposed to D.O. concentrations of 0.5 - 1.0 mg/L for 19 h over a temperature range of 6.7 - 28.3 C. Adult white perch avoided waters with < 35% saturation of oxygen over a temperature range of 8 - 21 C (Meldrim et al., 1974).

pH

A paucity of information exists concerning the effects of pH on various life stages of white perch. Klauda (1989) reported that laboratory and field data concerning the tolerance of white perch early life stages was lacking. However, he proposed that reproductive success of white perch would be significantly reduced if an acid pulse of pH 6.5 - 6.7, in association with a total monomeric aluminum concentration of 25 ug/L and dissolved calcium levels of 2 mg/L, continued for 7 d. Klauda (1989) also suggested that short duration (≤ 48 h) acidic pulses to pH 6.0 could severly impact survival of white perch larvae. Stanley and Danie (1983) assumed that adult white perch tolerate a pH range of 6.0 - 9.0.

Suspended Solids

The effects of suspended solids on white perch eggs were examined in four studies. Morgan et al. (1983) reported that hatching success was not significantly affected when eggs were exposed for 12 h to concentrations ≤ 5250 mg/L, however, hatching was delayed 24 h at a concentration of 5250 mg/L. Schubel and Wang (1973) reported suspended sediment concentrations as low as 100 and 500 mg/L caused hatching delays of 4 - 6 h. Auld and Schubel (1974), using unreplicated data, reported continuous exposure at a concentration of 1000 mg/L natural fine-grained sediment significantly reduced hatching success. It was reported in Schubel et al. (1977) that deposition of sediment on white perch eggs was more important than suspended sediment concentration. They reported 100% mortality when eggs were covered with a 1.1 mm layer of sediment on top of the eggs. They also reported no significant reduction in hatching success when a sediment layer (0.45 mm) less than one-half egg diameter was deposited around eggs.

Two studies were conducted on the deleterious effects of suspended solids to white perch larvae. Morgan et al. (1973,

1983) reported 24 h and 48 h LC50 values of 67,000 mg/L and 6,900 mg/L, respectively.

Only one study examined the effects of suspended sediments on juvenile white perch. Auld and Schubel (1974) indicated that concentrations of suspended solids ≥ 500 mg/L significantly reduced survival of juvenile white perch.

McInnich and Hocutt (1987) examined the response of adult white perch to strobe lights and bubble curtains in varying levels of turbidity. They reported only 40% avoidance to strobe lights at high turbidity (102 - 138 NTU). White perch avoided bubble curtains at low turbidity (45 NTU) but were attracted in clear and high turbidity conditions.

Shear

The effects of shear forces on white perch eggs and larvae were investigated in one study. Morgan et al. (1976) stated that shear stress can cause mortality of eggs and larvae by creating excess rotation or deformation. They reported that LS50 (median lethal shear that would kill 50% of test animals in a given time period) values calculated from time-shear exposure experiments were much greater than those present within the Chesapeake and Delaware canal. They also indicated the magnitude of shear force required to cause significant mortality is only present within a very thin boundary layer (20 mm).

TOXICITY TO SINGLE CONTAMINANTS

Toxicity data for white perch egg, larval and adult life stages exposed to nine different single chemicals are presented in Table 2. Two studies have examined the deleterious effects of total residual chlorine (TRC) on white perch eggs. Morgan and Prince (1977) reported a 76 h LC50 value of 0.27 mg/L TRC for white perch eggs maintained at 15 C in 2.5 ppt salinity. Later, Morgan and Prince (1978) reported that egg development ceased at the early embryo stage when exposed to 0.55 mg/L TRC at 15 C in 2.5 ppt salinity.

Six studies examined the effects of larval white perch exposed to chlorine. When comparing chlorine toxicity data, the terms total residual chlorine (TRC), chlorine produced oxidants (CPO), and total residual oxidants (TRO) are equivalent. A 24 h LC50 value of 0.31 mg/L TRC for white perch larvae maintained at 15 C in 2.5 ppt salinity was reported by Morgan and Prince (1977). In another study, Morgan and Prince (1978) indicated that length of larvae at hatch decreased with increasing TRC concentrations, and reported that length of larvae at hatch was significantly less (2.5 - 5.5%) than the length of control larvae at concentrations ≥ 0.10 mg/L TRC. Burton et al. (1979), and Hall et al. (1979; 1983) reported that mortality of larval white perch was a function of TRC and exposure duration. They also reported that temperature changes ≤ 10 C above an acclimation temperature of 18 C in 0.5 - 2.5 ppt salinity for ≤ 4 h did not affect survival of larval white perch. Hall et al. (1981) later reported that larvae acclimated at 23 C exhibited greater mortality at all treatment conditions than larvae acclimated at 15 C. They concluded the changing temperature effect resulted from an increased observation period (36 - 96 h).

Rehwolt et al. (1971) examined the effects of three heavy metal ions to adult white perch acclimated at 17 C. Adult perch were twice as sensitive to copper (96 h TL50 = 6.2 mg/L) as they were to either nickel or zinc (96 h TL50 = 13.6 and 14.3 mg/L, respectively).

Rehwolt et al. (1974) examined the toxic effects of No. 2 and 4 fuel oils, an oil collection agent, a dispersant, and mixtures of each to adult white perch. The toxicity of the dispersant (96 h TL50 = 4.2 mg/L) was 8 - 9 times greater than the toxicity of either fuel oil (96 h TL50 values ranged from 31 - 37 mg/L), while the oil collecting agent was not toxic to perch (96 h TL50 > 500 mg/L). Toxicity of the fuel oils increased greatly when the dispersant was added, which was due to partial solubilization of the oils (96 h TL50 ranged from 1.0 - 1.4 mg/L). Fuel oil toxicities were not significantly affected by the addition of the collecting agent.

Meldrim et al. (1981) reported that total chlorine was more toxic to adult white perch in salt water (1 ppt) at 14.5 C than in freshwater at 11 - 26 C. Ninety-six h LC50 values were 0.10 mg/L in saltwater and 0.61 - 0.87 mg/L in freshwater. Conversely, ozone was more toxic to adult white perch in freshwater at 11 - 27 C (96 h LC50 = 0.22 - 0.37 mg/L) than in saltwater (1 ppt) at 14.5 C (96 h LC50 > 0.66 mg/L). Meldrim et al. (1981) also reported that avoidance responses and physiographic studies (cough responses) were consistant with trends observed in the acute toxicity experiments. A 24 h TL50 value of 2.8 mg/L total chlorine was reported by Lauers (1973) when he exposed adult white perch to a single 2 h dose of NaOCl under static conditions.

PSE&G (1978) reported a 96 h TL50 value of 0.22 mg/L TRC for adult white perch acclimated at 16.7 C and 2.7 ppt salinity, and an avoidance concentration mean of 0.21 mg/L TRC for adult perch tested at 4 - 28 C and 0 - 8 ppt salinity. Gullans (1977) reported 96 h LC50 values for CPO of 0.21 and 0.15 mg/L for adult white perch acclimated at 15 and 25 C, respectively. Block (1977) and Block et al. (1977) examined the physiological effects of CPO on adult perch in freshwater at 14 - 16 C. After 0.5 h exposure to a concentration of 1.3 mg/L CPO, Block et al. (1977) reported that blood pH decreased from 7.5 to 7.0, and gill carbonic anhydrase and hematocrit increased 76% and 106%, respectively. Block et al. (1978) also reported that in a saline environment (13.6 ppt) blood pH decreased from 7.6 to 6.8 and hematocrit decreased 14%.

Meldrim et al. (1974) reported an inverse relationship between temperature and concentration of Free Residual Chlorine (FRC) required to bring about an avoidance response by adult white perch. A similar relationship was observed between salinity and concentration of FRC. PSE&G (1978) indicated that an inverse relationship existed between the percentage of FRC in chlorine and the concentration of total chlorine required to bring about an avoidance response.

Meldrim and Flava (1977) examined the avoidance response of adult white perch to TRO, and TRO with a temperature increase of 2 - 3 C, in fresh and saline waters (0 - 7 ppt) at temperatures of 0 - 27 C. He reported adult perch were more sensitive to TRO with a 2 - 3 C temperature change when ambient water temperatures were 0 - 12 C. Conversely, adult perch were more sensitive to the concentration of TRO, and less sensitive to a temperature change, when ambient water temperatures ranged from 13 - 27 C.

Rosenkranz et al. (1978) and Richardson et al. (1983) reported similar 96 h LC50 values (0.20 - 0.22 mg/L) of ozone produced oxidants (OPO) for adult white perch. In both of these studies histological changes were observed on gill surfaces within 24 h of exposure to concentrations $\geq$ 0.01 mg/L OPO. In addition, Richardson et al. (1983) indicated that blood pH was significantly reduced at OPO concentrations $\geq$ 0.15 mg/L and that hematocrit significantly increased when OPO concentrations $\geq$ 0.10 mg/L.

Contaminated harbor water

One experiment examined the sublethal effects of chemicals present within a specific body of water on adult white perch

(Table 3). Morgan et al. (1973b) examined the sublethal effects of Baltimore harbor water on adult white perch by exposing them for 30 days in 25 C harbor water at 5 ppt salinity. Sublethal physiological effects to adult perch included increased levels of thrombocytes, and decreased neutrophil and basolphil levels. Biochemical effects included changes in lactate dehydrogenase (LDH), acetylcholinesterase, and catalase levels. Increased LDH activity in white perch blood serum was in response to poor water quality. Organophosphorous pesticides were responsible for the reduced acetylcholinesterase activity within white perch brains, while liver damage from metal ions resulted in decreased catalase levels.

CONCLUSIONS

1. Populations of white perch have dramatically declined within the Chesapeake Bay in recent years. White perch spawn in fresh water and oligohaline (0.5 - 4.0 ppt) tributaries of the Bay, while larval and juvenile stages also inhabit similar environments. Early life history stages of this species are thus exposed to potentially toxic conditions within the Chesapeake Bay and associated tributaries.

2. The optimum hatching temperature for white perch eggs is 14.1 C at 0 ppt salinity. Maximum length at hatch for larvae occurred at 18 C when acclimated over a temperature range of

8 - 26 C. A temperature of 31.2 C was preferred by juveniles acclimated at 24 C. A critical thermal maximum temperature of 36.4 C was reported for juveniles, but this value was dependent upon acclimation temperature. Significant differences in final temperature preferenda were observed for geographically separated populations of age-0 white perch along the mid-Atlantic coast. Adult white perch avoided temperatures < 9.5 C and > 34.5 C.

3. White perch eggs tolerate a salinity range of 0 - 10 ppt when exposed to a temperature range of 8 - 26 C. Larval and juvenile perch prefer salinities of < 1.5 and < 3 ppt, respectively. Adults exhibit a natural preference for salinity ranging from 5 -18 ppt, while spawing occurs in salinities < 4.2 ppt.

4. Age-0 white perch survived (60%) for 19 h after exposure to dissolved oxygen concentrations of 0.5 - 1.0 mg/L at 6.7 - 28.3 C. Adults avoided waters with < 35% saturation of dissolved oxygen.

5. It was suggested that a short-duration (≤ 48 h) acidic pulse to pH 6.0 could significantly reduce survival of white perch larvae. Adult white perch presumably can tolerate a pH range of 6.0 - 9.0.

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6. Concentrations of 100 and 500 mg/L suspended solids delayed hatching of white perch eggs 4 - 6 h. A 48 h LC50 value of 6900 mg/L was reported for larvae, while concentrations $\geq$ 500 mg/L significantly reduced survival of juveniles.

7. Toxicity data were available for various life stages of white perch exposed to nine single chemicals. A 76 h LC50 value of 0.27 mg/L total residual chlorine (TRC) was reported for white perch eggs. Egg development ceased when exposed to a concentration of 0.55 mg/L TRC. A 24 h LC50 value of 0.31 mg/L TRC was reported for larval white perch. Ninety-six h LC50 values of 0.22 mg/L chlorine produced oxidants (CPO) and 0.15 mg/L CPO were reported for adult perch acclimated at 15 and 25 C, respectively. In addition, the length of observation period (36 - 96 h) affected LC50 values.

8. Total chlorine was more toxic to adult white perch in saltwater than in freshwater. A 24 h LC50 value of 2.8 mg/L total chlorine was reported.

9. As temperature increases, the concentration of free residual chlorine (FRC) required to bring about an avoidance response in adult white perch decreased. A similar relationship existed between salinity levels and FRC concentrations.

10. Adult white perch were more sensitive to total residual

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oxidants (TRO) with a 2 - 3 C temperature increase over a temperature range of 0 - 12 C. Conversely, at temperatures of 13 - 27 C, adult perch were less sensitive to TRO with a temperature increase and more sensitive to the TRO concentration.

11. Ozone was more toxic to adult white perch in freshwater than in saltwater. Ninety-six h LC50 values of 0.20 - 0.22 mg/L of ozone produced oxidants were reported for adult white perch.

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DRAFT

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DRAFT

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

Parameter	Life Stage	Data	Reference
Temperature	Eggs	Acclimation temp. = 13.5 - 14.5C. Exposed for ≤ 1h to temp. increases of 6 - 10C resulted in no significant effect on hatching success.	Schubel, 1974
Temperature	Eggs	Normal hatch occurred at 30.5C.	Ecological Analysts, 1978
Temperature	Eggs	Maximum experimental hatching (81.5%) occurred at 14C in freshwater.	Morgan and Rasin, 1982
Temperature	Eggs	Temperature drops of 4 to 5C were lethal, sudden drops of 2 to 3C induced mortality, minimum summer temperature of 7C were lethal; extensive mortality occured at 10C.	Auclair, 1960 Hardy, 1978
Temperature	Larvae	Maximum length at hatch occurred between 16C - 18C at all salinities (0 to 10 ppt).	Morgan and Rasin, 1982
Temperature	Yolk sac larvae	24h TL50 = 30.2 - 31.8C	
Temperature	Juvenile	Exhibited temperature preference of 31.2C; acclimation temp = 24C. 14d TL50 = 33.8C 96h TL50 = 32.4 - 34.7C	Ecological Analysts, 1978

DRAFT

Table 1. (Continued)

Parameter	Life Stage	Data	Reference
Temperature	Juvenile	Exposure to ≥ 8.4C increases for longer than 15 min. resulted in mortalities for fish acclimated to temperatures between 21.1 - 26.7C.	Meldrim and Gift, 1971
Temperature	Juvenile	36.4C was critical thermal maxima. 84% survival was reoirted at 30.6C.	Dorfman and Westman, 1970
Temperature	Juvenile	96h TL50 = 34C	Texas Instruments, 1976
Temperature	Juveniles	Acclimated at 6, 12, 18, 24, 30, and 33C. Final temperature preferences ranged from 15.2 - 31.0C and were dependent upon acclimation temperature.	Hall et al., 1979
Temperature	YOY	Collection temperature: low 5.7C high 40C	Marcy, 1976

Table 1. (Continued)

Parameter	Life Stage	Data	Reference
Temperature	YOY	Temperature preference increased as acclimation temperatures increased from 6 - 24C. Acclimation temperatures $\geq$ 30C resulted in preferred temperatures less than or equal to acclimation temperatures. Final temperature preferenda ranged from 31.6 - 32.5C for North Carolina populations, 28.9 - 30.6 for Maryland populations, and 29.2 - 29.6C for New Jersey populations.	Hall et al., 1978
Temperature	Adults	Fish acclimated to 10.0, 17.5, 20.3 and 28.5C resulted in LD50 = 26.2, 27.7, 29.2 and 33.2C, respectively.	McErlean and Brinkley, 1971
Temperature	Adult	Organisms acclimated to 5, 15 and 25C and exposed to 5C delta T experienced ventilation rates of 35.5, 64.4, and 105.1 freq/min., respectively. An acclimation temperature of 30C with a 2.5 delta T resulted in 114.0 freq/min.	Burton, 1979

DRAFT

DRAFT

Table 1. (Continued)

Parameter	Life Stage	Data	Reference
Temperature	Adult	Maximum preferred temperatures recorded for white perch were 32C when ambient acclimation was 23.9C in mid July and 31.1C when ambient acclimation was 30C in mid August. Minimum preferred temperatures were 5C when ambient acclimation was 1.1C and 1.7C in February. 4 - 9 ppt salinity.	Meldrim and Gift, 1971
Temperature	Adult	Acclimation between 15.5 - 26.7C. Mortality resulted after exposure to a temperature increase ≥ 29C for ≥ 15 min.	Meldrim and Gift, 1971
Temperature	Adult	Avoidance temperatures ranged from 6.7C for fish acclimated to 1.1C in February to a maximum of 35C for perch acclimated to 25C in August.	Meldrim and Gift, 1971
Temperature	Adult	Exhibited temperature preference of 27.8C.	Ecological Analysts, 1978
Temperature	Adult	Fish from New Jersey exhibited 32C avoidance temperature. Critical thermal maximum temperature was 37.6C.	Gift and Westman, 1971

DRAFT

Table 1. (Continued)

Parameter	Life Stage	Data	Reference
Temperature	Adult	Temperature preferena of 23, 22.8 and 21.5C were reported at acclimation temperatures of 5, 8 and 10C, respectively. (26.5 - 27.0 ppt salinity)	Terpin et al., 1977
Temperature	Adult	Seasonal upper lethal temperatures: Fish collected in March at 2.9C and acclimated to 10C had LD50 = 26C. Fish collected in September at 24.5C and acclimated to 28.5C had LD50 = 33C.	McErlean and Brinkley, 1971
Temperature	Adult	Fish acclimated from 1 - 26C experienced avoidance temperatures from 7 - 37C pH = 7.0 - 8.0.	Meldrim et al., 1974
Temperature	Adult	Cold shock: Fish acclimated at 14C in most cases survived a delta T near 12C. Fish acclimated at 26C and exposed to 6C experienced total mortality.	PSE&G, 1978

DRAFT

Table 1. (Continued)

Parameter	Life Stage	Data	Reference
Temperature	Adult	Upper lethal temperature: Median lethal temperature for fish acclimated at 21C was about 33C. Exposure to 36C resulted in 100% mortality after 48 h. Fish acclimated at 6C experienced 50% mortality near 22C and 100% at 32C. (Salinity = 3 - 10ppt.)	PSE&G, 1978
Temperature	Adult	At rising acclimation temperatures, fish acclimated to 6C were observed to avoid 12C; those acclimated to 26C were observed to avoid 29 and 34C. Upon falling acclimation temperatures, fish acclimated to 1C were observed to avoid 7 and 9C; those acclimated to 18C were observed to avoid temperatures between 21 and 31C.	PSE&G, 1978
Temperature	Adult	Fish from the Hudson River exhibited temperature preferences between 14 - 34C. Avoidance responses occurred at temperature < 9.5C and > 34.5C.	Texas Instruments, 1976
Salinity	Eggs	Salinities up to 10 ppt were tolerated.	Morgan and Rasin, 1982

DRAFT

Table 1. (Continued)

Parameter	Life Stage	Data	Reference
Salinity	Eggs	Mean egg diameter was significantly greater at 0 ppt (0.86mm) than at all higher salinities (0.80mm).	Morgan and Rasin, 1982
Salinity	Larvae	Usually found in salinities from 0 to 8 ppt, but have also been found at 30 ppt.	Stanley and Danie, 1983
Salinity	Juveniles	From 3 ppt to 8 ppt, but rarely to 13 ppt.	Stanley and Danie, 1983
Salinity	Adults	Normal salinities occurred between 5 to 18 ppt; spawning occurred at less than 4.2 ppt.	Hardy, 1978
Salinity	Adults	Salinities of 0.0, 6.0 and 12.0 ppt resulted in mean active oxygen consumption ranges of 115 - 961, 173 - 1740 and 222 - 904 mg O_2/kg-h respectively. (Temp = 5 - 27C)	Meldrim et al., 1974
Dissolved Oxygen (D.O.)	Young of the year	≈ 40% mortality when DO = 0.5 - 1.0 ppm for 19h in 10 gal. chambers.	Dorfman and Westman, 1970
	Adult	Levels of oxygen reduced to 35% saturation was acceptable to fish. (pH = 7.4 - 7.7, temp 8 - 21C Salinity = 2.5 - 12.5 ppt.)	

DRAFT

Table 1. (Continued)

Parameter	Life Stage	Data	Reference
pH	Adult	pH 6.0 - 9.0 was tolerated in freshwater.	Stanley and Danie, 1983
Suspended sediments	Eggs	Percent hatch was not affected by 50 - 5250 mg/L but development was slowed at concentrations above 1500 mg/L during 12h exposure.	Morgan et al., 1983
Suspended sediments	Eggs	Concentrations of 1000 mg/L significantly reduced hatching success. (Temp = 13.5 to 17.0C.)	Auld and Schubel, 1974
Suspended sediments	Eggs	Suspensions of natural, fine grained sediment had no effect on the hatching success. Concentrations of 100 and 500 mg/L resulted in a 4 - 6 h delay in hatching relative to controls.	Schubel and Wang, 1973
Suspended sediments	Eggs	Concentrations of 2000 - 3250 mg/L reduced egg development to 80 - 85% of controls.	Morgan et al., 1973a
Suspended sediments	Larvae	24h LD50 = 66,989 mg/L 48h LD50 = 6,903 mg/L	Morgan et al., 1973a

DRAFT

Table 1. (Continued)

Parameter	Life Stage	Data	Reference
Suspended sediments	Larvae	Sediment concentrations of 1626, 2438, 3022, 5380 mg/L resulted in 15, 16, 17, 19% mortality respectively. 24h LC50 = 67,000 mg/L 48h LC50 = 69,000 mg/L	Morgan et al., 1983
Suspended sediments	Juveniles	Natural, fine grained sediments ≥ 500 mg/Lsignificantly reduced survival ($p \leq 0.05$).	Auld and Schubel, 1974
Shear	Eggs	1 min LS50 = 425 $dynes/cm_2$ 2 min LS50 = 415 $dynes/cm_2$ 5 min LS50 = 175 $dynes/cm_2$	Morgan et al., 1976
Shear	Larvae	1 min LS50 = 415 $dynes/cm_2$ 2 min LS50 = 340 $dynes/cm_2$ 4 min LS50 = 125 $dynes/cm_2$	
Turbidity	Eggs - adult	Has little effect but may limit food production hence restricting populations.	Hardy, 1978
Turbidity	Adult	Experienced 40% avoidance at high turbidity (102 - 138 NTU) to strobe lights. Exhibited attraction to bubble curtains in clear and high turbidity conditions and avoidance at low turbidity (45 NTU).	McInrich and Hocutt, 1987

Table 2. Toxicity data for various life stages of white perch exposed to various single chemicals. (NA = Not Available). All studies were static unless otherwise noted (FT = flow-through).

Life Stage	Chemical	Water Type	Test Temperature (C)	Data	Reference
Egg	Total Residual Chlorine (TRC)	NA (FT)	NA	76h LC50 = 0.27 mg/L	Morgan and Prince, 1977
Egg	TRC	Saline (2.5ppt)	15	0.055 mg/L TRC prevented egg development past embryo stage.	Morgan and Prince, 1978
Larvae	TRC	NA (FT)	NA	24h LC50 = 0.31 mg/L	Morgan, 1977
Larvae	TRC	NA (FT)	NA	Larval length: decreased significantly by 2.5 - 5.5% at > 0.5 mg/L.	Morgan, 1978
Larvae	TRC	Saline 3.0 2.5	 15 23	Exposure to TRC concentrations of 0.00, 0.15 and 0.30 mg/L and temperature increases of 2.6 and 10C above acclimation temperature for 0.08, 2.0 and 4.0 h were conducted. Conditions were maintained for 96h. Larvae acclimated at 23°C showed greater mortality at all treatment levels than those tested at 15C.	Hall et al., 1981

DRAFT

Table 2. (Continued)

Life Stage	Chemical	Water Type	Test Temperature (C)	Data	Reference
Larvae	TRC	Saline (0.5-2.5ppt)	18C	Exposed to 0.00, 0.15, and 0.30 mg/L TRC for 0.08, 2, and 4h exposure periods at delta T's of 2, 6 and 10C above acclimation were conducted. Temperature change did not affect survival. TRC was a major factor influencing mortality.	Hall et al., 1983
Adult	Chlorine Produced Oxidants (CPO)	NA (FT)	15	96h LC50 = 0.21 mg/L	Gullans, 1977
			25	96h LC50 = 0.15 mg/L	
Adult	Total Residual Oxidant (TRO)	Saline (0-7ppt)	0-27C	Avoidance to TRO(A) and TRO + delta T(B): A. 0-12C (ambient): 0.10-0.35 mg/L 13-27C (ambient): 0.04-0.07 mg/L B. 0-12C (ambient) + delta T: 0.07-0.28 mg/L 13-27C (ambient) + delta T: 0.06-0.15 mg/L delta T: 2-3C	Meldrim and Flava, 1977
Adult	TRC	Saline (0-8ppt)	4-28C	Avoidance mean = 0.21 mg/L	PSE&G, 1978

Table 2. (Continued)

Life Stage	Chemical	Water Type	Test Temperature (C)	Data	Reference
Adult	Ozone	Saline (1-2.5ppt)	20-27C	Avoidance concentrations from 0.03 to 0.20 mg/L (mean = 0.07)	Meldrim et al., 1981
Adult	Ozone	Fresh (FT)	6-25.8C	Avoidance concentrations from 0.04 to 0.16 mg/L (mean = .11 mg/l)	
Adult	Total chlorine	Saline (0.2-2.5ppt) (FT)	22.5-28C	Avoidance concentrations from 0.01 to 0.20 mg/L	
Adult	Total chlorine	Fresh (FT)	7.8-26.8C	Avoidance concentrations from 0.10 to 0.36 mg/L	
Adult	Total chlorine	Saline (2ppt) (FT)	24C	Initial "cough" response at 0.02 mg/L	
Adult	Ozone	Saline (1-2ppt) (FT)	15-28.5C	Initial "cough" response at 0.02 mg/L	
Adult	Total chlorine	Fresh (FT)	5-24C	Initial "cough" response from 0.03 to 0.25 mg/L	
Adult	Ozone	Fresh (FT)	6.5-23C	Initial "cough" response concentrations were from 0.09 - 0.17 mg/L	

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DRAFT

Table 2. (Continued)

Life Stage	Chemical	Water Type	Test Temperature (C)	Data	Reference
Adult	Chlorine produced oxidants (CPO)	Saline (13.6ppt)	15C	Physiological responses to acute CPO exposure: Blood pH decreased 7.6 to 6.8; hematocrit decreased 14%: plasma osmolality increased 35%; no effect in PNa +; pCl- increased 47%; pMg ++ increased > 300%; pCatt increased 199% CA-RBC activity increased 28% gill Na-k ATPase decreased 93% gill protein decreased 17%	Block et al., 1978
Adult	Ozone produced oxidants (OPO)	NA (FT)	15C	96h LC50 = 0.22 mg/L Histological changes were evident on gills within 24h of exposure to concentrations ≥ 0.01 mg/L	Rosenkranz et al., 1978
Adult	OPO	NA (FT)	15C	96h LC50 = 0.20 mg/L. Blood pH significantly reduced when concentrations ≥ 0.15 mg/L. Hematocrit significantly increased when concentrations ≥ 0.10 mg/L. Minimal effects on gill tissue at 0.01 mg/L, moderate epithelial sloughing with excess mucus production at 0.05 mg/L and severe tissue damage when concentrations ≥ 0.10 mg/L.	Richardson et al., 1983

DRAFT

Table 2. (Continued)

Life Stage	Chemical	Water Type	Test Temperature (C)	Data	Reference
Adult	TCL	NA	NA	24-48h LC50 = 2.8 mg/L Single 2 hour dose of NaOCl	Lauers, 1973
Adult	FRC	Saline (.5-7.0ppt)	4-27C	Avoidance: ≥ 0.16 mg/l (4C and 1.5 ppt salinity) ≥ 0.10 mg/l (4C and 7 ppt salinity) ≥ 0.04 mg/l (22C and 5 ppt salinity) ≥ 0.03 mg/l (22C and 1.5 ppt salinity)	Meldrim et al., 1974
Adult	CPO	Fresh	14.2-16C	Blood pH decreased from 7.5 to 7.0 after only a 30 min exposure to a concentration of 1.3 mg/L CPO. Hematocrit and gill carbonic anhydrase increased (106% and 76%, respectively) in response to lowered blood pH levels. Hypothesized that hemoglobin is oxidized to methemoglobin in the presence of chlorine at the gill surface, which ultimately causes death due to increased blood CO_2 and decreased blood pH.	Block et al., 1977; Block, 1977

Table 2. (Continued)

Life Stage	Chemical	Water Type	Test Temperature (C)	Data	Reference
Adult	TRC	Saline (mean = 2.7ppt)	mean = 16.9C	96h mean TL50 = 0.22 ± 0.08 mg/L mean pH = 7.6 TRC + pH were only variables to significantly affect mean survival times (MST). TRC was inversely related to MST while pH was directly related.	PSE&G, 1978
Adult	FRC	Saline (0.5-7.0ppt) (FT)		FRC explained 48% of variation in avoidance concentration. When chlorine contained no FRC, estimated avoidance concentration was 0.39 mg/L, whereas when chlorine was 100% FRC estimated avoidance concentration was 0.10 mg/l.	PSE&G, 1978
Adult	No. 2 fuel oil	NA	19	24-96h TL50 = 41.6- 37.2 mg/L. Addition of a sublethal amount of linear alkylate sulfonate (LAS) eispersant a 24-96h TL_m of 3.0-1.4 mg/L was reported.	Rehwolt et al., 1974
Adult	No. 4 fuel oil	NA	19	24-96h TL50 = 32.0-31.0 mg/L. Addition of a sublethal amount of LAS resulted in a 24-96h TL_m of 1.4 - 1.0 mg/L	

DRAFT

Table 2. (Continued)

Life Stage	Chemical	Water Type	Test Temperature (C)	Data	Reference
Adult	Fuel oil collecting agent (Harder)	NA	19	24-96h TL50 = > 500 mg/L	
Adult	Linear akylate sulfonate (dispersant)	NA	19	24-96h TL50 = 6.1 - 4.2 mg/L	
Adult	Cu	NA	17	48h TL50 = 8.0 mg/L 96h TL50 = 6.2 mg/L	Rehwolt et al., 1971
Adult	Zn	NA	17	48h TL50 = 10.2 mg/L 96h TL50 = 14.3 mg/L	Rehwolt et al., 1971
Adult	Ni	NA	17	48h TL50 = 16.2 mg/L 96h TL50 = 13.6 mg/L	Rehwolt et al., 1971
Adult	Total chlorine (TC)	Saline (1ppt)	14.5	2h intermittent exposure 96h LC50 = 0.10 mg/L	Meldrim et al., 1981
Adult	TC	Fresh	11	96h LC50 = 0.87 mg/L	
Adult	TC	Fresh	19	96h LC50 = 0.69 mg/L	
Adult	TC	Fresh	22	96h LC50 = 0.61 mg/L	
Adult	TC	Fresh	26	96h LC50 = 0.74 mg/L	
Adult	Ozone	Fresh	11	96h LC50 = 0.37 mg/L	
Adult	Ozone	Fresh	19	96h LC50 = 0.26 mg/L	
Adult	Ozone	Fresh	21	96h LC50 = 0.22 mg/L	
Adult	Ozone	Fresh	27	96h LC50 = 0.29 mg/L	

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Table 2. (Continued)

Life Stage	Chemical	Water Type	Test Temperature (C)	Data	Reference
Larvae	TRC	Saline (1.5ppt) (FT)	18	Exposed to TRC concentrations of 0.00, 0.15, and 0.30 mg/L TRC and temperature increase of 2, 6 and 10C above acclimation temperature for 0.08, 2.0 and 4.0 h. Conditions were maintained for 36h. Temperature changes ≤ 10C for ≤ 4h did not affect survival. Mortality was a function of TRC and exposure duration.	Burton et al., 1979; Hall et al., 1979

DRAFT

Table 3. Toxicity data for adult white perch exposed to contaminated harbor water.

Life Stage	Chemical	Water Type	Test Temperature (C)	Data	Reference
Adult	Baltimore Harbor water	Saline (5ppt)	25C	Examine sublethal effects of Baltimore Harbor water through 14d and 30d exposures. Sublethal effects were observed in fish exposed to harbor water for 30d. Biochemical effects include increased lactate dehydrogenase activity within blood serum. Also, decreased acetylcholinesterase (brain) and catalase levels (liver) were reported. Physiochemical effects include increased thrombocyte levels, and decreased basophil and neutrophil levels.	Morgan et al., 1973b

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