DISSOLVED-OXYGEN REQUIREMENTS FOR EARLY LIFE STAGES OF SOUTH PLATTE RIVER FISHES

Submitted To

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Approximately 32 species of fish may be found in or near the portion of the South Platte River referred to as Segment 15 by the U. S. Environmental Protection Agency (EPA; Table 1). This reach, which extends from above the outflow of the Denver Metro wastewater treatment facility (just upstream of Sand Creek in Commerce City, north of Denver) to Fort Lupton, probably serves (or once served) as spawning and nursery grounds for many of the warmwater (non-salmonid) species. However, dissolved-oxygen concentrations at some locations have been reported below present EPA minimums for early life stages of warmwater fishes (i.e., instantaneous lows of 5.0 mg/l and 7-day means of 6.0 mg/l; Chapman 1986). For this portion of the river and the resident species, these standards may be unnecessarily high. In the interest of Denver Metro, whose effluent at times accounts for as much as 95% of the flow, EPA is considering site-specific oxygen standards (R. C. Erickson, pers. comm.).

To proceed with this consideration, EPA needs specific information on oxygen requirements of early life stages of fishes in Segment 15 of the South Platte River. Based on reviews and summaries of dissolved-oxygen literature by Doudoroff and Shumway (1970), EIFAC (1974), Davis (1975), Holeton (1980), Billard et al. (1981), and, most recently, Chapman (1986), little of this information is available in literature published prior to 1985. With this report, we identify and assess information on dissolved-oxygen requirements published since 1985.

About 100 references were identified in a search for pertinent literature published from 1985 to early 1991. Based on scans of many of these papers and titles or abstracts of the others, we prepared the indexed bibliography included at the end of this report. For species of concern, we found 10 articles pertaining to effects of low dissolved oxygen on embryos, larvae, or young-of-the-year juveniles. But only six of these publications provided some potentially useful response-threshold data (Tables 2 and 3; similar tables covering a broad spectrum of species are provided for older literature by Doudoroff and Shumway 1970 and Davis 1975). Of these six papers, all but one pertained to young-of-the-year juveniles and none covered embryos. The one non-juvenile paper concerned larvae of walleye *Stizostedion vitreum*, a species rare in Segment 15. Based on our survey of recent literature, it appears that knowledge of effects of hypoxia on early life stages of fishes likely to be present in the South Platte River, or freshwaters in general, has not advanced much beyond that summarized 5 years ago by Chapman (1986). Much of the data needed by EPA does not yet exist.

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(See Dissolved Oxygen Bibliography for References in Table 2)

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Table 1. Fishes reported in the South Platte River Basin in Colorado by EPA (Denver, R. Erickson, pers. comm.) and Propst (1982), exclusive of cold headwater streams. Among species listed as in or near Segment 15 of the river, Denver to Fort Lupton, those denoted by a plus sign (+) were reported in the reach by both sources, those denoted by a minus sign (-) were reported in the reach by EPA and near but not in the reach by Propst, those denoted by an asterisk (*) were reported in the reach and basin only by EPA, and those denoted by a question mark (?) were reported only for areas near but not in the reach by Propst (potential species). Species listed as not likely in or near Segment 15 were reported only from elsewhere in the basin by Propst. Abundance in the basin was categorized by Propst and Carlson (1986) as common (C), uncommon (U), or rare (R); species reported only by EPA are listed as rare (R).

NATIVE SPECIES			NON-NATIVE SPECIES		
Scientific Name	**Common Name**	**Abund.**	**Scientific Name**	**Common Name**	**Abund.**
Fishes in or near Segment 15 of the South Platte River					
Clupeidae			**Cyprinidae**		
? *Dorosoma cepedianum*	gizzard shad	R	* *Carassius auratus*	goldfish	R
Cyprinidae			- *Cyprinus carpio*	common carp	C
- *Campostoma anomalum*	central stoneroller	C	**Salmonidae**		
? *Luxilus cornutus*	common shiner	R	- *Oncorhynchus mykiss*	rainbow trout	R
? *Notropis dorsalis*	bigmouth shiner	U	- *Salmo trutta*	brown trout	R
? *Cyprinella lutrensis*	red shiner	U	**Poeciliidae**		
- *Notropis stramineus*	sand shiner	C	* *Gambusia affinis*	western mosquitofish	R
+ *Pimephales promelas*	fathead minnow	C	**Centrarchidae**		
+ *Rhinichthys cataractae*	longnose dace	C	* *Lepomis gibbosus*	pumpkinseed	R
- *Semotilus atromaculatus*	creek chub	C	- *Lepomis macrochirus*	bluegill	R
Catostomidae			- *Micropterus salmoides*	largemouth bass	R
+ *Catostomus catostomus*	longnose sucker	C	* *Pomoxis annularis*	white crappie	R
+ *Catostomus commersoni*	white sucker	C	- *Pomoxis nigromaculatus*	black crappie	R
Ictaluridae			**Percidae**		
- *Ameiurus melas*	black bullhead	R	+ *Perca flavescens*	yellow perch	R
- *Ictalurus punctatus*	channel catfish	R			
Cyprinodontidae					
- *Fundulus sciadicus*	plains topminnow	U			
- *Fundulus zebrinus*	plains killifish	C			
Gasterosteidae					
- *Culaea inconstans*	brook stickleback	U			
Centrarchidae					
+ *Lepomis cyanellus*	green sunfish	C			
- *Lepomis humilis*	orangespotted sunfish	R			
Percidae					
- *Etheostoma exile*	Iowa darter	U			
- *Etheostoma nigrum*	johnny darter	U			
* *Stizostedion vitreum*	walleye	R			
Fishes of the South Platte River Basin Not Likely in Segment 15					
Cyprinidae			**Ictaluridae**		
Hybognathus hankinsoni	brassy minnow	U	*Ameiurus nebulosus*	brown bullhead	R
Hybognathus placitus	plains minnow	R	**Salmonidae**		
Phenacobius mirabilis	suckermouth minnow	U	*Salvelinus fontinalis*	brook trout	R
Phoxinus eos	northern redbelly dace	R			
Catostomidae					
Carpiodes carpio	river carpsucker	R			

Table 2. Lethal concentrations of dissolved oxygen (DO) for non-salmonid fishes likely to be present in Segment 15 of the South Platte River. Abstracted from literature published between 1985 and early 1991. Based on a variety of field and laboratory test procedures which make the results difficult to compare and interpret. The lowest values are mean residual dissolved-oxygen concentrations following death in sealed-jar-hypoxia bioassays; they do not necessarily represent the lowest dissolved oxygen concentrations which the specified fishes can survive over extended periods of time.

Species Source	DO (mg/l)	Temp (°C)	Comments
Eggs/Embryos			
Larvae			
Stizostedion vitreum			
Loadman, et al. 1989	<3.0	24	- Anecdotal: accidental hypoxia during intensive culture experiments at 8 days posthatching — after only 1 hr at <3 mg/l, lost all larvae in two trays and about 25% in remaining 6 trays.
Young-of-the-Year Juveniles			
Ictalurus punctatus			
Mazik et al. 1987	0.6-0.4	23	- Sealed-jars-hypoxia bioassays with individual fish ≥130 day posthatching; fish fed vitamin C-free diet.
	0.4	23	As above but fish fed diet with vitamin C.
Micropterus salmoides			
Carmichael and Williamson 1988	0.7-0.8	22	- Sealed-jar-hypoxia bioassays with individual fish ≥70 days posthatching, 8-15 g. Fish were acclimated to test temperature for 30 days prior to tests. Range combines results for northern, Florida, and hybrid strains.
	0.6-0.8	14	- As above.
	0.8-0.9	22	- As above, but with >6 g/l salts or 25 mg/l MS-222 added to test water.
	1.1-2.0	22	- As above, but 0.7 mg un-ionized ammonia added to test water.
Yearling or Older Juveniles or Adults			
Campostoma anomalum			
Chagnon and Hlohowskyj 1986	1.3, 1.8, 1.9, & 2.3		- Laboratory experiments. Based on loss of equilibrium during hypoxia test (test method not reported) following 48 hour exposures to sublethal concentrations of phenol: 6, 8, 10, & 12 mg/l respectively.
	1.9		- Control, fish not exposed to phenol.
Cyprinella lutrensis			
Rutledge and Beitinger 1989	1.2-2.0	>33	- Laboratory experiments. Determined while testing for critical thermal maxima at various DO concentrations with and without free access to the surface. DO limit based on loss of equilibrium. During trials, temperature was increased 1 degree every 3 minutes beginning at acclimation temperature, 30°C.
Lepomis macrochirus			
Springer and Neill 1988	0.6	25	- Critical oxygen concentration for routinely active fish (minimum DO required for survival and routine activity assuming no other external stresses). Determined for a 24.5 g fish with an automated respirometer and experimental control system.
Perca flavescens			
Suthers and Gee 1986	3.6-6.7	~25	- Values are lowest DO with survival >50% and highest with survival < 50% based on a set of 12 hr overnight and overday in-situ experiments in a cat-tail marsh, 5 yearlings per cage. DO was recorded at end of each 12 hr trial. Deaths occurred in most trials including tests with ending DO averaging 9.8 mg/l. Some fish survived tests with mean ending DO as low as 1.6 mg/l.

Table 3. Non-lethal response-threshold concentrations of dissolved oxygen (DO) for non-salmonid fishes likely to be present in Segment 15 of the South Platte River. Abstracted from literature published between 1985 and early 1991. Based on a variety of field and laboratory test procedures which make the results difficult to compare and interpret.

Species Source	DO (mg/l)	Temp (°C)	Comments
Eggs/Embryos			
Larvae			
Young-of-the-Year Juveniles			
Pimephales promelas			
Magnuson et al. 1985	<4	<4	- Field observations in a winterkill lake. Most young (YOY) left the lake prior to DO dropping below 4 mg/l which the authors considered stressful.
Ictalurus punctatus			
Zhang and Boyd 1988	1-4		- In pond culture experiment, reduced growth from reduced food consumption and conversion in unaerated ponds, usually between 1-3 mg/l, as compared to aerated ponds, always above 4 mg/l.
	<1		- In pond culture experiment, on a few mornings when DO in unaerated ponds dropped to <1 mg/l, fish were at the surface and apparently stressed; emergency aeration was applied and only a few fish died.
Etheostoma exile			
Magnuson et al. 1985	<4	<4	- Field observations in a winterkill lake. Most young (YOY) left the lake prior to DO dropping below 4 mg/l which the authors considered stressful.
Yearling or Older Juveniles or Adults			
Pimephales promelas			
Magnuson et al. 1985	>1.0 (<6.6)	≤3.6	- Field observations on adult-size fish in a winterkill lake. When DO was ≤1.0 mg/l near the bottom, fish aggregated near the ice-water interface where DO was higher. When bottom DO was 6.6 mg/l, most fish were found near the bottom (no observations when bottom DO was between 1.0 and 6.6 mg/l.
Culaea inconstans			
Magnuson et al. 1985	>1.0 (<6.6)	≤3.6	- As above.
	<2.2	<1	- Field observations on adult-size fish in a winter kill lake. Fish aggregated near an inlet with higher DO concentrations when DO away from the inlet, under ice, dropped below 2.2 mg/l.
Lepomis Macrochirus			
Heuer and Seawell 1987	≤2.0		- Observations in large outdoor channels modified to simulate natural conditions but with experimentally controlled DO levels. No evidence of nesting.
	3-4		- Observations in outdoor channels as above. Partially cleared but unused nests.
	5		- Observations in outdoor channels as above. Cleaned nests but no sign of successful spawning. Successful spawning observed only in channel with ambient DO levels, about 7 mg/l.
Perca flavescens			
Suthers and Gee 1986	≤1.5		- Field observations, avoidance DO levels based on DO in cat-tail marsh habitats when fish were or were not collected.
Suthers and Gee 1986	1.5-3.0	18	- Laboratory preference experiments; avoidance levels under conditions of decreasing DO.

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