INSTITUTE FOR
ENVIRONMENTAL SCIENCES

Report for MOD1: Environmental Modelling II

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Introduction

Knowing about different payoffs from anthropogenic and natural chaos in endangered or harmful species is a vital crux in practical ecology. For setting the appropriate methods to identify the impacts of chaos is the manipulative test which is a vital problem, because entrance to the listed species is always restricted for preventing brittle decreasing populations. Researchers mostly prefer surrogate species for this restriction because scientifically surrogate species show same behaviour for the impacts of toxicant chemical as like endangered or threatened species. When few surrogate species are applied to determine the impacts of chaos like chemical toxicants or contaminants on physiological equalities, other surrogate species are selected on same bonds for livelihood history criterions. (Banks et al., 2010).

For determining threats on endangered species from toxicants or pollutants, researchers previously depended on LC50 experiments applied at surrogate species. But this LC50 experiment has a problem for calculating vital ecological indicators consists of sublethal impacts. To avoid this problem, researchers suggested to developed techniques for solving these factors by giving importance on much complicated population consequences likewise much appropriate parameters of exact toxicological impacts. To determine the life history traits of surrogate species, LC50 approach is too much simplistic that's why it has been criticised, for getting more accurate impacts on surrogate species for specific toxicants chemicals a matrix model has been developed. In this kind of matrix model, researchers try to understand the life history traits of surrogate species and also try to understand the correlation of resulting impacts due to toxicant chemicals for both surrogate species and listed species. (Banks et al., 2010).

In this research journal, researchers describe Salmonids likewise threatened or listed species and 4 species likewise surrogate species for population researches. This technique comprises livelihood history criterions information's on matrix model that expresses the population increasing rates above duration of stage constructed fish population whose comprises 4 population stage includes neonates, juveniles, young reproductive and mature reproductive. Livelihood history criterions whose had been considered were survival rates and fecundity of every population stages. (Banks et al., 2010).

The main objective of this paper is the population dynamics of chosen species which is calculated by survival rates and fecundity.

Tasks of the project: Research, outcomes and final discussions

Task A: Draw the life cycle graph.

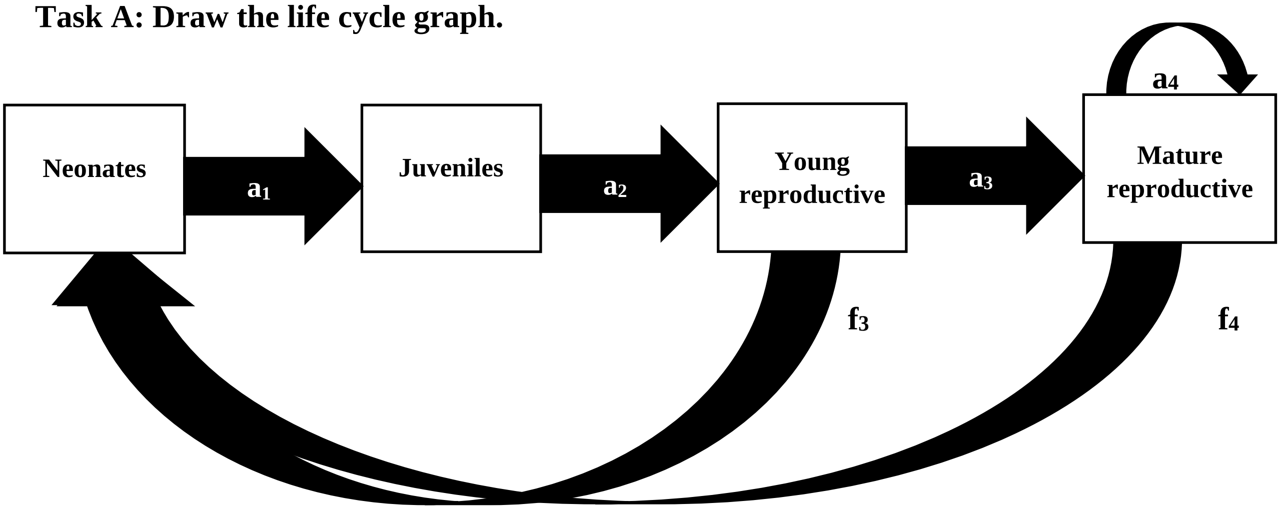

Figure 1: Fish population life cycle

Neonates, Juveniles, Young reproductive and Mature reproductive are the age classifications of fish population whose indicates their life cycle. Primarily, a1 is the survival rate when Neonates turns into Juveniles. Then, a2 is the survival rate when Juveniles turns into Young reproductive. Finally, a3 is the survival rate when Young reproductive turns into Mature reproductive. a4 is a chance for staying on similar age for Mature reproductive. f4 is the fecundity rate during the birth of Neonates from Mature reproductive. f3 is the fecundity rate during the birth of Neonates from Young reproductive. (Banks et al., 2010).

Task B: For all five species given in Table 1 use the matrix model described in eq. 1 to calculate the asymptotic finite rate of exponential growth and the stable stage distribution.

Actually, stage-formed fish population has 4 stages described earlier for who's the researchers applied a model whose name is Leslie matrix which standardly explains population increase rate over time. Individual numbers of 4 stages is expressed by x_i when i = (1,2,3,4) and the population vector is X= [x1, x2, x3, x4] ^{T}. Here in the below is a matrix equation which expresses the increase of population:

$$X(t+1) = \begin{bmatrix} x_1(t+1) \\ x_2(t+1) \\ x_3(t+1) \\ x_4(t+1) \end{bmatrix} = \begin{bmatrix} 0 & 0 & f3 & f4 \\ a1 & 0 & 0 & 0 \\ 0 & a2 & 0 & 0 \\ 0 & 0 & a3 & a4 \end{bmatrix} \times \begin{bmatrix} x_1(t) \\ x_2(t) \\ x_3(t) \\ x_4(t) \end{bmatrix} = AX(t), \qquad (1)$$

Here a_i expresses the individuals surviving rate for the subsequent stage (0 < a_i < 1, i =1,2,3 and 0≤a_4 < 1).

Population will increase if dominant eigenvalue(λ) in matrix A will be higher in comparison with 1. For computing ordinary solutions of dominant eigenvalue(λ), the matrix equation and computation will be like this for the ordinary solution:

$$F = \begin{bmatrix} 0 & 0 & f3 & f4 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \quad T = \begin{bmatrix} 0 & 0 & 0 & 0 \\ a1 & 0 & 0 & 0 \\ 0 & a2 & 0 & 0 \\ 0 & 0 & a3 & a4 \end{bmatrix}$$

$$F(I-T)^{-1} = \begin{bmatrix} f_3a_1a_2 + \dfrac{f_4a_1a_2a_3}{1-a_4} & f_3a_2 + \dfrac{f_4a_2a_3}{1-a_4} & f_3 + \dfrac{f_4a_3}{1-a_4} & \dfrac{f_4}{1-a_4} \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \quad (2)$$

When the eigenvalue is $\{f_3a_1a_2 + \frac{f_4a_1a_2a_3}{1-a_4}, 0, 0, 0\}$, then the rate of net reproductivity will be like this (Banks et al., 2010):

$$R_0 = f_3a_1a_2 + \frac{f_4a_1a_2a_3}{1-a_4} = f_3a_1a_2 + f_4a_1a_2a_3(1 + a_4 + a_4^2 + a_4^3 + \cdots) \quad (3)$$

Livelihood history criterions values for 5 species are expressed below:

Table I. Values of Life History Parameters Taken or Calculated from Transition Matrix for Four Surrogate Species and Listed (Salmonid) Species in Spromberg and Birge[4]

Life History Parameters	Round Goby (*Neogobius melanostomus*)	Smallmouth Bass (*Micropterus dolomieu*)	Fathead Minnow (*Pimephales promelas*)	Cutthroat Trout (*Oncorhynchus clarki lewisi*)	Chinook & Coho Salmon (*O. tschawytscha & O. kisutch*)
a_1	0.03	0.04	0.5	0.05	0.05
a_2	0.1	0.3	0.18	0.25	0.05
a_3	0.2	0.4	0.12	0.25	0.5
a_4	0.05	0.15	0	0.15	0
f_3	187.5	25	6	22.5	0.3
f_4	1050	187.5	62.5	300	920
ε	0.22	0.36	0.21	0.38	0.15

From the table 2, asymptotic finite rate shows that four species growth rate is more than 1 and one species growth rate is less than 1 so it is assuming that the four species population will keep increasing over the time on the other hand remaining one species population will keep decreasing over the time.

The stability ratio of every population stage is called stable stage distribution. From the result we can say that neonates population stage is more stable than other population stage for all five species.

Table 2: change of stable stage distribution with Asymptotic finite rate

Species	Asymptotic Finite Rate of Increase	Stable Stage Distribution	
ROUND GOBY (Neogobius melanostomus)	1.058807+0i	0.9694240669+0i (N) 0.0025941869+0i (YR)	0.0274674384+0i (J) 0.0005143078+0i (MR)
SMALLMOUTH BASS (Micropterus dolomieu)	1.081767+0i	0.950901922+0i (N) 0.009751002+0i (YR)	0.035161052+0i (J) 0.004186024+0i (MR)
FATHEAD MINNOW (Pimephales promelas)	0.5590646+0i	0.889354583+0i (N) 0.025609055+0i (YR)	0.079539526+0i (J) 0.005496837+0i (MR)
CUTTHROAT TROUT (Oncorhynchus clarki lewisi)	1.08644+0i	0.943895656+0i (N) 0.009995912+0i (YR)	0.043439839+0i (J) 0.002668594+0i (MR)
CHINOOK & COHO SALMON (O. tschawytscha & O. kisutch)	1.035733+0i	0.950813915+0i (N) 0.002215848+0i (YR)	0.045900536+0i (J) 0.001069701+0i (MR)

***N – Neonates, J – Juveniles, YR – Young Reproductive, MR – Mature Reproductive**

Task C: Choose two species; vary each life history trait separately (in contrast to the analysis in the article) by -10 % to -30 % and recalculate the asymptotic finite rate of exponential growth and the stable stage distribution. Likewise, vary all survival rates and in a second step all fecundities by -10 % to -30 % and recalculate the asymptotic finite rate of exponential growth and the stable stage distribution.

For the simulation, listed species named Chinook & Coho salmon (Oncorhynchus tschawytscha & O. kisutch) and the surrogate species named Round goby (Neogobius melanostomus) had been selected. From the table 1, life history traits had been gathered for these two species.

Here in the below are the details of simulation outcomes:

1. In case of Chinook & Coho salmon (Oncorhynchus tschawytscha & O. kisutch)

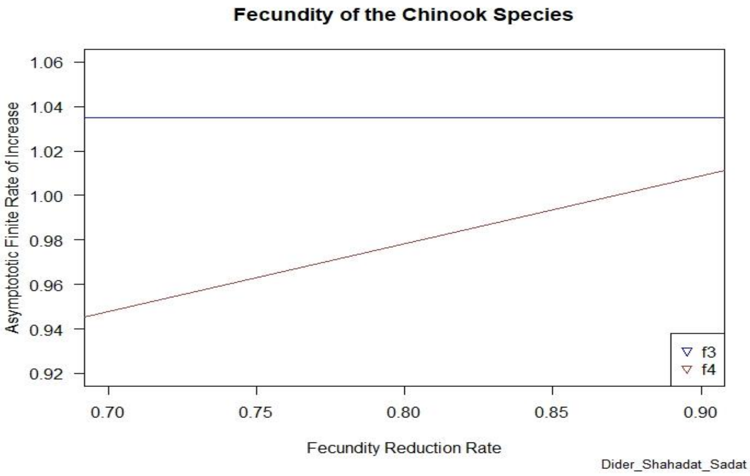

Figure 2: Effect of fecundity on the asymptotic finite rate of increase of chinook species

In these graphs from figure 2, we can understand that the continuous diminishing of f4 has an effect on exponential growth rate which is not positive and diminishing of f3 does not impact the raising rate of population that means it expresses constant values. So, in the basis of the diminishing of fecundity rates, mature reproductive populations can have extinction because raising rate is below 1 for diminishing of 15% and for the population of young reproductive, there are no impacts in raising rates.

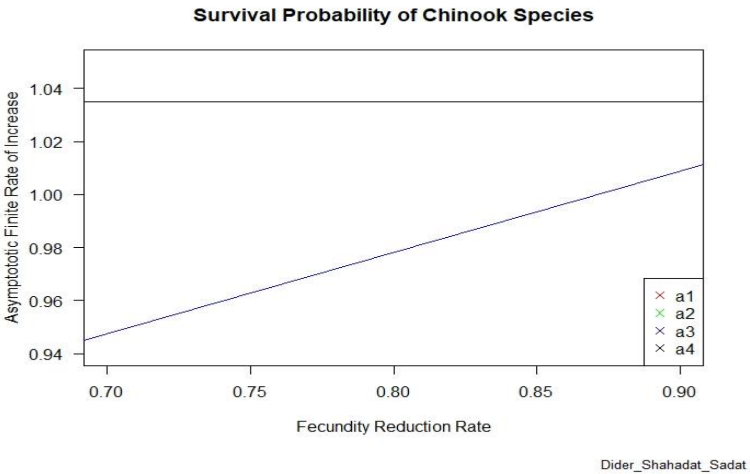

Figure 3: Effect of survival rate on the asymptotic finite rate of increase of salmon species.

In these graphs from figure 3, In the survival probability graphs, diminishing of a1, a2 and a3 has non affirmative effects in the population raising rates but the survival chances for staying in the a4 age stage are not impacting the raising rates of populations. So, from these cases we can understand that the raising rates of populations are hugely relying in the neonates, juveniles and young reproductive survival chances in comparison to mature reproductive populations.

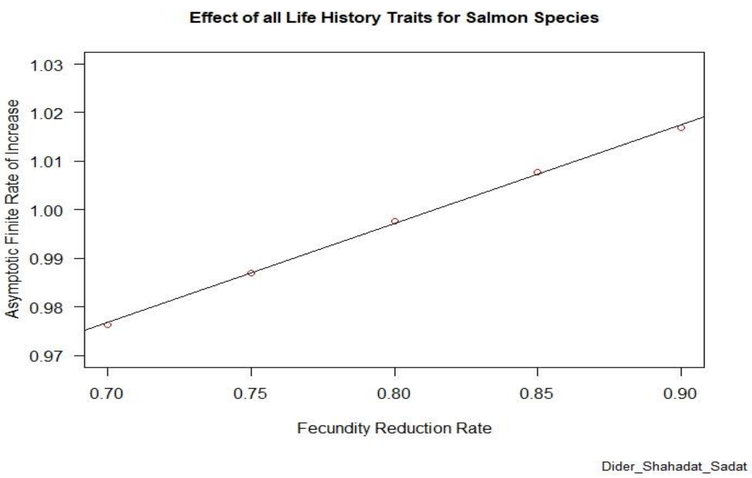

Figure 4: Effect of the reduction of all life traits on the population growth of salmon species.

For the case of Chinook & Coho salmon (Oncorhynchus tschawytscha & O. kisutch) species, figure 4 expresses every life history trait impacts in the exponential growth of asymptotic finite rate. In the graph of figure 4, we can understand that the population extinction occurs as every life history trait diminishing also diminish the raising rates of population so it is also assured that the diminishing of fecundity and survival rates in every stage.

As the ratio of neonates was comparatively greater in comparison with all other population age class in the stable stage, so stable stage distribution expresses same outcomes in every simulation.

2. In case of Round goby (Neogobius melanostomus)

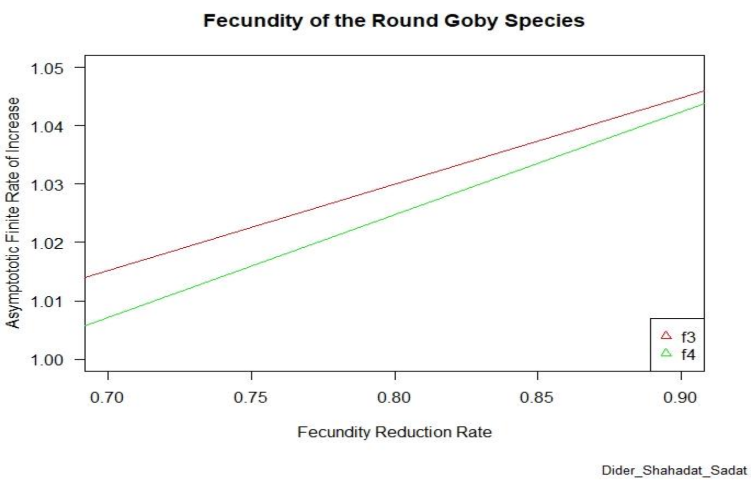

Figure 5: Effect of fecundity on the asymptotic finite rate of increase of Round Goby Bass species

Impact of fecundity rate and survival chance in the asymptotic finite rate of exponential growth rate are described in figure 5. In the graph we can see that the species may be static at 30% diminishing of fecundity rate as two of the fecundity rates impact the raising rate while they diminished continuously though 30% of the raising rates does not reach below 1. But the fecundity rate was diminishing for the diminishing of f4 in case of Chinook & Coho salmon (Oncorhynchus tschawytscha & O. kisutch).

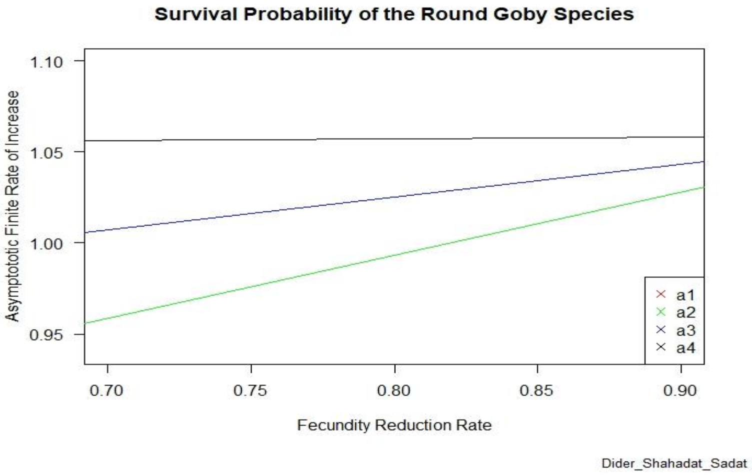

Figure 6: Effect of survival rate on the asymptotic finite rate of increase of Round Goby Bass species.

In these graphs from figure 6, In case of survival rate, we can see that continuous diminishing of survival rates in every age stages impacts the raising rates not affirmatively for Round goby (Neogobius melanostomus) species but only greater than 25% diminishing of a2 may impact the population not affirmatively which is really different from the outcomes gathered in case of Chinook & Coho salmon (Oncorhynchus tschawytscha & O. kisutch) species.

Every life history trait in the asymptotic finite rate of exponential growth are expressed in figure 6 in case of Round goby (Neogobius melanostomus) species. It is almost same for Chinook & Coho salmon (Oncorhynchus tschawytscha & O. kisutch) species where diminishing of every life history trait impacts asymptotic finite rate of exponential growth in a non-affirmative basis.

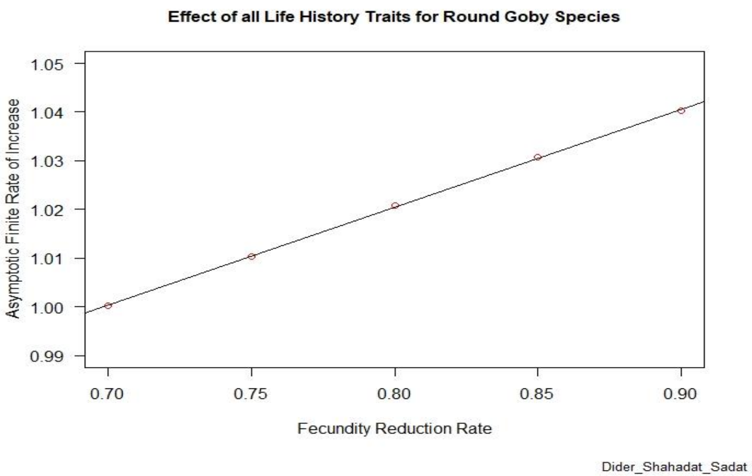

Figure 7: Effect of all life history traits on the asymptotic finite rate of increase

Diminishing of every life history trait measurement impact on Chinook & Coho salmon (Oncorhynchus tschawytscha & O. kisutch) species is almost same likewise Round goby (Neogobius melanostomus) species because the segmentation represents greater ratio of neonates in the stable stage in comparison with all other age stages.

Conclusion

In a nutshell, this study actually evaluates the overall toxicant chemical effect on surrogate species to hypothesis how the future population dynamics of listed or endangered species changes. In our simulation process which is based on one surrogate species and one listed species that determines the impact of toxicant chemical application for certain life history traits parameter with the decreasing of fecundity rates. From the simulation results of fecundity rates for both Chinook & Coho salmon (Oncorhynchus tschawytscha & O. kisutch) species and Round goby (Neogobius melanostomus) species, it can be observed that the fecundity rates for both species shows same behaviour. In case of survival rates for mature reproductive with fecundity rate reduction is showing same characteristics both species. On the other hand, the survival rate for neonates, juveniles and young reproductive of Chinook & Coho salmon (Oncorhynchus tschawytscha & O. kisutch) species has same results whereas the survival rate for neonates and juveniles of Round goby (Neogobius melanostomus) species shows same characteristics. But survival rate for young reproductive not as like as for young reproductive of Chinook & Coho salmon (Oncorhynchus tschawytscha & O. kisutch) species which gives mislead consumption about future population dynamics condition for listed or Round goby (Neogobius melanostomus) species. According to (Banks et al., 2010), this is happened for several reasons such as too much simplistic model without intricate considerations, avoid the consideration of interaction of listed or endangered species with other species, not considered density-dependence and anthropogenic disturbance also. Though this model gives us ideas about reproduction rates of surrogate species based on sublethal effects which can be useful for determining the fortune of listed species due to stressors, but the fate of listed species can be more reliable if more surrogate species as well as more life stages should be considered into the matrix model. Because only four surrogate species cannot be useful to predict the future of wide population dynamics of endangered species.

References

Banks, J. E., Ackleh, A. S., & Stark, J. D. (2010). The use of surrogate species in risk assessment: using life history data to safeguard against false negatives. Risk Analysis: An International Journal, 30(2), 175-182.

Appendix

i. For Chinook & Coho Salmon

		Reduction				
Life traits		**10%**	**15%**	**20%**	**25%**	**30%**
f_3	Asymptotic Finite Rate of Increase	1.035715+0i	1.035707+0i	1.035698+0i	1.035689+0i	1.035689+0i
	Stable Stage Distribution	0.950813056+0i 0.045901269+0i 0.002215921+0i 0.001069754+0i	0.950812626+0i 0.045901636+0i 0.002215957+0i 0.001069780+0i	0.950812197+0i 0.045902003+0i 0.002215994+0i 0.001069807+0i	0.950811767+0i 0.045902369+0i 0.002216030+0i 0.001069834+0i	0.950811337+0i 0.045902736+0i 0.002216067+0i 0.001069860+0i
f_4	Asymptotic Finite Rate of Increase	1.008822+0i	0.9945165+0i	0.9795658+0i	0.9638972+0i	0.9474248+0i
	Stable Stage Distribution	0.949454163+0i 0.047057579+0i 0.002332304+0i 0.001155954+0i	0.948699888+0i 0.047696537+0i 0.002397976+0i 0.001205599+0i	0.947886812+0i 0.048383007+0i 0.002469615+0i 0.001260566+0i	0.947006184+0i 0.049123814+0i 0.002548187+0i 0.001321815+0i	0.946047250+0i 0.049927298+0i 0.002634895+0i 0.001390556+0i
a_1	Asymptotic Finite Rate of Increase	1.008803+0i	0.9944881+0i	0.9795267+0i	0.9638468+0i	0.9473622+0i
	Stable Stage Distribution	0.954276769+0i 0.042567718+0i 0.002109813+0i 0.001045701+0i	0.956055447+0i 0.040857560+0i 0.002054201+0i 0.001032793+0i	0.957868582+0i 0.039115567+0i 0.001996656+0i 0.001019194+0i	0.959718781+0i 0.037339393+0i 0.001936998+0i 0.001004827+0i	0.9616090418+0i 0.0355263468+0i 0.0018750140+0i 0.0009895973+0i
a_2	Asymptotic Finite Rate of Increase	1.008803+0i	0.9944881+0i	0.9795267+0i	0.9638468+0i	0.9473622+0i
	Stable Stage Distribution	0.949784529+0i 0.047074813+0i 0.002099881+0i 0.001040778+0i	0.949211483+0i 0.047723622+0i 0.002039495+0i 0.001025400+0i	0.948592400+0i 0.048420955+0i 0.001977320+0i 0.001009324+0i	0.9479205222+0i 0.0491738177+0i 0.0019131860+0i 0.0009924741+0i	0.9471875644+0i 0.0499907855+0i 0.0018468940+0i 0.0009747561+0i
a_3	Asymptotic Finite Rate of Increase	1.008822+0i	0.9945165+0i	0.9795658+0i	0.9638972+0i	0.9474248+0i
	Stable Stage Distribution	0.949563928+0i 0.047063019+0i 0.002332574+0i 0.001040479+0i	0.948871482+0i 0.047705164+0i 0.002398410+0i 0.001024944+0i	0.948125847+0i 0.048395209+0i 0.002470238+0i 0.001008707+0i	0.9473192291+0i 0.0491400525+0i 0.0025490296+0i 0.0009916888+0i	0.9464420747+0i 0.0499481351+0i 0.0026359946+0i 0.0009737956+0i
a_4	Asymptotic Finite Rate of Increase	1.035733+0i	1.035733+0i	1.035733+0i	1.035733+0i	1.035733+0i
	Stable Stage Distribution	0.950813915+0i 0.045900536+0i 0.002215848+0i 0.001069701+0i	0.950813915+0i 0.045900536+0i 0.002215848+0i 0.001069701+0i	0.950813915+0i 0.045900536+0i 0.002215848+0i 0.001069701+0i	0.950813915+0i 0.045900536+0i 0.002215848+0i 0.001069701+0i	0.950813915+0i 0.045900536+0i 0.002215848+0i 0.001069701+0i

ii. Smallmouth Bass (Micropterus dolomieu)

Life traits		Reduction 10%	15%	20%	25%	30%
f_3	Asymptotic Finite Rate of Increase	1.044553+0i	1.037327+0i	1.030034+0i	1.022673+0i	1.015245+0i
	Stable Stage Distribution	0.9689707487+0i 0.0278292593+0i 0.0026642279+0i 0.0005357642+0i	0.9687357649+0i 0.0280163183+0i 0.0027008194+0i 0.0005470974+0i	0.9684949577+0i 0.0282076625+0i 0.0027385179+0i 0.0005588619+0i	0.9682481106+0i 0.0284034384+0i 0.0027773712+0i 0.0005710799+0i	0.9679949971+0i 0.0286037982+0i 0.0028174294+0i 0.0005837753+0i
f_4	Asymptotic Finite Rate of Increase	1.042706+0i	1.034319+0i	1.025687+0i	1.016793+0i	1.007615+0i
	Stable Stage Distribution	0.9689110284+0i 0.0278768317+0i 0.0026735091+0i 0.0005386308+0i	0.9686369028+0i 0.0280949165+0i 0.0027162718+0i 0.0005519088+0i	0.9683496584+0i 0.0283229453+0i 0.0027613622+0i 0.0005660342+0i	0.9680480838+0i 0.0285618082+0i 0.0028090095+0i 0.0005810985+0i	0.9677307956+0i 0.0288125190+0i 0.0028594772+0i 0.0005972082+0i
a_1	Asymptotic Finite Rate of Increase	1.052869+0i	1.037548+0i	1.021565+0i	1.004848+0i	0.9873096+0i
	Stable Stage Distribution	0.953969830+0i 0.032618411+0i 0.009294151+0i 0.004117608+0i	0.955552547+0i 0.031313054+0i 0.009053961+0i 0.004080439+0i	0.957171115+0i 0.029982895+0i 0.008804989+0i 0.004041002+0i	0.958828504+0i 0.028626080+0i 0.008546392+0i 0.003999024+0i	0.960528152+0i 0.027240481+0i 0.008277185+0i 0.003954181+0i
a_2	Asymptotic Finite Rate of Increase	1.027902+0i	1.011546+0i	0.9945071+0i	0.9767096+0i	0.9580654+0i
	Stable Stage Distribution	0.9714914476+0i 0.0255182625+0i 0.0024825583+0i 0.0005077316+0i	0.9725550753+0i 0.0245170725+0i 0.0024237222+0i 0.0005041301+0i	0.9736406526+0i 0.0234964392+0i 0.0023626216+0i 0.0005002867+0i	0.9747499417+0i 0.0224548565+0i 0.0022990310+0i 0.0004961708+0i	0.9758849769+0i 0.0213905914+0i 0.0022326860+0i 0.0004917457+0i
a_3	Asymptotic Finite Rate of Increase	1.042706+0i	1.034319+0i	1.025687+0i	1.016793+0i	1.007615+0i
	Stable Stage Distribution	0.9689632198+0i 0.0278783333+0i 0.0026736531+0i 0.0004847938+0i	0.9687170993+0i 0.0280972426+0i 0.0027164967+0i 0.0004691613+0i	0.9684592946+0i 0.0283261520+0i 0.0027616748+0i 0.0004528786+0i	0.9681887370+0i 0.0285659581+0i 0.0028094177+0i 0.0004358872+0i	0.9679042077+0i 0.0288176821+0i 0.0028599896+0i 0.0004181206+0i
a_4	Asymptotic Finite Rate of Increase	1.058032+0i	1.057646+0i	1.057262+0i	1.056878+0i	1.056496+0i
	Stable Stage Distribution	0.9694022293+0i 0.0274869387+0i 0.0025979302+0i 0.0005129018+0i	0.9693913452+0i 0.0274966567+0i 0.0025997967+0i 0.0005122013+0i	0.9693804844+0i 0.0275063533+0i 0.0026016598+0i 0.0005115025+0i	0.9693696466+0i 0.0275160285+0i 0.0026035195+0i 0.0005108054+0i	0.969358832+0i 0.027525682+0i 0.002605376+0i 0.000510110+0i