

APPENDIX G; FISH CARRYING CAPACITY ARRANGED BY SPECIES AND  
MAJOR RESERVOIR GROUPS

Appendix G  
Fish Carrying Capacity Arranged by Species and Malar Reservoir Groups

Species or Species Group	Carrying Capacity	Carrying Capacity Biases in Pounds per Acre Supported by Each Food Compartment				
		Detritus	Benthos	Zooplankton	Fish	Terrestrial
Culpeper and South Atlantic Drainage Area						
Gars	0.6				0.6	
Bowfin	0.5				0.5	
Gizzard shad	25.5	24.2	1.3			
Threadfin shad	6.4	4.5	1.9			
Pickers	0.8				0.8	
Carp	18.1	10.9	5.	1.8		
Minnnows	0.7		0.1	0.6		
Carp suckers						
Suckers	5.2	4.2	0.3	0.8		
Hog suckers						
Buffalofishes						
Redhorses	5.2		5.2			
Bullheads	2.5	0.7	1.4		0.5	
Catfishes	6.8		1.2		5.5	
Madtoms						
Silversides						
Temperate basses	0.8				0.8	
Sunfish	18.8	0.9	12.8		1.7	3.4
Black basses	10.0		0.8		8.6	0.6
Crappies	8.2	0.3	1.7	1.5	4.8	0.6
Perches	1.4		0.3	0.3	0.9	
Freshwater drUID						
All other species	1.2		1.2			
<b>Total</b>	<b>112.8</b>	<b>45.7</b>	<b>33.6</b>	<b>4.9</b>	<b>24.7</b>	<b>4.0</b>
Buckhorn, Flannagan, Sutton, and Summersville Reservoirs Drainage Area						
Gars						
Bowfin						
Gizzard Shad						
Threadfin shad	0.8	0.5	0.2			
Pickerels						
Carp	1.4	0.9	0.4	0.1		
Minnnows	1.2		0.2	1.0		
Carp suckers	0.2	0.2	0.01	0.03		
Suckers	0.2	0.2	0.01	0.03		
Hog suckers	1.1	0.9	0.1	0.2		
Buffalofishes						
Redhorses	17.8		17.8			
Bullheads	0.8	0.2	0.5		0.2	
Catfishes	3.2		0.6		2.7	
Madtoms						
Silversides						
Temperate basses	0.1				0.1	
Sunfish	17.6	0.9	12.0		1.6	3.2

(Continued)

Appendix G (Continued)

Species or Species Group	Carrying Capacity	Carrying Capacity Biomass in Pounds per Acre Supported by Each Food Component				
		Detritus	Plenthos	Zooplankton	Fish	Terrestrial
<u>Buckhorn, Flannagan, Sutton, and Summersville Reservoirs Drainage Area (Continued)</u>						
Black basses	11.5		0.1		1.1	0.7
Crappies	3.1	0.1	0.1	0.1	1.8	
Perches	0.1		0.1	0.1	0.3	
Freshwater drum	1.4	0.1	0.8		0.5	
All other species	0.1		0.1			
<b>Total</b>	<b>61.0</b>	<b>3.1</b>	<b>34.3</b>	<b>2.0</b>	<b>17.0</b>	<b>3.1</b>
<u>Green and Cumberland Rivers and Dover Reservoir Drainage Area</u>						
Gars	0.1				0.1	
Bowfin						
Gizzard shad	60.6	57.6	3.0			
Threadfin shad	5.1	3.1	1.7			
Pickerels						
Carp	32.4	19.4	1.7	3.2		
Minnows	0.5		0.1	0.4		
Carp suckers	0.4	0.3	0.02	0.1		
Suckers	4.1	3.3	0.2	0.1		
Hog suckers						
Buffalofishes	16.7	7.5	0.8	8.3		
Redhorses	15.8		15.8			
Bullheads	2.0	0.5	1.1		0.4	
Catfishes	1.2		1.1		5.1	
Madtoms						
Silverides						
Temperate basses	1.3				1.3	
Sunfish	15.8	0.8	10.7		1.4	2.8
Black basses	11.5		0.1		1.1	0.7
Crappies	8.2	0.3	1.7	1.5	4.8	
Perches	1.5		0.3	0.3	0.1	
Freshwater drum	10.8	0.1	1.3		3.7	
All other species	0.3		0.3			
<b>Total</b>	<b>193.9</b>	<b>94.6</b>	<b>53.8</b>	<b>14.4</b>	<b>27.6</b>	<b>3.5</b>
<u>Lower Mississippi Valley Drainage Area</u>						
	4.1				4.1	
Bowfin	0.4				0.4	
Gizzard shad	62.5	59.4	3.1			
Threadfin shad						
Pickerels						
Carp	1.2	5.5	2.8	0.1		
Minnows	4.3		0.1	3.4		
Carp suckers	0.4	0.3	0.02	0.1		
Suckers	3.5	2.8	0.2	0.5		
Hog suckers						
Buffalofishes	70.9	31.9	3.1	35.5		
Redhorses	0.4		0.4			

(Continued)

Appendix G (Continued.)

Species or Species Group	Carrying Capacity	Carrying Capacity Biomass in Pounds per Acre Supported by Each Food Compartment				Terrestrial
		Detritus	Benthos	Zooplankton	Fish	
Lower Mississippi Valley Drainage Area (Continued)						
Bullheads	0.1	0.1	0.2		0.1	
Catfishes	24.9		1.5		20.4	
Madtoms	0.2	0.1	0.1		0.04	
Silversides						
Temperate basses	1.0				1.0	
Sunfish	10.4	0.5	7.1		0.1	1.0
Black basses	15.5		1.2		13.3	0.1
Crappies	17.8	0.7	1.6	3.1	10.3	
Perches						
Freshwater drum	26.1	2.1	15.1		8.1	
All other species	0.1		0.1			
<b>Total</b>	<b>253.1</b>	<b>103.4</b>	<b>42.9</b>	<b>43.6</b>	<b>60.4</b>	<b>2.8</b>
Blue Mountain, Nimrod, and Wister Reservoirs Drainage Area						
Gars	17.3				17.3	
Bowfin						
Gizzard shad	49.7	47.2	1.5			
Threadfin shad						
Pickerels						
Carp	39.2	23.5	11.7	3.1		
Minnows	1.1		0.1	0.1		
Carp suckers						
Suckers	7.8	6.3	0.1	1.2		
Hog suckers						
Southern silversides	264.2	118.9	13.2	132.1		
Redhorses						
Bullheads	0.3	0.1	0.1		0.1	
Catfishes	12.1		1.1		1.1	
Madtoms						
Silversides						
Temperate basses	1.0				6.0	
Sunfish	10.3	0.5	7.0		0.1	1.0
Black basses	16.6		1.3		14.3	1.0
Crappies	26.3	1.1	5.3	1.7	15.3	
Perches						
Freshwater drum	55.4	1.1	32.1		18.8	
All other species						
<b>Total</b>	<b>506.3</b>	<b>201.9</b>	<b>76.1</b>	<b>142.8</b>	<b>82.6</b>	<b>1.1</b>
Arkansas River main Drainage Area*						
Gars	1.7				1.7	
Bowfin						
Gizzard shad	125.8	119.5	6.3			
Threadfin shad	1.3	0.1	0.1			
Pickerels						
Carp	58.0	34.8	17.4	5.8		

(Continued)

\* Blue Mountain, Nimrod, Wister, and Great Salt Plains excluded.

Appendix C (Continued)

Species or Species Group	Carrying Capacity Biomass in Pounds per Acre Supported by Each Food Compartment					
	Carrying Capacity	Detritus	Benthos	Zooplankton	Fish	Terrestrial
Arkansas River Basin Drainage Area (Continued)						
<b>Minnows</b>	0.1		0.1	0.3		
Carp suckers	36.4	29.1	1.1	1.1		
Suckers						
Hog suckers						
<b>Buffalofishes</b>	86.1	38.8	1.3	43.1		
Redhorses	4.1		4.1			
Bullheads	3.7	1.0	2.1		0.7	
Catfishes	21.8		3.1		11.9	
<b>Madtoms</b>						
<b>Silversides</b>						
Temperate basses	1.3				1.3	
Sunfish	17.1	0.1	11.6		1.1	1.1
<b>Black basses</b>	13.5		1.1		11.6	0.1
Crappies	19.0	0.1	3.1	1.1	11.0	
Perches						
Freshwater drum	49.2	3.1	28.6		16.7	
All other species						
<b>Total</b>	<b>446.9</b>	<b>229.6</b>	<b>85.9</b>	<b>58.0</b>	<b>69.5</b>	<b>1.1</b>
Red River Basin Drainage Area						
Carp	1.3				1.3	
<b>Bowfin</b>	0.1				0.1	
Gizzard shad	66.8	63.4	3.1			
Threadfin shad	0.1	1.7	2.1			
Pickerels	0.1				0.1	
<b>Carp</b>	1.2	4.1	2.1	0.1		
Minnows	1.2		1.2	1.1		
Carp suckers						
Suckers	1.1	1.1	1.3	0.1		
Hog sucker						
<b>Buffalofishes</b>						
Redhorses	22.8		22.8			
Bullheads	0.1	1.2	1.1		1.1	
Catfishes	10.0		1.1		1.2	
<b>Madtoms</b>						
<b>Silversides</b>	1.1		0.03	1.1		
Temperate basses	3.1				1.0	
Sunfish	35.8	1.1	24.3		1.2	1.1
<b>Black basses</b>	17.5		1.4		15.1	1.1
Crappia	7.2	1.3	1.4	1.3	4.2	
Perches	1.1		0.1	0.1	1.3	
Freshwater drum	1.0	0.1	1.7		2.7	
All other species	0.1		1.1			
<b>Total</b>	<b>196.1</b>	<b>80.4</b>	<b>65.3</b>	<b>4.1</b>	<b>39.3</b>	<b>7.1</b>

(Continued)

Appendix G (Concluded)

Species	Species Group	Carrying Capacity	Carrying Capacity Biomass in Pounds per Acre Supported by Each Food Compartment				Terrestrial
			Detritus	Benthos	Zooplankton	Fish	
White River Basin Drainage Area							
Gars		0.1				0.1	
Bowfin							
Gizzard shad		66.9	63.6	3.3			
Threadfin shad		1.0	1.1	2.1			
Pickerels							
Carp		10.8	11.5	1.2	1.1		
Minnows		0.7		0.1	0.1		
Carp suckers		2.0	2.1	0.1	0.1		
Suckers		2.1	1.9	0.1	0.1		
Hog suckers							
Buffalofishes		27.8	12.8	1.1	13.9		
Redhorse		34.9		34.9			
Bullheads		0.8	0.2	0.1		0.2	
Catfish		1.7		1.7		1.7	
Mudpuppies		0.2	0.1	0.1		0.04	
Silversides		0.1		0.1	0.1		
Temperate basses		1.1				1.1	
Sunfish		19.5	1.0	1.2		1.8	1.1
Black bass		14.1		1.1		12.1	0.1
Crappies		1.1	0.2	1.1	1.0	1.2	
Perch		1.5		0.1	0.1	0.1	
Freshwater drum		2.1	0.2	1.5		0.1	
All other species		0.1		0.1			
<b>Total</b>		<b>211.4</b>	<b>93.3</b>	<b>65.3</b>	<b>17.9</b>	<b>30.6</b>	<b>4.3</b>

APPENDIX H: ANNUAL FISH HARVEST

**Appendix H: Part I**  
**Annual Sport Fish Harvest**

Drainage Areas	Area-Weighted Sport Fish Harvest	Area-Weighted Sport Fish Harvest Supported by Each Food Compartment*											
		Plant Material		Detritus		Benthos		Zooplankton		Fish		Terrestrial	
		lb/acre	% TH	lb/acre	% TH	lb/acre	% TH	lb/acre	% TH	lb/acre	% TH	lb/acre	% TH
Central and South Pacific	27.5	2.3	8.4	1.1	4.0	14.3	52.0	1.0	3.6	6.1	22.2	2.7	9.8
Central Valley	31.1	2.0	6.4	1.2	3.8	10.2	32.8	2.5	8.0	13.4	43.1	1.8	5.8
Columbia Basin	4.8	0.2	4.2	0.04	0.8	2.2	45.8	0.5	10.4	1.6	33.3	0.3	6.2
Great Basin	26.8	1.3	4.8			15.9	59.3	4.0	14.9	2.9	10.8	2.7	10.1
Colorado Basin	7.1	0.4	5.6	0.03	0.4	2.8	39.4	0.6	8.4	2.6	36.6	0.6	8.4
Missouri Basin	5.1	0.4	7.8	0.6	11.8	1.5	29.4	0.4	7.8	2.2	43.1	0.2	3.9
White River Basin	25.9	1.3	5.0	0.6	2.3	5.5	21.2	1.7	6.6	16.2	62.5	0.8	3.1
Arkansas River Basin	51.0	2.7	5.3	2.0	3.9	11.9	23.3	4.2	8.2	28.4	55.7	0.8	1.6
Red River Basin	32.1	1.6	5.0	1.1	3.4	10.9	34.0	1.7	5.3	14.9	46.4	1.9	5.9
Rio Grande and Gulf	57.5	2.6	4.5	2.2	3.8	13.1	22.8	3.4	5.9	33.9	59.0	2.1	3.6
Lower Mississippi	8.8	0.5	5.7	0.4	4.5	2.2	25.0	0.9	10.2	4.5	51.1	0.2	2.3
Upper Mississippi	12.7	2.1	16.5	2.5	19.7	3.5	27.6	0.8	6.3	3.2	25.2	0.2	1.6
Tennessee Valley	10.3	0.5	4.8	0.4	3.9	2.7	26.2	0.8	7.8	5.8	56.3	0.2	1.9
Ohio Basin	12.4	0.8	6.4	0.6	4.8	3.8	30.6	0.7	5.6	5.9	47.6	0.6	4.8
South - Gulf	11.7	0.6	5.1	0.4	3.4	3.0	25.6	0.8	6.8	6.3	50.8	0.5	4.3
South - Atlantic	7.6	0.3	3.9	0.2	2.6	1.6	21.0	0.6	7.9	4.7	61.8	0.2	2.6
Middle Atlantic	19.0	1.5	7.9	1.3	6.8	6.1	32.1	0.6	3.2	8.2	43.2	1.3	6.8
New England	2.5	0.1	4.0	0.045	1.8	0.8	32.0	0.2	8.0	1.3	52.0	0.1	4.0
Great Lakes and St. Lawrence	11.7	0.9	7.7	0.8	6.8	3.0	25.6	1.2	10.2	5.8	49.6	0.1	0.8
Area-Weighted Average	12.1	0.6	5.0	0.4	3.3	3.4	28.1	0.9	7.4	6.3	52.1	0.5	4.1

\* TH = total harvest



**Appendix H: Part 11**  
Annual Commercial Fish Harvest

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<b>Drainage Area</b>	<b>Plant Material</b>	<b>Area-Weighted Harvest Supported by Each Food</b>			<b><u>Fish</u></b>
		<b><u>Compartment</u> in Pounds Per Acre</b>			
		<b>Detritus</b>	<b>Benthos</b>	<b>Zooplankton</b>	
<b>Colorado Basin</b>	0.3	<b>1.0</b>	0.4	<b>1.1</b>	0.3
<b>Missouri Basin</b>	0.2	0.8	0.4	0.8	0.2
<b>Upper Mississippi</b>	2.5	9.1	4.4	10.1	2.9
<b>Rio Grande and Gulf</b>	0.3	<b>1.0</b>	0.5	<b>1.1</b>	0.3
<b>Arkansas River Basin</b>	0.4	<b>1.3</b>	0.6	<b>1.4</b>	0.4
<b>Red River Basin</b>	0.1	0.3	0.2	0.3	0.1
<b>Tennessee Valley</b>	1.3	4.6	2.2	5.1	1.4
<b>Ohio Basin</b>	0.3	<b>1.1</b>	0.5	<b>1.2</b>	0.3
<b>Great Lakes and St. Lawrence</b>	3.3	<b>11.9</b>	5.8	13.2	3.8
<b>Area-Weighted Average</b>	0.6	2.4	<b>1.1</b>	2.4	0.7

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**APPENDIX I: MAXIMUM SPECIFIC DAILY GROWTH RATES IN WEIGHT  
FOR RESERVOIR FISH SPECIES**

Appendix I  
Maximum Specific Daily Growth Rates in Weight for Reservoir Fish Species

Species	Age Class				
	I	II	III	IV	V
Golden redhorse		0.00662	0.00274	0.00138	0.00130
<b>Smallmouth buffalo</b>		<b>0.00250</b>	<b>0.00256</b>	0.00139	0.00113
<b>Bigmouth buff</b> 10		0.00398	0.00289	<b>0.000665</b>	0.00144
<b>Black buffalo</b>		0.00190	0.00124	0.00171	
<b>Carp</b>		0.00560	<b>0.00509</b>	0.00245	0.00195
<b>River carpsucker</b>		0.00723	0.00377	0.00317	0.00270
<b>Golden shiner</b>		0.00344	<b>0.000855</b>	0.00103	<b>0.000594</b>
<b>White sucker</b>		0.00520	<b>0.00255</b>	0.00170	0.00212
<b>Longnose sucker</b>		0.00371	0.00207	0.00160	<b>0.00156</b>
<b>Freshwater drum</b>		0.00703	0.00342	0.00240	<b>0.00181</b>
<b>Longnose gar</b>		0.00177	0.000797	<b>0.000652</b>	0.000299
<b>Paddlefish</b>		<b>0.00658</b>			
<b>Mountain whitefish</b>				0.00282	<b>0.00159</b>
<b>Round whitefish</b>		0.0018]	<b>0.000856</b>		
Brook trout	0.021]	0.0216*	0.00270	0.000707	
<b>Lake trout</b>		0.00190	0.00207	0.0017)	0.00190
<b>Brown trout</b>		0.00727	0.00267	0.0028]	0.00169
<b>Rainbow trout</b>		<b>0.00683</b>	0.00302	0.00171	0.00082]
<b>Cutthroat trout</b>		0.00516	0.00234	0.00114	0.000734
<b>Kokanee</b>		0.00282	<b>0.000593</b>		<b>0.000515</b>
<b>Largemouth bass</b>	0.0291	0.00721	0.00344	0.00395	0.00283
<b>Smallmouth ba--</b>	<b>0.0183*</b>	<b>0.0121*</b>	<b>0.00451</b>	0.00180	<b>0.00251</b>
<b>Spotted ba--</b>		0.00287	0.00317	0.00166	<b>0.000988</b>
<b>Green sWift.h</b>		0.00847	0.00679	0.00198	<b>0.00145</b>
<b>Pumpkinseed</b>	0.00349	0.00115	0.00163	0.00131	0.000716
<b>Bluegill</b>	0.00631	0.00681	<b>0.00527</b>	0.003))	0.002]2
<b>Redear sunfish</b>		0.00533	0.00360	0.00294	0.00199
<b>SpotUd sunfish</b>		0.00713			
<b>Warmouth</b>		0.00742	<b>0.00414</b>	0.00246	0.00169
<b>Rock bass</b>	0.00644	0.005)7	0.00210	<b>0.00156</b>	0.00130
<b>White crappie</b>		0.00226	0.00263	0.00237	0.00206
<b>Black crappie</b>		0.00669	<b>0.00408</b>	0.00180	<b>0.00145</b>
<b>White bass</b>		0.00812	<b>0.00380</b>	<b>0.000967</b>	0.00245
<b>Yellow perch</b>		<b>0.00494</b>	0.000821	0.00133	0.00109
<b>Walleye</b>		<b>0.00351</b>	0.00190	0.00085	0.000902
<b>Sauger</b>		0.000715	0.00293	<b>0.000945</b>	0.000512
<b>Chain pickerel</b>		0.00303	0.00190	0.00262	0.00114
<b>Northern pike</b>		0.00684	0.00301	0.00411	0.00174
<b>Channel catfish</b>	0.0213	0.00853	<b>0.00489</b>	0.00184	<b>0.00434</b>
<b>Flathead catfish</b>		0.00913	0.00478	0.00291	0.00275

\* Laboratory studies over limited time periods. All other data are from field studies and represent the maximum values reported in the literature.

**Appendix I (Concluded)**

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<u>Species</u>	<u>Age Class</u>				
	I	II	III	IV	V
<b>Blue</b> catfish	0.00558	0.00377	0.00262	0.00140	0.00179
<b>Yellow</b> bullhead		0.00703	0.000913	0.000614	0.000509
<b>Brown</b> bullhead			0.000857		
Black bullhead		0.00522	0.00685	0.00350	0.00304
Silver <b>redhorse</b>		0.00496	0.00260	0.00188	0.00123
Northern redhorse		0.00560	0.00223	0.00440	0.000493

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APPENDIX J: DIGESTIVE EFFICIENCIES AND FOOD CONSUMPTION OF FISH

## Appendix J

## Digestive Efficiencies and Food Consumption of Fish

Species	Study Location	Age, length, or weight	Assimilation Efficiency	Ecological Growth Efficiency	Daily Meal as % Body Weight	Comments	Reference
Largemouth bass	?	fingerling to 454 g			4.0=optimum level	Water temp.=21.1°C.	Thompson (1941)
Largemouth bass	Concrete ponds, AL	20-255 g		24.1		Fed on fish. Water temp.=26.7-32.2°C. Jun-Sep.	Prather (1950)
Largemouth bass	Laboratory	71-115 g, $\bar{x}$ =89 g			7.01	Fed on mosquitofish or mollies. Water temp.=24-25°C.	Hunt (1960)
Largemouth bass	Laboratory		95.7 for protein N. 95.5 for lipid. 89.6 for energy.				Beamish (1972)
Largemouth bass	Laboratory	22 g 464 g		31.2 15.2	5.4 2.0	Water temp.=19.4- 25.0°C, $\bar{x}$ =21.3°C. Fed on minnows.	Williams (1959)
Largemouth bass	Crab Orchard Lake, IL	90-450 g 451-900 g 901-1350 g 1351-1800 g 1800+ g			4.0 3.5 3.5 1.6 1.5	Apr-Oct	Lewis et al. (1974)
Smallmouth bass	?	7.5 g 27.4 g 39.5 g 57.0 g 111.5 g		30.7 21.4 19.3 27.2 22.8	9.4 3.2 2.8 2.8 3.0	Water temp.=19.4- 25.0°C, $\bar{x}$ =21.3°C. Fed on minnows.	Williams (1959)
Rock bass	Lake Opinicon, Ontario, Canada	29-90 g			2-4	Jun	Keast and Welsh (1968)
White bass	Lake Mendota, WI and Laboratory	44-77 mm	66.0-69.2, $\bar{x}$ =67.35	17.3-35.3, $\bar{x}$ =27.25		Annual cycle	Wissing (1974)
Bluegill	Laboratory	20.2-148.5 g	80.0 @ 15°C 79.9 @ 20°C 80.0 @ 25°C	44 @ 15°C 33 @ 20°C 30 @ 25°C	1.97 @ 15°C 1.88 @ 20°C 2.94 @ 25°C	16-hr. photoperiod.	Pierce and Wissing (1974)
Bluegill	Maple and Grove Lakes, MN	100-211 mm 27-114 g			Maple Lake: 2.04 @ 27 g 2.2 @ 55 g 1.84 @ 114 g Grove Lake: 1.67 @ 64 g 1.38 @ 95 g	Avg. water temp.= 22.2°C. Summer.	Seaburg and Moyle (1964)

(Continued)

## Appendix J (Continued)

Species	Study Location	Age, length, or weight	Assimilation Efficiency	Ecological Growth Efficiency	Daily Meal as % Body Weight	Comments	Reference
Bluegill	Laboratory	29.7 g	97.2 (protein absorption)	32=Maximum protein utilization for growth.	1.00=main-tenance. 3.5=maximum intake.	Avg. water temp.= 24.6°C.	Gerking (1955)
Bluegill	White Oak Lake, TN	III, IV		4.2=Apr-Oct	0.8-3.2, x=1.75	Jun-Jan	Kolehmainen (1974)
Bluegill	Wyland Lake, IN	II-V 14-85 g		17.2 for protein.	3.6 in Lab.	Avg. water temp.= 23.9°C. Data are a revision of Gerking (1962). Summer.	Gerking (1972)
Bluegill	Lake Opinicon, Ontario, Canada	11.1-58 g			2-4	Jun	Keast and Welsh (1968)
Carp	Laboratory		74	31		Fed on Chironimids.	Ivlev (1939)
Carp	White Oak Lake, TN	I-VII		8.0	3.9	Annual cycle.	Kevern (1966)
Carp			95			Data in doubt.	Kobashi and Deguchi (1971)
Blue catfish	Laboratory	3.78 g 8.69 g		35.5		20°C, 16-hr. photoperiod.	Tyler and Kilambi (1973)
Channel catfish	Laboratory	5.5 g 23 g		62.5 62.5		12-hr. photoperiod.	Stickney and Andrews (1971)
Channel catfish	Laboratory	4 g		55.6 @ 22°C 41.7 @ 18°C 52.6 @ 26°C 16.7 @ 18°C 33.3 @ 22°C 30 @ 26°C 9.4 @ 18°C 18.2 @ 22°C 28.6 @ 26°C	2 2 2 4 4 4 6 6 6		Andrews and Stickney (1972)
Channel catfish	Laboratory			9.56		32°C=optimum temperature for food conversion. 14-hr. photoperiod @ 32°C.	Kilambi et al. (1970)
Black crappie	Maple and Grove Lakes, MN	122-368 mm			Maple Lake: 2.12 @ 64 g 2.00 @ 104 g 1.58 @ 190 g	Avg. water temp.= 22.2°C. Summer.	Seaburg and Moyle (1964)

(Continued)

## Appendix J (Continued)

Species	Study Location	Age, length, or weight	Assimilation Efficiency	Ecological Growth Efficiency	Daily Meal as % Body Weight	Comments	Reference
Black crappie (Con't)	Maple and Grove Lakes, MN (Con't)				Grove Lake: 2.00 @ 32 g 1.00 @ 100 g 0.58 @ 159 g		
Florida gar	Laboratory	70-132 g, $\bar{x}$ =110 g 30, 35 g			2.81 4.26	Fed mosquitofish or mollies. Water Temp. 24-25°C.	Hunt (1960)
Longnose gar	Missouri creeks and rivers, and Labora- tory	6.00 g 13.88 g 24.69 g 33.49 g $\bar{x}$ =20.96 g		64.0 49.5 40.9 34.7 $\bar{x}$ =43.1	10.1 11.3 7.3 8.0 $\bar{x}$ =9.1	Water temp.=26.4°C.	Netsch and Witt (1962)
Goldfish	Laboratory		71.5-86.5			At maintenance level @ 21.5°C.	Davies (1964)
Blueback herring	James River, VA and Laboratory	1.16-3.97 g	80.0	9.3		Water temp.=16.4- 28.7°C. Constant light. Jun-Nov.	Burbidge (1974)
Muskellunge	Laboratory	17 g		36.7	6.4	Water temp.=17-22°C, $\bar{x}$ =19.5°C. Fed on minnows. 12-hr photoperiod.	Gammon (1963)
Yellow perch	Lake Opinicon, Ontario, Canada	7.8-26.5 g			2-4	Jun	Keast and Welsh (1968)
Northern pike	Lake Windemere, Great Britain	150 g	72	30		Data in doubt. Fed minnows. Annual cycle.	Johnson (1966)
Northern pike	Laboratory				5.0	Fed minnows and insects	Mongeau (1954, 1955)
Pumpkinseed	Lake Opinicon, Ontario, Canada	18-62 g				Jun	Keast and Welsh (1968)
Pumpkinseed	Maple and Grove Lakes, MN	100-179 mm 36-114 g			Maple Lake: 1.38 @ 36 g 1.03 @ 68 g 1.0 @ 127 g Grove Lake: 1.13 @ 77 g 0.61 @ 114 g	Summer. Avg. water temp.=22.2°C.	Seaburg and Moyle (1964)

(Continued)



## Appendix J (Continued)

Species	Study Location	Age, length, or weight	Assimilation Efficiency	Ecological Growth Efficiency	Daily Meal as % Body Weight	Comments	Reference
Sockeye salmon	Laboratory	Fingerlings		$\bar{x}=20$ , maximum=25	$Y=0.542 + 0.308X$ . $X=temp. ^\circ C$ . $=5.2 @ 15^\circ C$ .	Optimum temp.=15°C. Spring-Fall.	Brett et al. (1969)
Sockeye salmon	Laboratory	Young			1.5-11.3 for fingerlings. $\bar{x}=5$ 1.5-7.6 for yearlings.	Annual consumption amounts to 8-9 times final weight, which is typical of plantivores.	Krokhin (1959)
Brown trout	Laboratory	40.7 g 85.2 g		12.9 12.0		Fed on <u>Gammarus</u> .	Pentelow (1939)
Cutthroat trout	Laboratory	Under-yearling	84.9-86.1, $\bar{x}=85.5$	5.2-11.8 in the field.		10°C minimum assimilation efficiency.	Brocksen (1966)
Walleye	Laboratory	160-205 g, II-VI	$E_2=96.851-0.0045W$ ; $r=0.824$ $E_2=82.103-0.0041W$ ; $r=0.859$ $E=83.535-0.0045W$ $E=97.871-0.0045W$	14.3 @ 20°C 12.7 @ 16°C 11.3 @ 8-16°C 13.9 @ 12°C	4.0=optimum	Fed on age 0 perch. Fed on amphipods. Fed on crayfish. Fed on emerald shiner. W=weight (g), E=assimilation efficiency. 14-hr photo-period.	Kelso (1972)
Walleye and Sauger	Lake of the Woods, Ontario, Canada	III, IV		16.9 for Jun. 20 for other months.	1.0 in Jun, 2.0 in Jul, 3.0 in Aug-Sep.	Jun-Sep	Swenson and Smith (1973)
Warmouth	Laboratory	72-113 g, $\bar{x}=93$ g			4.37	Fed on mosquitofish or mollies. Water temp.=24-25°C.	Hunt (1960)
Reticulate sculpin	Laboratory	yearling	78.4-84.4, $\bar{x}=81.9$	38.6=optimum @ 8.3-15.0°C.		10°C minimum assimilation efficiency.	Davis and Warren (1965)
Stickleback	Laboratory	Adult			1.8-5.1, $\bar{x}=2.7$		Krokhin (1959)

(Continued)

## Appendix J (Continued)

Species	Study Location	Age, length, or weight	Assimilation Efficiency	Ecological Growth Efficiency	Daily Meal as % Body Weight	Comments	Reference
Green sunfish	Laboratory	II-IV or 68-110 mm		28		Avg. water temp.= 24.7°C. Jul-Aug	Gross et al. (1965)
Green sunfish	Laboratory	7.1-48.5 g max. age=IV	92.3 (nitrogen absorption) 95.7 (protein absorption)	38.7 for 7.1 g wet wt. (1.59 g dry wt.)=gross protein utilization for growth. 32.6 for 11.2 g wet (2.18 dry). 29.8 for 18.2 g wet (3.54 dry). 19.2 for 48.5 g wet (12.37 dry).		Avg. water temp.= 24.5-25.5°C. Fed mealworms.	Gerking (1952a)
Longear sunfish	Laboratory	9.1-103.3 g max. age=VI	94.0 (nitrogen absorption) 97.4 (protein absorption)	32 for 9.1 g wet wt. (2.56 dry wt.)=gross protein utilization for growth. 27.8 for 23.6 g wet (6.64 dry). 29.4 for 28.2 g wet (7.92 dry). 23.4 for 57.9 g wet (17.19 dry). 4.6 for 103.3 g wet (30.68 dry).		Avg. water temp.= 24.5-25.5°C. Fed mealworms.	Gerking (1952a)
Brook trout Brown trout Rainbow trout	Hatchery	98-240 mm			6.0 for 98-122 mm fish. 2.0 for 220-240 mm fish.	Max. allowances for growth @ 15.6°C.	Third Ed. N.Y. State Hatchery Feeding Chart (1952)
<u>Cichlasoma bimaculatum</u>	Laboratory		82.8 @ 20°C 84.0 @ 24°C 88.6 @ 28°C 85.6 @ 32°C 69.6 @ 36°C	33.7 44.0 51.7 43.4 14.5		Fed on <u>Tubifex</u> .	Warren and Davis (1967)

(Continued)

## Appendix J (Concluded)

Species	Study Location	Age, length, or weight	Assimilation Efficiency	Ecological Growth Efficiency	Daily Meal as % Body Weight	Comments	Reference
Roach	Laboratory and River Thames, Great Britain	21.2 g	78.9	5.5		Egestion and excretion assumed to be 20% of food intake. Seasonal temperature fluctuations. Annual cycle.	Mann (1965)
Bleak		34.3 g	79.5	6.6			
Dace		2.8 g	79.4	4.1			
Perch		3.1 g	79.2	4.8			
Gudgeon		4.5 g	79.4	4.6			
$\bar{x}$			79.4	6.0			
Plaice	Laboratory	Young		20			Colman (1970)
Bleak	Laboratory	Young	69.9	19.6		Water temp. 20°C. Egestion=30.1%.	Ivlev (1961)
Carnivorous fish			80	20		General budget based on review of various results up to 1956.	Winberg (1956)

APPENDIX K: ANNUAL, DAILY, AND INSTANTANEOUS NATURAL  
MORTALITY RATES FOR VARIOUS FISH SPECIES

**Appendix K**

Annual, Daily, and Instantaneous Natural Mortality Rates for Various Fish Species

<u>Species</u>	<u>Study Location</u>	<u>Age or Length</u>	<u>Annual Natural Mortality Rate</u>	<u>Daily Natural Mortality Rate</u>	<u>Instantaneous Natural Mortality Rate</u>	<u>Comments</u>	<u>Reference</u>
Large outh bass	Browns Lak , WI	•V	..0.136	0.00037			Mraz and Threlnen (1955) Gerking (1952b) Houser (unpublished)
	Gordy Lak , IN		.0.24	0.00066		Poor sampl •	
	Beaver Reservoir, AR	All ages	0.437-0.716	0.0015	0.575-1.259	1968-1975	
Rock bass	Nebish Lake, WI	X-XI	0.66	0.0018		Unexploited population	Ricker (1947)
		XI-XII	0.71	0.0019			
		XU-XIII	0.78	0.0021			
		XIII-XIV	0.79	0.0022			
Bluegill	Lodge Lake, MI		0.8519	0.0023	1.91	% dist. of natural mort.: 7 (spring), 81 (summer), 12 (fall), 0 (winter).	Patriarche (1968) Patriarche (1968)
	Jewett Lake, MI		0.7961	0.0022	1.9		
	Cordy Lake, IN	≥IV	≈0.47	0.0013			Gerking (1952b) Ricker (1945)
	Muskelung Lake, IN (1942-43)		≈0.49	0.0013			
	Shoe Lak , IN (1941-42)		-0.57	0.0016			Ricker (1945)
	Shoe Lake, IN (1942-43)		-0.59	0.0016			Ricker (1945)
	Wawasee Lake, IN		≈0.68	0.0019		20% st. exploitation rate.	Ricker (1945)
	Gordy Lak , IN	II-III	0.38	0.0010	0.481		Gerking (1952b)
		III-IX	0.49	0.0013	0.667		
Brown bullhead	Clear Lak , CA		0.17	0.00047			McCammon and Selby (1961) Rawstron (1967)
	Folsom Lake, CA		0.34	0.00093			
Channel catfish			0.314	0.00086	0.376		Ricker (1958)
White catfish	Clear Lake, CA		0.19	0.00052	0.21		McCammon and Selby (1961) Rawstron (1967)
	Folsom Lak , CA		0.57	0.0016			
Freshwater drum	Mississippi River		0.257	0.00070			Butler (1965)
Northern pike	Ball Club Lake, MN	III-VIII	0.60	0.0016			Johnson and Peterson (1955) Croebner (1960) Croebner (1960) Scidmore (1955)
	Lake in MN	III-VIII	0.769	0.0021			
	Lake in MN	III-VIII	0.708	0.0019			
	MN		0.497	0.0014			
Sauger	Lake Nipigon, Ontario, Canada	VIII-a	0.231	0.00063		Unexploited population	Ricker (1947)
		IX-X	0.26	0.00071			
		X-XI	0.30	0.00082			
		XI-XU	0.34	0.00093			
		XII-XIII	0.47	0.0013			
		XIII-XIV	0.60	0.0016			

(Continued)

## Appendix K (Concluded)

<u>Species</u>	<u>Study Location</u>	<u>Age or Length</u>	<u>Annual Natural Mortality Rate</u>	<u>Daily Natural Mortality Rate</u>	<u>Instantaneous Natural Mortality Rate</u>	<u>Comments</u>	<u>Reference</u>
American shad	Connecticut River		0.73	0.0020			Walburg (1961)
Longnose sucker	Great Slave Lake, Northwest Territories, Canada		0.55	0.0015			Ceen et al. (1966); Harris (1962); Harrh (1952)
Redear sunfish	Cordy Lake, IN	≥IV	≈ 0.40	0.0011			Cerking (1952h)
Brook trout	Pigeon River, MI East fish Lake, MI				0.012 0.003-0.004	Spring-Summer	Latta (1962) Alexander and Shetter (1961)
	New York Lakes Lawrence Creek, WI Ford and Hemlock Lakes, MI				1.34 0.56 0.75-0.96	Summer average Winter average	Hatch and Webster (1961) Hatch and Webster (1961) McFadden (1961)
Cutthroat trout	Yellowstone Lake, WY		0.16-0.75 0.614	0.00044-0.0021 0.0017			Hansen (1971) Ball and Cope (1961); Welsh (1952)
Rainbow trout	finger Lakes, NY		0.66	0.0018	1.08		Hartman (1959)
Willeye	Many Points Lake, MN	I-VII	0.0479	0.00013	0.0491		Olson (1957)
Whitefish	Lake Opeongo, Ontario, Canada	VI-VII VII-VIII VIII-IX IX-X X-XI XI-XII XII-XIII	0.41 0.46 0.48 0.51 0.56 0.56 0.59			Unexploited population	Ricker (1947)
	Shakespeare Island lake, Ontario, Canada	XI-XII XII-XIII XIII-XIV XIV-XV XV-XVI XVI-XVII XVII-XVIII XVIII-XIX XIX-XX XX-XXI XXI-XXII XXII-XXIII XXIII-XXIV XXIV-XXV XXV-XXVI XXVI-XXVII	0.08 0.09 0.10 0.11 0.11 0.12 0.13 0.15 0.17 0.21 0.24 0.27 0.32 0.36 0.40 0.45			Unexploited population	Ricker (1947)
	Georgian Bay of Lake Huron, Ontario, Canada	>III	0.41				Cucin lind Regier (1965)

APPENDIX L: METABOLIC RATES OF FISH

Appendix L: Part I

Regression Equations Relating Active Metabolism at Various  
Temperatures to Fish Weight

<u>Species</u>	<u>Temperature, °C</u>	<u>Regression Equation*</u>	<u>Reference</u>
Brook trout	5	$\log Y = -0.730 + 0.942 \log W$	Job (1955)
	10	$\log Y = -0.461 + 0.862 \log W$	
	15	$\log Y = -0.391 + 0.851 \log W$	
	20	$\log Y = -0.075 + 0.750 \log W$	
Sockeye salmon	15	$\log Y = -0.050 + 0.970 \log X$	Brett (1965)
	20		
	30		
	34		
	37		
	39		
	41		
	43		
	45		
	47		

\* Y = metabolic rate (mgO<sub>2</sub>/hr)

W =

X = weight (g)



## Appendix L: Part II

Regression Equations Relating Standard Metabolism at  
Various Temperatures to Fish Weight

<u>Species</u>	<u>Temperature, °C</u>	<u>Regression Equation*</u>	<u>Reference</u>
Goldfish	10	$\log Y = -1.568 + 0.882 \log X$	Beamish and Mookherjee (1964)
	20	$\log Y = -0.348 + 0.913 \log X$	
	30	$\log Y = -0.577 + 0.717 \log X$	
	35	$\log Y = -0.670 + 0.887 \log X$	
Carp	10	$\log Y = -1.735 + 0.983 \log X$	Beamish (1964a)
	20	$\log Y = -1.137 + 0.909 \log X$	
	30	$\log Y = -0.733 + 0.876 \log X$	
	35	$\log Y = -0.550 + 0.810 \log X$	
Brown bullhead	10	$\log Y = -1.696 + 0.998 \log X$	Beamish (1964a)
	20	$\log Y = -0.986 + 0.903 \log X$	
	30	$\log Y = -0.721 + 0.874 \log X$	
White sucker	10	$\log Y = -1.460 + 0.994 \log X$	Beamish (1964a)
	15	$\log Y = -0.772 + 0.828 \log X$	
	20	$\log Y = -0.497 + 0.770 \log X$	
Brook trout	10	$\log Y = -1.476 + 1.107 \log X$	Beamish (1964a)
	15	$\log Y = -0.996 + 1.014 \log X$	
	20	$\log Y = -0.905 + 1.036 \log X$	
Brown trout	10	$\log Y = -0.847 + 0.877 \log X$	Beamish (1964a)
Sockeye salmon	15	$\log Y = -0.632 + 0.775 \log X$	Brett (1965)

\* Y = metabolic rate (mgO<sub>2</sub>/hr)  
X = weight (g)

Appendix L: Part III  
Summary of Fish Metabolic Rates at Various Temperatures,  
Ages, and Weights

Species	Age	Wet Weight, g	Temperature, °C	Oxygen Consumption, mlO <sub>2</sub> /g/hr						Reference		
				Standard	1/4 Active	1/2 Active	3/4 Active	Routine	Full Active		Active/Standard	Routine/Standard
Sockeye salmon	Yearling	36.7	5	0.0287					0.360	12.5	Brett (1964)	
	Yearling	32.9	10	0.0420					0.439	10.5		
	Yearling	55.2	15	0.0497	0.0924	0.175	0.336		0.627	12.6		
	Yearling	62.9	20	0.0840					0.596	7.1		
	Yearling	52.2	24	0.137					0.594	4.3		
	Underyearling	3.38	15	0.161	0.231	0.322	0.462		0.644	4.0	Brett (1965)	
	Underyearling	8.47	15	0.0770	0.130	0.210	0.361		0.581	7.5		
	Underyearling	19.1	15	0.0889					0.490	5.5		
	Adult (jacks)	746	15	0.0497	0.882	0.158	0.287		0.511	10.3		
	Adult	1432	15	0.308	0.0616	0.123	0.245		0.502	16.3		
	Brook trout	?		5	0.0240*							Graham (1949)
?			5	0.0259*							Flörke et al. (1954)	
15			5	0.0867*							Job (1955)	
164			10	0.0480*					0.217	4.5	Graham (1949)	
164			10						0.224*		Basu (1959)	
?			10	0.0434*							Flörke et al. (1954)	
15			10	0.153*							Job (1955)	
100			10	0.0555				0.0926			1.7	Beamish (1964a)
100			15	0.0750				0.159			2.1	
164			15	0.0800*					0.343	4.3	Graham (1949)	
164			15						0.343*		Basu (1959)	
?			15	0.0700*							Flörke et al. (1954)	
15			15	0.227*							Job (1955)	
15			20	0.287*								
100			20	0.103*				0.152			1.5	Beamish (1964a)
?			20	0.091*								Flörke et al. (1954)
164		20	0.110*					0.245	2.2	Graham (1949)		
164		20						0.210*		Basu (1959)		
?		25	0.150*							Graham (1949)		
Rainbow trout			5	0.0420*							Flörke et al. (1954)	
			10	0.0700*								
			15	0.105*								
			20	0.140*								
Brown trout		100	10	0.0566							Beamish (1964a)	

\* Determined from a graph.

## Appendix L: Part III (Continued)

Species	Age	Wet Weight, g	Temperature, °C	Oxygen Consumption, mlO <sub>2</sub> /g/hr				Full Active	Active/Standard	Routine/Standard	Reference
				Standard	1/4 Active	1/2 Active	3/4 Active				
Lake trout	Age I	27.7	10	0.0350*				0.190	5.4	Gibson and Fry (1954)	
		27.7	15	0.0600*				0.300	5.0		
		27.7	20	0.900*				0.280	3.1		
	Age II	82.8	10	0.0250*				0.205	8.2		
		82.8	15	0.0400*				0.265	6.6		
		82.8	20	0.0650*				0.265	4.1		
White sucker		100	10	0.0243			0.0572		2.4	Beamish (1964a)	
		100	15	0.0550			0.0725		1.3		
		100	20	0.0773			0.0962		1.2		
Brown bullhead		15	5	0.0252*				0.0630	2.5	Fry (1947)	
		15	10	0.0504*				0.147	2.9		
		15	15	0.105*				0.231	2.2		
		15	20	0.168*				0.378	2.3		
		15	25	0.273*				0.567	2.1		
		15	30	0.357*				0.756	2.1		
		15	35	0.399*				0.945	2.4		
		100	10	0.0140			0.0371		2.7		
		100	20	0.0463			0.0680		1.5		
		100	30	0.0743			0.0946		1.3		
Carp		100	10	0.0119						Beamish (1964a)	
		100	20	0.0336			0.0791		2.4		
		104	20					0.476*			
		100	30	0.0732			0.140		1.9		
		104	30					0.630*			
		100	35	0.0821							
Goldfish		3.8	5	0.0150*				0.0280	1.9	Fry and Hart (1948)	
		3.8	10	0.0250*				0.0600	2.4		
		74	10					0.196*			
		100	10	0.0110							
		100	15	0.0140							
		3.8	15	0.0550*				0.115	2.1		
		3.8	20	0.0800*				0.155	1.9		
		74	20					0.245*			
		100	20	0.0211							
		100	25	0.0315							
		3.8	25	0.145*				0.260	1.8		
		3.8	30	0.175*				0.295	1.7		
		74	30					0.350*			
		100	30	0.0504							
	100	35	0.0889								

(Continued)

Appendix L: Part 111 (Concluded)

Species	Age	Wet Weight g	Temperature, °C	Standard	Oxygen Consumption, 102/s/hr				Pull Active Standard	Routine Standard	Reference
					1/4 Active	1/2 Active	3/4 Active	Routine			
Goldfish (Cont.)		18	35	0.220*				0.295	1.3	Fry and Hart (1948) Spoor (1946)	
		32	23-25	0.0750*				0.128	4.4		
Yellow perch		1	7	0.0126"						Flörke et al. (1954)	
		1	10	0.0259*							
		1	15	0.0420*							
		1	20	0.0700"							
Fish in general		1	11	0.0980"						Winberg (1956)	
									1.1		

\*\* See tables by Winberg (1956)

## Appendix L: Part IV

Summary of Fish Metabolic Rates at 20°C\*

Species	Wet Weight, g	Respiration, mlO <sub>2</sub> /g/hr			Reference
		Standard	Routine	Active	
Sockeye salmon	62.9	0.0840		0.596	Brett (1964)
Brook trout	100	0.103	0.152		Beamish (1964b)
	?	0.091			Flörke et al. (1954)
	164			0.210	Basu (1959)
Rainbow trout	?	0.140			Flörke et al. (1954)
Lake trout	27.7	0.0900		0.281	Gibson and Fry (1954)
	82.8	0.0650		0.265	
White sucker	100	0.0773	0.0962		Beamish (1964b)
Brown bullhead	15	0.168		0.378	Fry (1947)
	100	0.0463	0.0680		Beamish (1964b)
Carp	100	0.0336	0.0791		
	104			0.476	Basu (1959)
Goldfish	3.8	0.0800		0.155	Fry and Hart (1948)
	74			0.245	Basu (1959)
	100	0.0211			Beamish and Mookherjee (1964)
Yellow perch	?	0.0700			Flörke et al. (1954)
Generalized reservoir fish (estimated values)	100	0.0500	0.150	0.300	

\* For additional data see Winberg (1956).

APPENDIX M: FISH TEMPERATURE TOLERANCES

## Appendix M: Part I

## Temperature Tolerance and Preference Data for Various Fish Species

Species	Age or Length	Acclimation Temperature	T <sub>1</sub> Lower Lethal Temperature	Best Temperature Range for Growth			T <sub>4</sub> Upper Lethal Temperature	Comments	Reference
				T <sub>2</sub>	Optimum or (Preferred)	T <sub>3</sub>			
Gizzard shad		25	10.8				34.3		Hart (1952)
		30	14.5				35.9		
Carp		26					35.7	24-hr TL50	Black (1953)
Common shiner		5					26.7		Hart (1947)
		10					28.6		
		15	0.0				30.3		
		20	3.7						
		25	7.8				31.0		
		30					31.0		
Common shiner	Adult	5					26.7		Hart (1952)
		10					28.6		
		15					30.3		
		20					31.0		
		25					31.0		
Golden shiner		22.0				≈ 40		Alpaugh (1972)	
Golden shiner	Adult	10					29.5		Hart (1952)
		15					30.5		
		20					32.0		
		25					33.5		
		30					34.5		
Emerald shiner					27			McCormick and Mischuk (1973)	
Emerald shiner		5					23.2		Hart (1947)
		10					26.7		
		15	1.6				28.9		
		20	5.2				30.7		
		25	8.0				30.7		
Duskystripe shiner		21.5					32.0	Ultimate upper incipient lethal.	Hickman and Dewey (1973)
Bluntnose minnow		5					26.0		Hart (1947)
		10					28.3		
		15	1.0				30.6		
		20	4.2				31.7		
		25	7.5				33.3		

\* All temperatures in °C.

Sheet 1 of 5

Appendix M: Part I (Continued)

Species	Age or Length	Acclimation Temperature	T <sub>1</sub> Lower Lethal Temperature	Best Temperature Range for Growth			T <sub>4</sub> Upper Lethal Temperature	Comments	Reference
				T <sub>2</sub>	Optimum or (Preferred)	T <sub>3</sub>			
Flathead minnow		10					28.2		Hart (1947)
		20	1.5				31.7		
		30	10.5				33.2		
Creek chub		5					24.7		Hart (1952)
		10					27.3		
		15					29.3		
		20	0.7				30.3		
		25	4.5				30.3		
Chub		14					27.1	24 hr TL50	Black (1953)
Finescaled sucker		14					26.9	24 hr TL50	Black (1953)
White sucker		25					31.2		Brett (1944)
White sucker	Adult I-II	5					26.3		Hart (1947)
		10					27.7		
		15					29.3		
		20	2.5				29.3		
		25	6.0				29.3		
White sucker				27					McCormick (1973)
Brown bullhead		5					27.8		Hart (1952)
		10					29.0		
		15					31.0		
		20					32.5		
		25					33.8		
		30					34.8		
		34					34.8		
Brown bullhead		5					28.6		Brett (1944)
		10					30.2		
		15					31.8		
		20	-1.0				33.4		
		25	1.3				35.0		
		30	3.7				36.5		
Black bullhead		23					35		Black (1953)
Channel catfish	Yearling	25					35.5		Allen and Strawn (1968)
		35					38.0		
Channel catfish	Fingerling			18	30	34			Andrews and Stickney (1972)

(Continued)



## Appendix M: Part I (Continued)

Species	Age or Length	Acclimation Temperature	T <sub>1</sub> Lower Lethal Temperature	Best Temperature Range for Growth			T <sub>4</sub> Upper Lethal Temperature	Comments	Reference
				T <sub>2</sub>	Optimum or (Preferred)	T <sub>3</sub>			
Channel catfish		15	0.0				30.3		Hart (1952)
		20	2.5				32.8		
		25	6.0				33.5		
Bluegill		21.5					35.5		Hickman and Dewey (1973)
Bluegill	Adult	15	2.5				30.7		Hart (1952)
		20	5.0				31.5		
		25	7.5						
		30	11.1?				33.8?		
Bluegill	Juvenile	12.1	3.2				27.5	96-hr TL 50	Banner and Van Arman (1973)
		32.9	15.3				37.3	96-hr TL 50	
Bluegill	II				22				McComish (1971)
Longear sunfish	Juvenile	25					35.6		Neill et al. (1966)
		30					36.8		
		35					37.5		
Pumpkinseed		25					24.5		Brett (1944)
Smallmouth bass	Juvenile	16-35	1.6 @ 35		26.3		35.0	96-hr TL 50 (median tolerance limit)	Horning and Pearson (1973)
			10.1 @ 26						
Smallmouth bass					28.3				Peck (1965)
Largemouth bass	Fry	15-30			27.5 and 30.0				Strawn (1961)
Largemouth bass		18-30			25				Niimi and Beamish (1974)
Largemouth bass		20	5.5				32.5		Hart (1952)
		25					34.5		
		30	11.8				36.4		
Black crappie		29			22-25		32.5		Hokanson and Kleiner (unpublished)
Yellow perch		5					21.3		Hart (1947)
		10	1.1				25.0		
		15					27.7		
		25	3.7				29.7		
Yellow perch		25					30.9		Brett (1944)
Yellow perch	Juvenile	24		20.0		23.3			McCauley and Read (1973)
	Adult	24		17.6		20.1			

(Continued)

## Appendix M: Part I (Continued)

Species	Age or Length	Acclimation Temperature	T <sub>1</sub> Lower Lethal Temperature	Best Temperature Range for Growth			T <sub>4</sub> Upper Lethal Temperature	Comments	Reference
				T <sub>2</sub>	Optimum or (Preferred)	T <sub>3</sub>			
Yellow perch	Fingerling	8			(18.6)				Ferguson (1958)
		10			(19.3)				
		15			(23.0)				
		20			(23.1)				
		25			(24.5)				
		30			(26.7)				
European perch						30-31	Independent of acclimation temperature	Weatherley (1963)	
Sockeye salmon	Fry	5	0				22.2		Brett (1952)
		10	3.1				23.4		
		15	4.1				24.4		
		20	4.7				24.8		
Sockeye salmon	Juvenile	15		5	15	17		Brett et al. (1969)	
Coho salmon	Fry	5	0.2				22.9		Brett (1952)
		10	1.7				23.7		
		15	3.5				24.3		
		20	4.5				25.0		
Chinook salmon	Fry				18.4			Olson and Foster (1955)	
Northern pike	Larvae	17.7	3.2		26		28.4		Hokanson et al. (1973)
Northern pike	Juvenile	25					32.25		Scott (1964)
		27.5					32.75		
		30					33.25		
Lake trout	Yearling				(11.7)			Independent of acclimation temperature	McCauley and Tait (1970)
Lake trout				4(8)		(10) 18		Lake Louisa, Ontario, Canada	Martin (1952)
Lake trout				4(7)		(13) 18		Cayuga Lake, NY	Galligan (1962)
Lake trout				8		10.9		Lac la Ronge, Saskatchewan, Canada	Rawson (1961)
Lake trout				10		13		Moosehead Lake, MA	Cooper and Fuller (1945)
Lake trout	I-II	8, 15, 20			16.5		22.7, 23.5, 23.5		Gibson and Fry (1954)

(Continued)

## Appendix M: Part I (Concluded)

Species	Age or Length	Acclimation Temperature	T <sub>1</sub> Lower Lethal Temperature	Best Temperature Range for Growth			T <sub>4</sub> Upper Lethal Temperature	Comments	Reference
				T <sub>2</sub>	Optimum or (Preferred)	T <sub>3</sub>			
Rainbow trout	Juvenile	18					26.5		Alabaster and Welcomme (1962)
Rainbow trout	Under-yearling 4-5 cm	15-20		17	(18.4)	20			McCauley and Pond (1971)
Brook trout		5					23.7		Fry et al. (1946)
		10					24.4		
		15					25.0		
		20					25.3		
		25	0.5				25.3		
Brook trout					13				Baldwin (1957)
Brook trout				14	16	19			Graham (1949)
Brook trout					15.4				McCormick et al. (1972)
Brown trout	Young				15.6				Pentelov (1939)
Brown trout					15.4				Wingfield (1940)
Brown trout					7-9 and 16-19				Brown (1946)
Brown trout					8-17, $\bar{x}=125$				Brett (1970)
Brown trout	Juvenile	5, 10, 20					22.2, 23.4, 23.5		Bishai (1960)
Mosquitofish		15	1.5				35.4		Hart (1952)
		20	5.5				37.3		
		25					37.3		
		30					37.3		
Goldfish		5					29.0		Fry et al. (1946)
		10					30.8		
		15					32.8		
		20	2.0				34.8		
		25	6.0				36.6		
		30	9.0				38.6		
Prickley sculpin		18-19					24.1		Black (1953)
Squawfish		19-22					28.9	24-hr TL50	Black (1953)
Muskellunge	Juvenile	25					32.25		Scott (1964)
		27.5					32.75		
		30					33.25		
Golden topminnow	Adult	35					38.5		Strawn and Dunn (1967)
Bayou killifish		35					38.5		Strawn and Dunn (1967)

Appendix M: Part II  
Summary of Temperature Tolerances and  
 Preferences for Reservoir Fish\*

Species	T <sub>1</sub> Lower Lethal Temperature	Best Temperature Range for Growth			T <sub>4</sub> Upper Lethal Temperature
		T <sub>2</sub>	Optimum or Preferred	T <sub>3</sub>	
Gizzard shad	10.8 @ 25		16-18?		36.5 @ 35
Threadfin shad	<1.1 in field				
Northern pike	3.2 @ 17.7 for larvae		26 (larvae)		33.3 @ 30 for juveniles
Grass pickerel			25.5		
Chain pickerel			26.0		>36.7 in field
Muskellunge			24.0		33.3 @ 30 for juveniles
Carp	0.7		32.0		35.7 @ 26
Goldfish	0 @ 10		28.1		40.5 @ 35 (ultimate)
Golden shiner	1.5 @ 15				34.7 @ 30
Emerald shiner	1.6 @ 15		27		30.7 @ 25 (ultimate)
Common shiner	0 @ 15				32 @ 25-26
Spottail shiner					≥35 in field
Bluntnose minnow	1.0 @ 15				33.3 @ 25
Flathead minnow	1.5 @ 20				33.2 @ 30
Creek chub	0.7 @ 20				32.6 @ 25-26
Duskystripe shiner					32.0 @ 21.5
Longnose sucker					27 @ 11.5
White sucker	2.5 @ 20		27		31.2 @ 25-26
Largescale sucker					29.4 @ 19
Finescale sucker					26.9 @ 14
Brown bullhead	-1.0 @ 20				37.5 @ 36 (ultimate)
Black bullhead					35 @ 23
Channel catfish	0 at 15		30		38.0 @ 35 for yearlings
Banded killifish					≥38.3 in field
Golden topminnow					38.5 @ 35
Mosquitofish	1.5 @ 15				37.3 @ 20-35
Striped bass					32.2
Rock bass					35 @ 30

\* All temperatures in °C.

Appendix M: Part II (Concluded)

<u>Species</u>	<u>T<sub>1</sub></u> <u>Lower Lethal</u> <u>Temperature</u>	<u>Best Temperature Range</u> <u>for Growth</u>			<u>T<sub>4</sub></u> <u>Upper Lethal</u> <u>Temperature</u>
		<u>T<sub>2</sub></u>	<u>Optimum</u> <u>or Preferred</u>	<u>T<sub>3</sub></u>	
Longear sunfish	<7 in field				37.5 @ 35 for juveniles
Green sunfish					>34 in field
Redear sunfish	<6.5 in field				
Bluegill	2.5 @ 15		27.7		37.3 @ 32.9 for juveniles
Smallmouth bass	1.6 @ 15		27	28	35
Largemouth bass	5.2 @ 20	25	27	30	37.5 (average)
Pumpkinseed			31.5		24.5 @ 25
Black crappie		22		25	32.5 @ 29
Yellow perch	1.1 @ 10		24.2		30.9 @ 25
Rainbow trout	0		13.3		28
Brown trout		12	15.5	18	25.3 @ 20+ (ultimate)
Kokanee	0 @ 5		14.5		24.8 @ 20 for fry
Coho	0.2 @ 5				25.0 @ 20 for fry
Lake trout		8	12.0	12.0	23.5 @ 15 and 20
Brook trout	0.5 @ 25	10.8	12.8	14.8	26.6
Prickley sculpin					24.1 @ 18 and 19
Northern squawfish					29.3 @ 19-22