Report No. TR-250-10
BIO/WEST, Inc.

DEVELOPMENT OF A POPULATION MODEL FOR HUMPBACK CHUB (Gila cypha) IN GRAND CANYON

Program Element II. A Conceptual Population Model
Review Of Conceptual Model By Grand Canyon Researchers

Submitted to

Mr. Dave Wegner
Program Manager
Glen Canyon Environmental Studies
Flagstaff, Arizona

and

Mr. Larry Crist
Contract Officer Technical Representative
Bureau of Reclamation
Salt Lake City, Utah

Submitted by

Ronald J. Ryel, Ph.D.
and
Richard A. Valdez, Ph.D.
BIO/WEST, Inc.
Logan, Utah

April 15, 1994

REQUESTED REVIEW OF CONCEPTUAL POPULATION MODEL

The attached compartmental flow diagram is a conceptual population model for humpback chub (Gila cypha) in Grand Canyon. Most of you have already seen a version of this model as part of Appendix D of the 1992 BIO/WEST Annual Report (Valdez and Hugentobler 1993). The ensuing report provides a detailed description of the components of the conceptual population model. Also, you should have already received a copy of the Completion Report for Program Element I: Population Model Feasibility Evaluation (Ryel and Valdez 1994), which provides a complete description of the modelling program and its role in the Glen Canyon Environmental Studies (GCES).

We need your help in reviewing and refining this conceptual model so that it reflects, as accurately as possible, a characterization of the population of humpback chub in Grand Canyon. This will enable us to proceed with identification of important state and rate variables, and assimilation of appropriate information.

PLEASE RETURN THE FOLLOWING BY MAY 20, 1994 (use the self-addressed, stamped envelope):

1. **FIGURE 1**: Written comments on the 11" x 17" insert of the conceptual model. Add, delete, or modify state variables (compartments) or rate variables (arrows) that best reflect your perception of the humpback chub population in Grand Canyon--Please explain or justify any changes.

2. **TABLE 1**: Mark (x) under "Data Available" field in Table 1 to indicate state or rate variables for which you may be able to provide quantified data, given your analysis of your data.

We plan to integrate your written comments into a report that will present a consensus conceptual population model for humpback chub in Grand Canyon, and identify data sources for the model.

Thank you for your cooperation and assistance in developing this population model.

Richard A. Valdez, Ph.D.
Principal Investigator

Ronald J. Ryel, Ph.D.
Population Modeller

TABLE OF CONTENTS

INTRODUCTION 1

DESCRIPTION OF CONCEPTUAL POPULATION MODEL 2
Component a. Colorado River Upstream (CRU) 2
Component b. Colorado River/LCR Inflow (CRI) 3
Component c. Colorado River Downstream (CRD) 3
Component d. Little Colorado River (LCR) 4
Component e. Tributaries (TRI) 4

LIST OF TABLES

Table 1. Descriptions of state and rate variables for each component of a conceptual population model for humpback chub in Grand Canyon . . . 6

LIST OF FIGURES

Figure 1. Conceptual model of humpback chub population in Grand Canyon. Five components--(a) Colorado River Upstream (CRU), (b) Colorado River/LCR Inflow (CRI), (c) Colorado River Downstream (CRD), (d) Little Colorado River (LCR), (e) Tributaries (TRI). Abundance in age groups are shown by boxes while solid lines and arrows indicate progression from one age to another, or movement of fish. Rates are indicated as: s = survival, f = fecundity, and m = movement. See Table 1 for a detailed description of state and rate variables. 5

INTRODUCTION

The purpose for this conceptual model is to provide a visual representation of state and rate variables of the humpback chub population in Grand Canyon. The objectives of the conceptual model are to:

1. Develop a compartmental representation of perceived state and rate variables of the population.

2. Refine the conceptual model through input from Grand Canyon researchers.

3. Solicit data and information from Grand Canyon researchers on important state and rate variables.

4. Provide a framework for the infrastructure of the population

This document addresses objectives 1 and 2 above. This review will define the conceptual model, and help identify important model parameters, including estimated numbers of individuals in various age groups (state variables), and fecundity (reproductive), survival, and movement rates (rate variables). This conceptual model does not contain values for state or rate variables, but simply identifies the parameters (blocks) and interrelationships (arrows) within the population.

This conceptual model will provide the first organizational framework to help assess the current knowledge of the humpback chub population in Grand Canyon. It will identify missing data, and rate and state variables that may affect the greatest change in the population. This conceptual model will be extremely useful in integrating information collected by past and present researchers in Grand Canyon, and as an organizational tool to assess the status of data collected for GCES humpback chub studies.

This conceptual model also provides the framework for a quantitative modelling effort. While mathematical formulations rarely include entire conceptual models, this consensus picture of the population is essential in identifying and quantifying important state and rate variables, as well as gaining a better understanding of the infrastructure of the population.

DESCRIPTION OF CONCEPTUAL POPULATION MODEL

In the initial conceptual model (Figure 1), all humpback chub in Grand Canyon are considered one population. This assumption is made until further information and analyses allow for clear segregation of aggregates or subpopulations. The conceptual population model for humpback chub in Grand Canyon is based on five basic population components (Table 1):

a. Colorado River Upstream (CRU) of LCR component.

b. Colorado River/LCR inflow (CRI).

c. Colorado River Downstream (CRD) of LCR component.

d. Little Colorado River (LCR).

e. Tributaries (TRI).

Each component is identified with state variables (i.e., eggs, larvae, age 0, age I, etc.), and rate variables (i.e., survival, reproduction, movement), in Table 1, as shown in Figure 1, and explained in the following subsections.

One or more of the five components identified above may not be significant contributors to overall numbers of humpback chub in Grand Canyon. Nevertheless, all possible components, and associated state and rate variables are identified so that all probable population interrelationships are considered. We also recognize that many of these variables may be too insignificant to consider. Where these relationships are determined to not exist, state or rate variables will equal zero, and be removed from the flow diagram.

Component a. Colorado River Upstream (CRU)

About 5 percent of the humpback chub captured by BIO/WEST in the Colorado River in Grand Canyon, from 1990 through 1993, were found in regions of the Colorado River outside of the 30-km area around the LCR inflow (RM 58-77). Little is known about these fish, including their origin, abundance, distribution, movement, reproduction, and survival. Small aggregations were found at Tiger Wash (RM 27), near South Canyon (RM 30), and from Malagosa Canyon to Awatubi Canyon (RM 57-58). The aggregation at RM 30 is the largest (mark-recapture population estimate shows about 30 fish), and

map for Canyon

the only evidence of local reproduction is young-of-year humpback chub captured by AGF from below President Harding Rapid (RM 44.3).

We believe that there are no significant numbers of humpback chub upstream of these aggregations to contribute to this component. Larvae and Age 0 from this component may move downstream into the CRI component, but extensive marking programs show no exchange of Age I fish and older.

Component b. Colorado River/LCR Inflow (CRI)

Current research shows that about 95 percent of the humpback chub in the mainstem Colorado River in Grand Canyon are found within a 19-mile (30-km) area around the LCR inflow (RM 58-77). The relationship between this Colorado River/LCR inflow component and the LCR component is not clear. Radiotelemetry and extensive mark-recapture studies in the mainstem show that the majority of adults of this component ascend the LCR annually to spawn in February-May, and descent in June-July. These fish spawn simultaneously with adults of the LCR component in the lower 13 km of the LCR. It is not presently known if some adults of the CRI component remain for one or more years in the LCR before returning to the mainstem. The numbers of adults ascending the LCR to spawn is approximately known.

Large numbers of young humpback chub (age 0 and age I) descend annually from the LCR into the mainstem Colorado River. It is not known if these fish are primarily the progeny of the CRI component, of the LCR component, or a mixture of the two. Large numbers of young (age 0, age I), subadult (age II), and adult (age III, III+) humpback chub remain in the LCR year around.

Component c. Colorado River Downstream (CRD)

Humpback chub downstream of the CRI component have been found as individuals and small aggregations at RM 83-84 (Clear Creek), RM 92-93, RM 108-109 (Shinumo Creek), RM 114-115, RM 119-120, RM 143-144 (Kanab Creek), RM 156-157 (Havasu Creek), and RM 195. The largest aggregation downstream of the CRI component occurs at RM 126-129 (mark-recapture population estimates show about 100 fish). Very small numbers of larvae and small age 0 humpback chub in these regions indicates some successful reproduction or transport from the LCR. Most fish in this

region probably originated from the LCR component, although some successful mainstem reproduction or local tributary reproduction cannot be discounted. There is little evidence of reproduction by humpback chub in Grand Canyon outside of the LCR, primarily because cold water released from Glen Canyon Dam prevents maturation of eggs and survival of larvae in the mainstem.

Component d. Little Colorado River (LCR)

Past and current research indicates that a large proportion of humpback chub in Grand Canyon reside in the LCR (LCR component), all or most of the year. The number of adults and juveniles that remain in this tributary year around, and the numbers that ascend annually from the mainstem to spawn are approximately known from population estimates in the LCR and population estimates and movement information from the mainstem Colorado River.

The LCR Component probably consists of a resident population, with reproduction from age 3+ fish. Adults, resident to the mainstem, also ascend and spawn in the LCR annually. The proportion of larvae, age 0, age 1, and age 2 fish from each of these components that remains in the LCR or descends to the mainstem is unknown.

Although the lower LCR is a low to moderate gradient stream, it is unlikely that larvae, age 0, or age 1 fish ascend upstream into the LCR. Also, it appears that nearly all larvae, age 0, and age 1 fish transported from the LCR are downstream of that inflow.

Component e. Tributaries (TRI)

Small numbers of humpback chub have been historically and recently captured in a number of tributary inflows, including Bright Angel Creek, Shinumo Creek, Kanab Creek, and Havasu Creek. Thorough sampling has not been conducted in these tributaries to determine if these fish are tributary residents or emigrants from another component of the Grand Canyon population. Young humpback chub captured in these tributaries indicates either local successful reproduction or ascent by mainstem fish attracted to warmer tributary temperatures. Some reproduction may be occurring in these tributaries (e.g., Bright Angel, Shinumo, Kanab, Tapeats, Havasu creeks), but evidence--such as gravid fish, incubating eggs, and larvae--has not been found in these streams recently.

LAKE POWELL

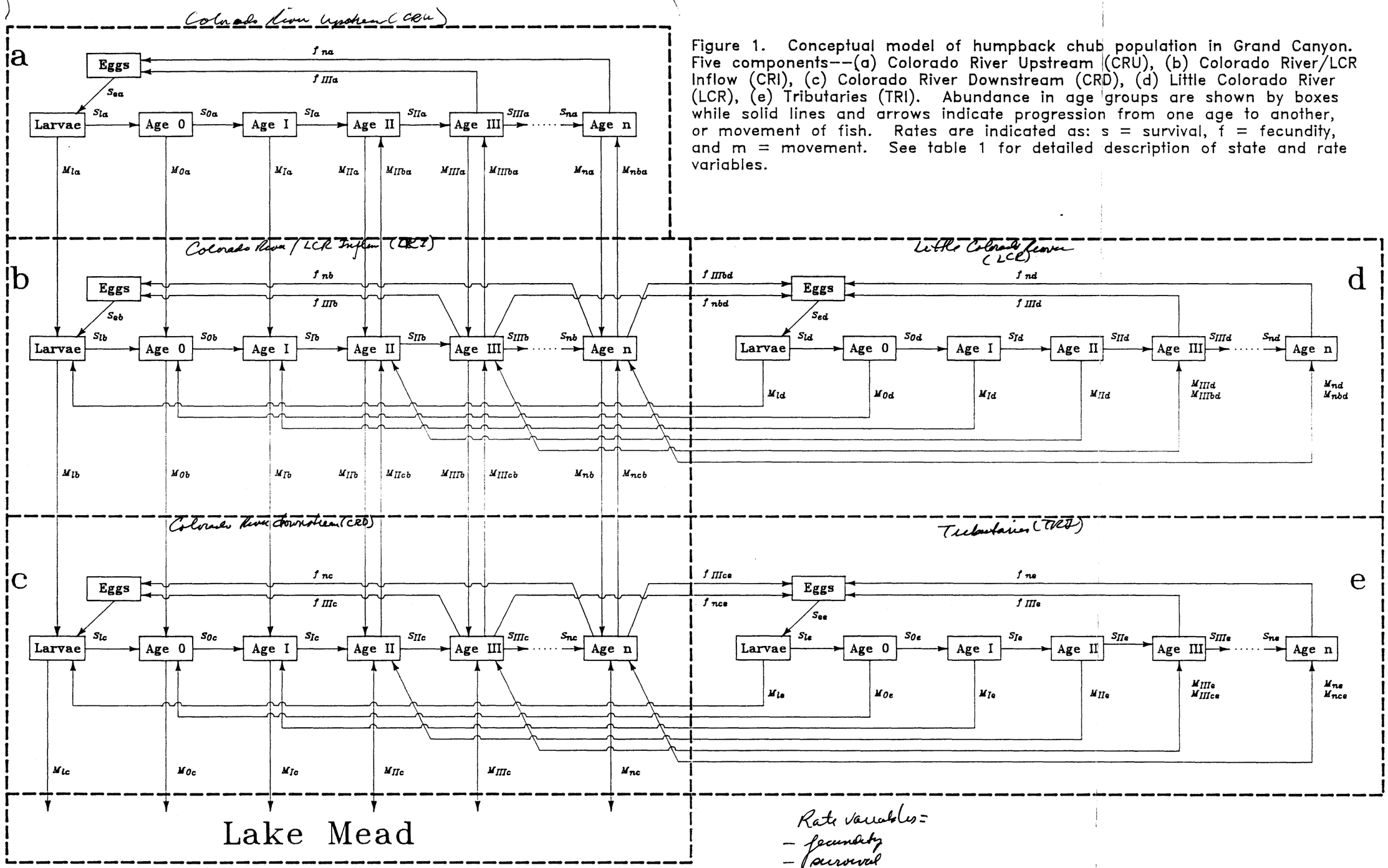

Figure 1. Conceptual model of humpback chub population in Grand Canyon. Five components--(a) Colorado River Upstream (CRU), (b) Colorado River/LCR Inflow (CRI), (c) Colorado River Downstream (CRD), (d) Little Colorado River (LCR), (e) Tributaries (TRI). Abundance in age groups are shown by boxes while solid lines and arrows indicate progression from one age to another, or movement of fish. Rates are indicated as: s = survival, f = fecundity, and m = movement. See table 1 for detailed description of state and rate variables.

Rate variables =
- fecundity
- survival
- movement

State variables =
estimated #'s of indiv. in various age groups.

âTable1. Descriptions of state and rate variables for each component of a conceptual population model for humpback chub in Grand Canyon.

Component . State & Rate Variables	Description	Data Available
Component a: Colorado River Upstream (CRU)		
State Variables		
Eggs	No. eggs in CRU	
Larvae	No. of larvae in CRU	
Age 0	No. of fish less than 1 year old in CRU	
Age I	No. of fish less than 2 years old in CRU	
Age II	No. of fish less than 3 years old in CRU	
Age III	No. of fish less than 4 years old in CRU	
Age n	No. of fish n years (age IV...age n) in CRU	
Rate Variables		
F_{IIIa}	Fecundity of Age III fish in CRU	
F_{na}	Fecundity of Age n fish in CRU	
S_{ea}	Survival of eggs in CRU	
S_{la}	Survival of larvae in CRU	
S_{0a}	Survival of Age 0 in CRU	
S_{Ia}	Survival of Age I in CRU	
S_{IIa}	Survival of Age II in CRU	
S_{IIIa}	Survival of Age III in CRU	
$S_{IIIa}...S_{na}$	Survival of Age n in CRU	
M_{la}	Movement of larvae from CRU to CRI	
M_{0a}	Movement of Age 0 from CRU to CRI	
M_{Ia}	Movement of Age I from CRU to CRI	
M_{IIa}	Movement of Age II from CRU to CRI	
M_{IIIa}	Movement of Age III from CRU to CRI	
M_{na}	Movement of Age n from CRU to CRI	
M_{IIba}	Movement of Age II from CRI to CRU	
M_{IIIba}	Movement of Age III from CRI to CRU	
M_{nba}	Movement of Age n from CRI to CRU	
Component b: Colorado River/LCR Inflow (CRI)		
State Variables		
Eggs	No. eggs in CRI	
Larvae	No. of larvae in CRI	
Age 0	No. of fish less than 1 year old in CRI	
Age I	No. of fish less than 2 years old in CRI	
Age II	No. of fish less than 3 years old in CRI	
Age III	No. of fish less than 4 years old in CRI	
Age n	No. of fish n years (age IV...age n) in CRI	
Rate Variables		
F_{IIIb}	Fecundity of Age III fish in CRI	
F_{nb}	Fecundity of Age n fish in CRI	
F_{IIIbd}	Fecundity of Age III fish from CRI to LCR	
F_{nbd}	Fecundity of Age n fish from CRI to LCR	
S_{eb}	Survival of eggs in CRI	
S_{Ib}	Survival of larvae in CRI	
S_{0b}	Survival of Age 0 in CRI	
S_{Ib}	Survival of Age I in CRI	

S_{IIb}	Survival of Age II in CRI
S_{IIIb}	Survival of Age III in CRI
$S_{IIIb}...S_{nb}$	Survival of Age n in CRI
M_{lb}	Movement of larvae from CRI to CRD
M_{0b}	Movement of Age 0 from CRI to CRD
M_{Ib}	Movement of Age I from CRI to CRD
M_{IIb}	Movement of Age II from CRI to CRD
M_{IIIb}	Movement of Age III from CRI to CRD
M_{nb}	Movement of Age n from CRI to CRD
M_{IIcb}	Movement of Age II from CRD to CRI
M_{IIIcb}	Movement of Age III from CRD to CRI
M_{ncb}	Movement of Age n from CRD to CRI

Component c: Colorado River Downstream (CRD)

State Variables

Eggs	No. females x wt.:no. eggs in CRD
Larvae	No. of larvae in CRD
Age 0	No. of fish less than 1 year old in CRD
Age I	No. of fish less than 2 years old in CRD
Age II	No. of fish less than 3 years old in CRD
Age III	No. of fish less than 4 years old in CRD
Age n	No. of fish n years (age IV...age n) in CRD

Rate Variables

F_{IIIc}	Fecundity of Age III fish in CRD
F_{nc}	Fecundity of Age n fish in CRD
F_{IIIce}	Fecundity of Age III fish from CRD to TRI
F_{nce}	Fecundity of Age n fish from CRD to TRI
S_{ec}	Survival of eggs in CRD
S_{lc}	Survival of larvae in CRD
S_{0c}	Survival of Age 0 in CRD
S_{Ic}	Survival of Age I in CRD
S_{IIc}	Survival of Age II in CRD
S_{IIIc}	Survival of Age III in CRD
$S_{IIIc}...S_{nc}$	Survival of Age n in CRD
M_{lc}	Movement of larvae from CRD to Lake Mead
M_{0c}	Movement of Age 0 from CRD to Lake Mead
M_{Ic}	Movement of Age I from CRD to Lake Mead
M_{IIc}	Movement of Age II from CRD to Lake Mead
M_{IIIc}	Movement of Age III from CRD to Lake Mead
M_{nc}	Movement of Age n from CRD to Lake Mead

Component d: Little Colorado River (LCR)

State Variables

Eggs	No. females x wt.:no. eggs in LCR
Larvae	No. of larvae in LCR
Age 0	No. of fish less than 1 year old in LCR
Age I	No. of fish less than 2 years old in LCR
Age II	No. of fish less than 3 years old in LCR
Age III	No. of fish less than 4 years old in LCR
Age n	No. of fish n years (age IV...age n) in LCR

Rate Variables

F_{IIId}	Fecundity of Age III fish in LCR
F_{nd}	Fecundity of Age n fish in LCR
S_{ed}	Survival of eggs in LCR

S_{ld}	Survival of larvae in LCR
S_{0d}	Survival of Age 0 in LCR
S_{Id}	Survival of Age I in LCR
S_{IId}	Survival of Age II in LCR
S_{IIId}	Survival of Age III in LCR
$S_{IIId}...S_{nd}$	Survival of Age n in LCR
M_{ld}	Movement of larvae from LCR to CRI
M_{0d}	Movement of Age 0 from LCR to CRI
M_{Id}	Movement of Age I from LCR to CRI
M_{IId}	Movement of Age II from LCR to CRI
M_{IIId}	Movement of Age III from LCR to CRI
M_{nd}	Movement of Age n from LCR to CRI
M_{IIIbd}	Movement of Age III from CRI to LCR
M_{nbd}	Movement of Age n from CRI to LCR

Component e: Tributaries (TRI)

State Variables

Eggs	No. females x wt.:no. eggs in TRI
Larvae	No. of larvae in TRI
Age 0	No. of fish less than 1 year old in TRI
Age I	No. of fish less than 2 years old in TRI
Age II	No. of fish less than 3 years old in TRI
Age III	No. of fish less than 4 years old in TRI
Age n	No. of fish n years (age IV...age n) in TRI

Rate Variables

F_{IIIe}	Fecundity of Age III fish in TRI
F_{ne}	Fecundity of Age n fish in TRI
S_{ee}	Survival of eggs in TRI
S_{le}	Survival of larvae in TRI
S_{0e}	Survival of Age 0 in TRI
S_{Ie}	Survival of Age I in TRI
S_{IIe}	Survival of Age II in TRI
S_{IIIe}	Survival of Age III in TRI
$S_{IIIe}...S_{ne}$	Survival of Age n in TRI
M_{le}	Movement of larvae from TRI to CRD
M_{0e}	Movement of Age 0 from TRI to CRD
M_{Ie}	Movement of Age I from TRI to CRD
M_{IIe}	Movement of Age II from TRI to CRD
M_{IIIe}	Movement of Age III from TRI to CRD
M_{ne}	Movement of Age n from TRI to CRD
M_{IIIce}	Movement of Age III from CRD to TRI
M_{nce}	Movement of Age n from CRD to TRI