BioVeL – Biodiversity Virtual e-Laboratory

Workflow Documentation

Orcinus orca (Killer whale) demography and population viability analysis (PVA) workflow for local execution

Augustus 2014

Capacities Programme of Framework 7: EC e-Infrastructure Programme – e-Science Environments - INFRA-2011-1.2.1

Grant Agreement No:	283359
Project Co-ordinator:	Mr Alex Hardisty
Project Homepage:	http://www.biovel.eu
Duration of Project:	36 months
Start Date:	Sept 2011
End Date:	Aug 2014

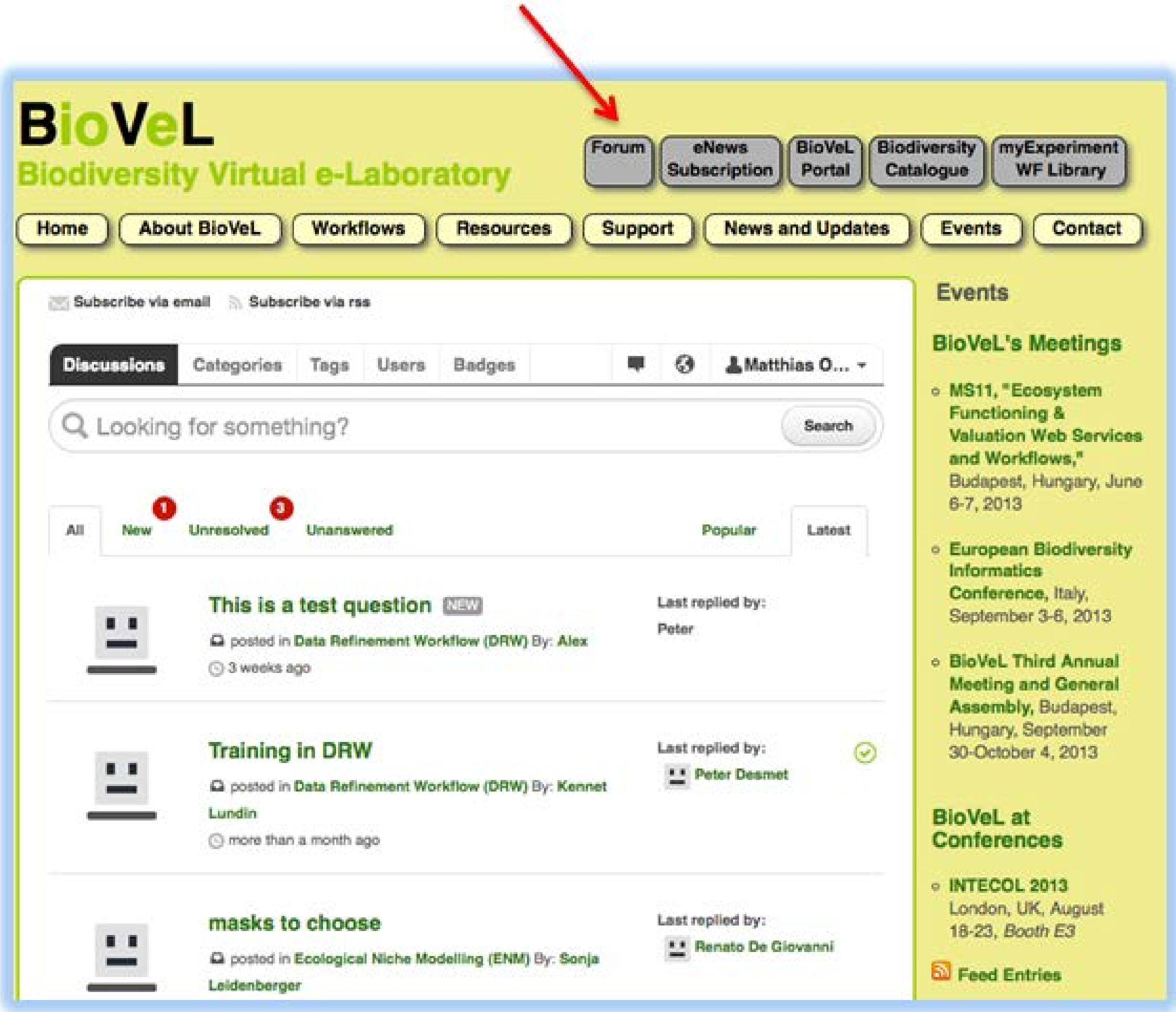
Orcinus orca (Killer whale) demography and population viability analysis (PVA) workflow

Contents

1. Sources of help

You can obtain help with using BioVeL workflows and services from 3 places:

1) From the BioVeL documentation website, here: https://wiki.biovel.eu/x/BIBp
2) By using the BioVeL community discussion Forum on our website, www.biovel.eu. If you have questions go to the Forum by clicking the grey button shown below and post your help request or question there.



By emailing to support@biovel.eu

2. Input files for tutorial

The workflow accepts input data in a .csv, coma delimited. The examples input files for the tutorial are available and described below. In this tutorial, four input files are used.

2.1 Input data

To download click here in the file:

Orcinus orca input data:

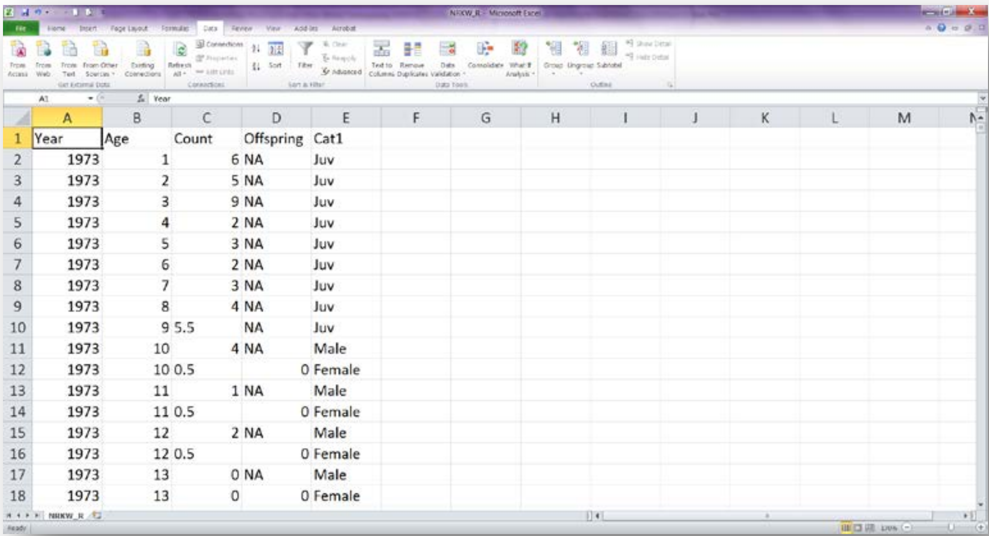
- NRKW_R or SRKW_R
- VR_combined

The following files are needed in order to get some necessary results to run (a second workflow), Interaction between killer whale population dynamics and Chinook salmon abundance workflow.

Chinook input data:

- Chinook_Ab_Definitions_R or Chinook_Ab_Defs_FI_R
- ChinookAbundance_Data_R or ChinookAbundance_FI_R

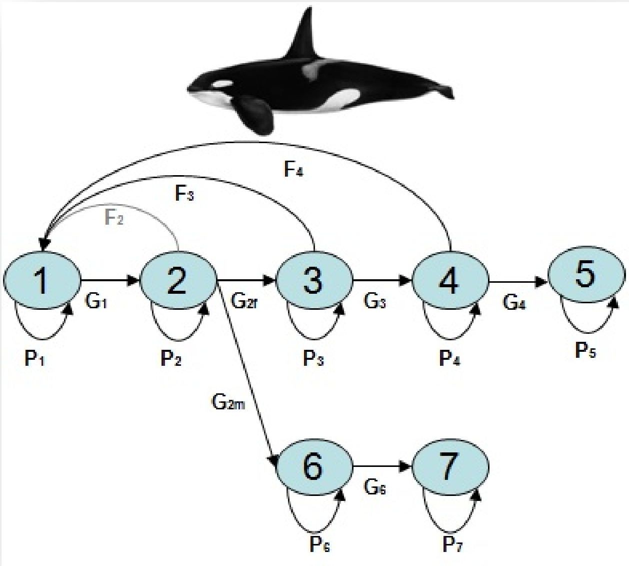
NRKW_R or SRKW_R: The input data (a .csv-file) has to have the format of a table containing the *Orcinus orca* demographic data with the columns named: Year, Age, Count, Offspring and Cat1. Each year, the number of individuals per age and the number of offspring per age reproductive female category are counted (females ≥ 10 years old). IF A Female category does not have offspring equals to 0. For the called column, Cat1; Ages 1 to 9 belongs to Juv (Juveniles) and 10 to 88 (this tutorial) belongs to Female or Male. Juv and Male categories must have a NA offspring.



Year	Age	Count	Offspring	Cat1
1973	1	6	NA	Juv
1973	2	5	NA	Juv
1973	3	9	NA	Juv
1973	4	2	NA	Juv
1973	5	3	NA	Juv
1973	6	2	NA	Juv
1973	7	3	NA	Juv
1973	8	4	NA	Juv
1973	9	5.5	NA	Juv
1973	10	4	NA	Male
1973	10	0.5	0	Female
1973	11	1	NA	Male
1973	11	0.5	0	Female
1973	12	2	NA	Male
1973	12	0.5	0	Female
1973	13	0	NA	Male
1973	13	0	0	Female

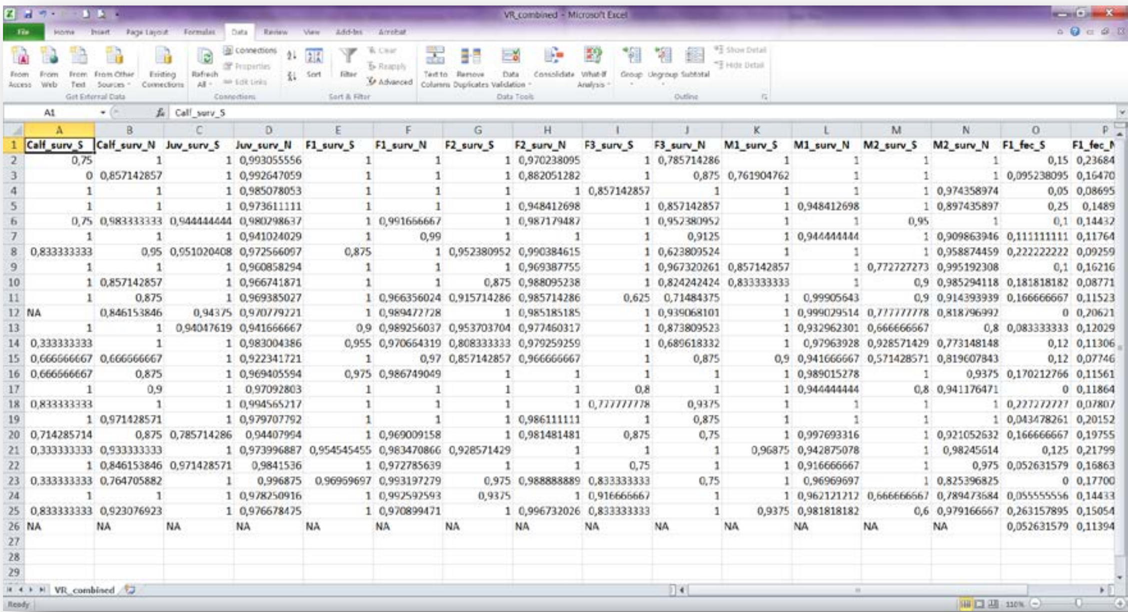
Orcinus orca (Killer whale) demography and population viability analysis (PVA) workflow

VR_combined



The stage-structured life cycle of resident killer whales with seven life stages:
(1) calves; (**Calf**)
(2) juveniles; (**Juv**)
(3) young reproductive females; (**F1**)
(4) old reproductive females; (**F2**)
(5) post-reproductive females; (**F3**)
(6) young mature males; and (**M1**)
(7) old mature males (**M2**).
Fi represent fertility; Gi represent stage transition probabilities, with female and male juvenile-to-adult transitions indicated as G2f and G2m, respectively; and, Pi represent the probability of surviving and remaining in stage i

The input data (a .csv-file) has to have the format of a table containing the survival and fecundity rates per stage, per year, per population of the *Orcinus orca.* E.g. Calf_surv_S = 0, 75 will the survival value of the first year (in this case 1987) of the SRKW calves stage.



VR_combined - Microsoft Excel

A1 Calf_surv_S

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Calf_surv_S	Calf_surv_N	Juv_surv_S	Juv_surv_N	F1_surv_S	F1_surv_N	F2_surv_S	F2_surv_N	F3_surv_S	F3_surv_N	M1_surv_S	M1_surv_N	M2_surv_S	M2_surv_N	F1_fec_S	F1_fec_N
2	0,75	1	1	0,993055556	1	1	1	0,970238095	1	0,785714286	1	1	1	1	0,15	0,23684
3	0	0,857142857	1	0,992647059	1	1	1	0,882051282	1	0,875	0,761904762	1	1	1	0,095238095	0,16470
4	1	1	1	0,985078053	1	1	1	1	0,857142857	1	1	1	1	0,974358974	0,05	0,08695
5	1	1	1	0,973611111	1	1	1	0,948412698	1	0,857142857	1	0,948412698	1	0,897435897	0,25	0,1489
6	0,75	0,983333333	0,944444444	0,980298637	1	0,991666667	1	0,987179487	1	0,952380952	1	1	0,95	1	0,1	0,14432
7	1	1	1	0,941024029	1	0,99	1	1	1	0,9125	1	0,944444444	1	0,909863946	0,111111111	0,11764
8	0,833333333	0,95	0,951020408	0,972566097	0,875	1	0,952380952	0,990384615	1	0,623809524	1	1	1	0,958874459	0,222222222	0,09259
9	1	1	1	0,960858294	1	1	1	0,969387755	1	0,967320261	0,857142857	1	0,772727273	0,995192308	0,1	0,16216
10	1	0,857142857	1	0,966741871	1	1	0,875	0,988095238	1	0,824242424	0,833333333	1	0,9	0,985294118	0,181818182	0,08771
11	1	0,875	1	0,969385027	1	0,966356024	0,915714286	0,985714286	0,625	0,71484375	1	0,99905643	0,9	0,914393939	0,166666667	0,11523
12	NA	0,846153846	0,94375	0,970779221	1	0,989472728	1	0,985185185	1	0,939068101	1	0,999029514	0,777777778	0,818796992	0	0,20621
13	1	1	0,94047619	0,941666667	0,9	0,989256037	0,953703704	0,977460317	1	0,873809523	1	0,932962301	0,666666667	0,8	0,083333333	0,12029
14	0,333333333	1	1	0,983004386	0,955	0,970664319	0,808333333	0,979259259	1	0,689618332	1	0,97963928	0,928571429	0,773148148	0,12	0,11306
15	0,666666667	0,666666667	1	0,922341721	1	0,97	0,857142857	0,966666667	1	0,875	0,9	0,941666667	0,571428571	0,819607843	0,12	0,07746
16	0,666666667	0,875	1	0,969405594	0,975	0,986749049	1	1	1	1	1	0,989015278	1	0,9375	0,170212766	0,11561
17	1	0,9	1	0,97092803	1	1	1	1	0,8	1	1	0,944444444	0,8	0,941176471	0	0,11864
18	0,833333333	1	1	0,994565217	1	1	1	1	0,777777778	0,9375	1	1	1	1	0,227272727	0,07807
19	1	0,971428571	1	0,979707792	1	1	1	0,986111111	1	0,875	1	1	1	1	0,043478261	0,20152
20	0,714285714	0,875	0,785714286	0,94407994	1	0,969009158	1	0,981481481	0,875	0,75	1	0,997693316	1	0,921052632	0,166666667	0,19755
21	0,333333333	0,933333333	1	0,973996887	0,954545455	0,983470866	0,928571429	1	1	1	0,96875	0,942875078	1	0,98245614	0,125	0,21799
22	1	0,846153846	0,971428571	0,9841536	1	0,972785639	1	1	0,75	1	1	0,916666667	1	0,975	0,052631579	0,16863
23	0,333333333	0,764705882	1	0,996875	0,96969697	0,993197279	0,975	0,988888889	0,833333333	0,75	1	0,96969697	1	0,825396825	0	0,17700
24	1	1	1	0,978250916	1	0,992592593	0,9375	1	0,916666667	1	1	0,962121212	0,666666667	0,789473684	0,055555556	0,14433
25	0,833333333	0,923076923	1	0,976678475	1	0,970899471	1	0,996732026	0,833333333	1	0,9375	0,981818182	0,6	0,979166667	0,263157895	0,15054
26	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0,052631579	0,11394
27																
28																
29																

VR_combined

Orcinus orca (Killer whale) demography and population viability analysis (PVA) workflow

Chinook_Ab_Definitions_R: Table that contains Chinook abundance definitions by stock aggregate, abundance type (TR: Terminal Run; OA: Ocean Abundance), time lag (5YA: 5-year running average), and hypothesis (SR: Southern Resident Killer Whale; NR: Northern Resident Killer Whale) and abundance ID. See below information about hypothesis.

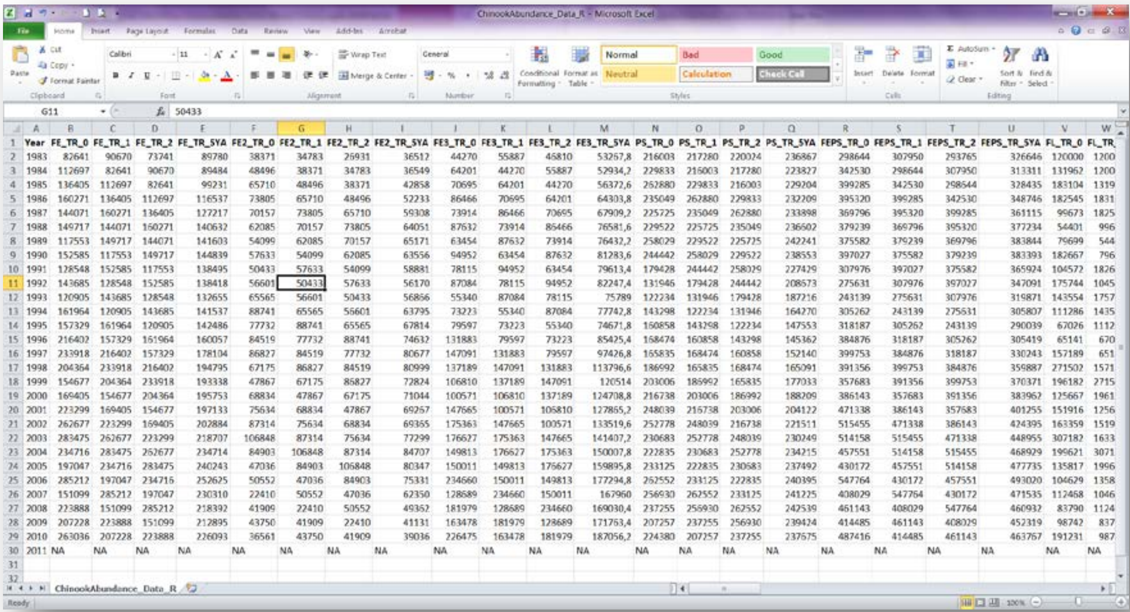
TimeSeries	Stock	Ab.Type	lag	SR_Hyp	NR_Hyp	Ab_ID
FE_TR_0	Fraser Early (Spring and Summer)	Terminal run	0	1a	2b	1
FE_TR_1	Fraser Early (Spring and Summer)	Terminal run	1	1a	2b	1
FE_TR_2	Fraser Early (Spring and Summer)	Terminal run	2	1a	2b	1
FE_TR_5YA	Fraser Early (Spring and Summer)	Terminal run	5YA	1a	2b	1
FE2_TR_0	Fraser Early (Spring)	Terminal run	0	1a	2b	1
FE2_TR_1	Fraser Early (Spring)	Terminal run	1	1a	2b	1
FE2_TR_2	Fraser Early (Spring)	Terminal run	2	1a	2b	1
FE2_TR_5YA	Fraser Early (Spring)	Terminal run	5YA	1a	2b	1
FE3_TR_0	Fraser Early (Summer)	Terminal run	0	1a	2b	1
FE3_TR_1	Fraser Early (Summer)	Terminal run	1	1a	2b	1
FE3_TR_2	Fraser Early (Summer)	Terminal run	2	1a	2b	1
FE3_TR_5YA	Fraser Early (Summer)	Terminal run	5YA	1a	2b	1
PS_TR_0	Puget Sound (Summer and Fall)	Terminal run	0	1a	2b	1
PS_TR_1	Puget Sound (Summer and Fall)	Terminal run	1	1a	2b	1
PS_TR_2	Puget Sound (Summer and Fall)	Terminal run	2	1a	2b	1
PS_TR_5YA	Puget Sound (Summer and Fall)	Terminal run	5YA	1a	2b	1
FEPS_TR_0	Fraser Early + Puget Sound	Terminal run	0	1a	2b	1
FEPS_TR_1	Fraser Early + Puget Sound	Terminal run	1	1a	2b	1
FEPS_TR_2	Fraser Early + Puget Sound	Terminal run	2	1a	2b	1
FEPS_TR_5YA	Fraser Early + Puget Sound	Terminal run	5YA	1a	2b	1

Chinook_Ab_Defs_FI_R: Table used to define fishery impacts (FI) on Chinook abundance by stock aggregate, time lag (5YA: 5-year running average), and hypothesis (SR: Southern Resident Killer Whale; NR: Northern Resident Killer Whale) and abundance ID. FI represent ocean catch of specific Chinook stocks or stock aggregates. See below information about hypothesis.

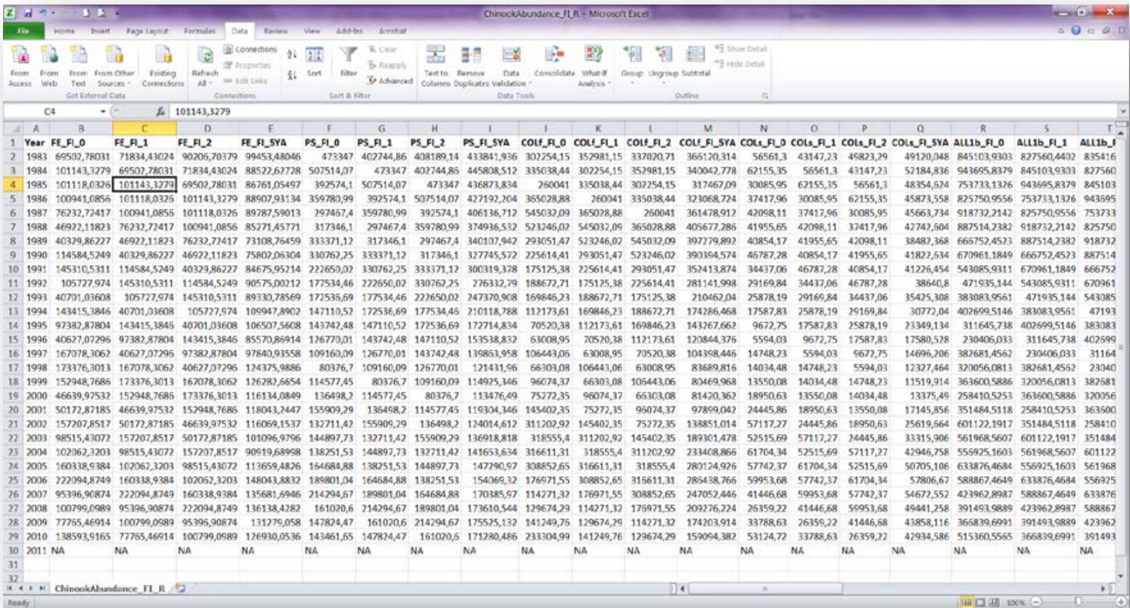
TimeSeries	Stock	Ab.Type	lag	SR_Hyp	NR_Hyp	Ab_ID
FE_FI_0	Fraser Early	Ocean Catch	0	NA	1b	3
FE_FI_1	Fraser Early	Ocean Catch	1	NA	1b	3
FE_FI_2	Fraser Early	Ocean Catch	2	NA	1b	3
FE_FI_5YA	Fraser Early	Ocean Catch	5YA	NA	1b	3
PS_FI_0	Puget Sound	Ocean Catch	0	2a	1b	3
PS_FI_1	Puget Sound	Ocean Catch	1	2a	1b	3
PS_FI_2	Puget Sound	Ocean Catch	2	2a	1b	3
PS_FI_5YA	Puget Sound	Ocean Catch	5YA	2a	1b	3
COLf_FI_0	Columbia Fall (UpRiver Brights+ Tule)	Ocean Catch	0	2a	1b	3
COLf_FI_1	Columbia Fall (UpRiver Brights+ Tule)	Ocean Catch	1	2a	1b	3
COLf_FI_2	Columbia Fall (UpRiver Brights+ Tule)	Ocean Catch	2	2a	1b	3
COLf_FI_5YA	Columbia Fall (UpRiver Brights+ Tule)	Ocean Catch	5YA	2a	1b	3
COLs_FI_0	Columbia Spring/Summer	Ocean Catch	0	2a	NA	3
COLs_FI_1	Columbia Spring/Summer	Ocean Catch	1	2a	NA	3
COLs_FI_2	Columbia Spring/Summer	Ocean Catch	2	2a	NA	3
COLs_FI_5YA	Columbia Spring/Summer	Ocean Catch	5YA	2a	NA	3
ALL1b_FI_0	Fraser Early+Puget Sound+Columbia Fall	Ocean Catch	0	NA	1b	3
ALL1b_FI_1	Fraser Early+Puget Sound+Columbia Fall	Ocean Catch	1	NA	1b	3
ALL1b_FI_2	Fraser Early+Puget Sound+Columbia Fall	Ocean Catch	2	NA	1b	3
ALL1b_FI_5YA	Fraser Early+Puget Sound+Columbia Fall	Ocean Catch	5YA	NA	1b	3

Orcinus orca (Killer whale) demography and population viability analysis (PVA) workflow

<u>ChinookAbundance_Data_R:</u> Table showing the time series of abundance (TR or OA) of all stocks and stock aggregates by time lag used in the analysis.



<u>ChinookAbundance_FI_R:</u> Table showing the time series of Fishery Impacts of all stocks by time lag used in the analysis.



2.1 Related publications

Vélez-Espino, L.A., John K.B. Ford, Eric Ward, Chuck K. Parken, Larrie LaVoy, Ken Balcomb, M. Bradley Hanson, Dawn. P. Noren, Graeme Ellis, Tom Cooney, and Rishi Sharma. 2013. Sensitivity of resident Killer Whale population dynamics to Chinook salmon abundance. Completion Report, Pacific Salmon Commission, Southern Boundary Restoration and Enhancement Fund, Vancouver BC. 191 p.

Vélez-Espino, L.A., Ford, J.K.B., Araujo, H.A., Ellis, G., Parken, C.K, & Balcomb, K. Comparative demography and viability of northeast Pacific resident killer whale populations at risk. Can. Tech. Rep. Fish. Aquat. Sci. 3084: vi + 56 p.

Vélez-Espino, L.A., John K.B. Ford, H. Andres Araujo, Graeme Ellis, Charles K. Parken and Rishi Sharma. *In Press*. Relative importance of Chinook salmon abundance on resident killer whale population growth and viability. Aquatic Conservation: Marine and Freshwater Ecosystems.

3. Tutorial: Killer Whale (*Orcinus orca*) Demography Workflow for portal execution

The *Orcinus orca* (Killer whale) demography and population viability analysis (PVA) workflow provides an environment to calculate a two-sex stage-structured matrix with no density dependence and to (i) quantify the differences in demographic rates between *Orcinus orca* population that explain population growth; (ii) to determine the relative influence vital rates on expected population growth; and, (iii) to generate projections of population size at various time horizons.

This workflow performs the following analyses:

- Vital rates estimation and probability distributions
- Construction of Birth-flow Matrix Model
- Eigen analysis
- Elasticity analysis (deterministic and stochastic)
- Damping time
- Stable stage distributions
- IID projection matrices representing discrete time periods
- Retrospective perturbation analysis
- Stochastic population growth from IID matrices and vital rate probability distributions
- Projections of population size

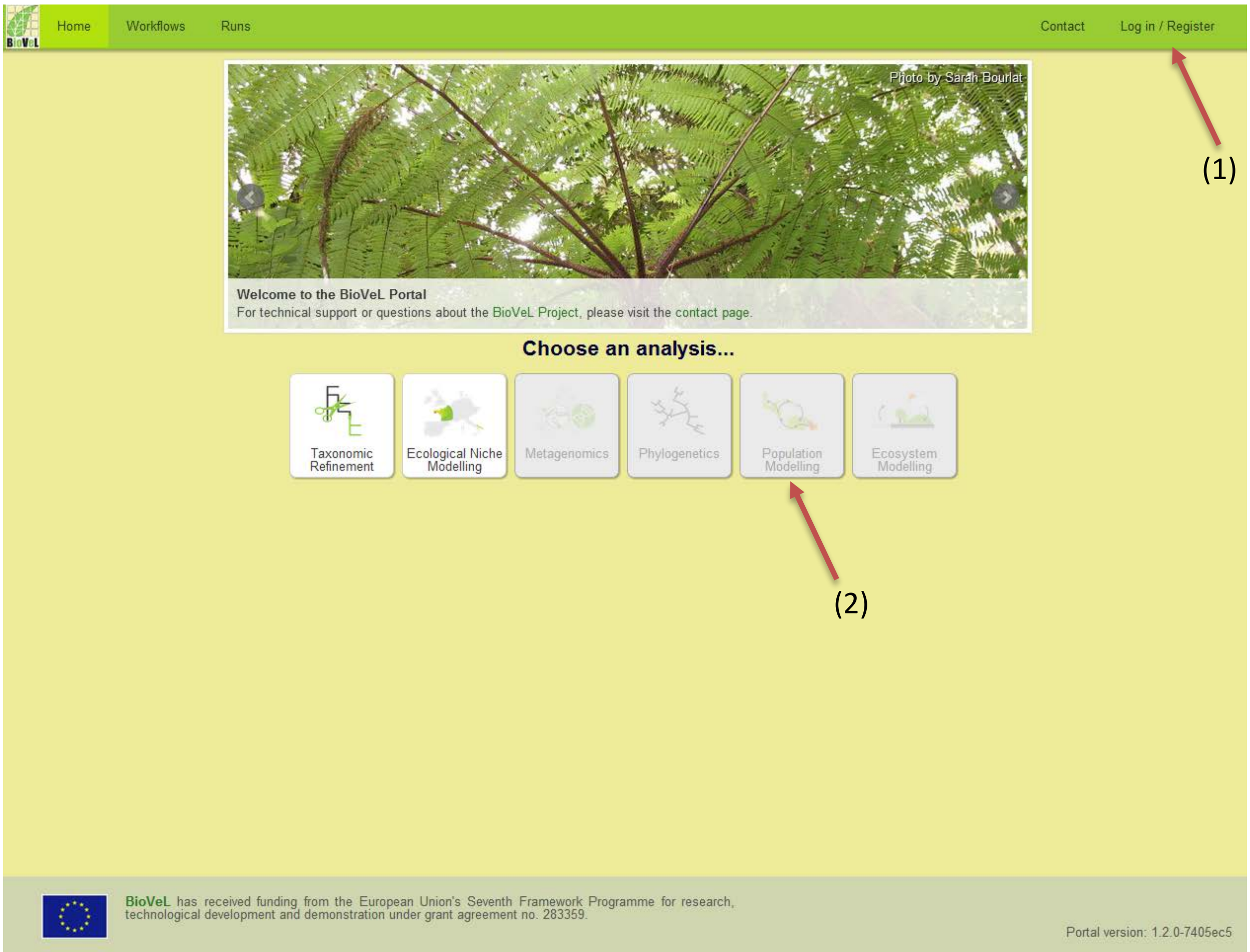
This tutorial explains the type of input data needed to run the workflow. The corresponding analysis use data from two distinct *O. orca* populations in Canada, Southern Resident Killer Whales (SRKW) and the Northern Resident Killer Whales (NRKW).

Two distinct populations of resident killer whales (*Orcinus orca*) in the northeastern Pacific Ocean have been identified in Canada and the U.S. as being of conservation concern. The Southern Resident Killer Whale (SRKW) population is currently listed as endangered under the U.S. Endangered Species Act on the grounds of its small population size and vulnerability to demographic stochasticity and catastrophic events such as oil spills (NMFS 2008). In Canada, under the Species At Risk Act (COSEWIC 2008), SRKW is listed as endangered due to its small and declining population size while the Northern Resident Killer Whale (NRKW) population is listed as threatened due to its small population size. The major threats identified for these two populations are nutritional stress associated with prey abundance levels and availability, particularly Chinook salmon (*Oncorhynchus tshawytscha*) (COSEWIC 2008, Ford et al. 2010a, 2010b), pollution and contaminants, and disturbances from vessels and sound (COSEWIC 2008, NMFS 2008). An important difference in the population-size trajectories of these two populations is that, in spite of their home range overlap and potential access to similar resources, SRKW has remained at a population size of less than 100 individuals for the last four decades with an average of 85 individuals in the last decade. NRKW population size has been generally increasing for the last four decades with 268 individuals at the end of 2011.

Orcinus orca (Killer whale) demography and population viability analysis (PVA) workflow

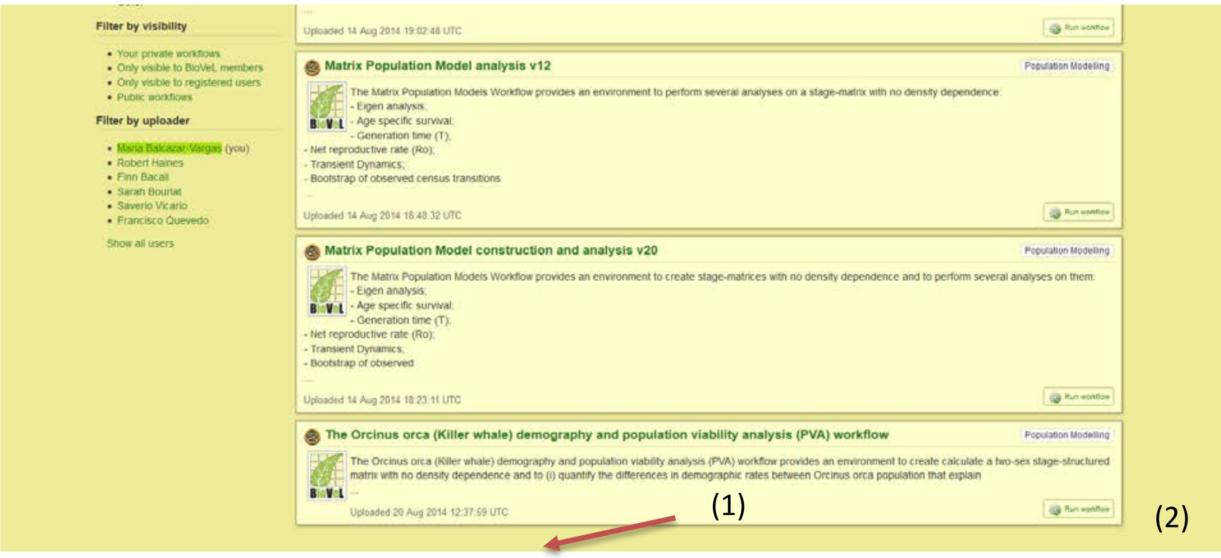
In your browser (preferably Firefox or Chrome) navigate to the [BioVeL Portal](http://portal.biovel.eu/) page (http://portal.biovel.eu/) and log in with your username and password (1). You will need to register if you have not already done so.

Choose the Population Modelling analysis and click, this will show you a list of relevant analysis:

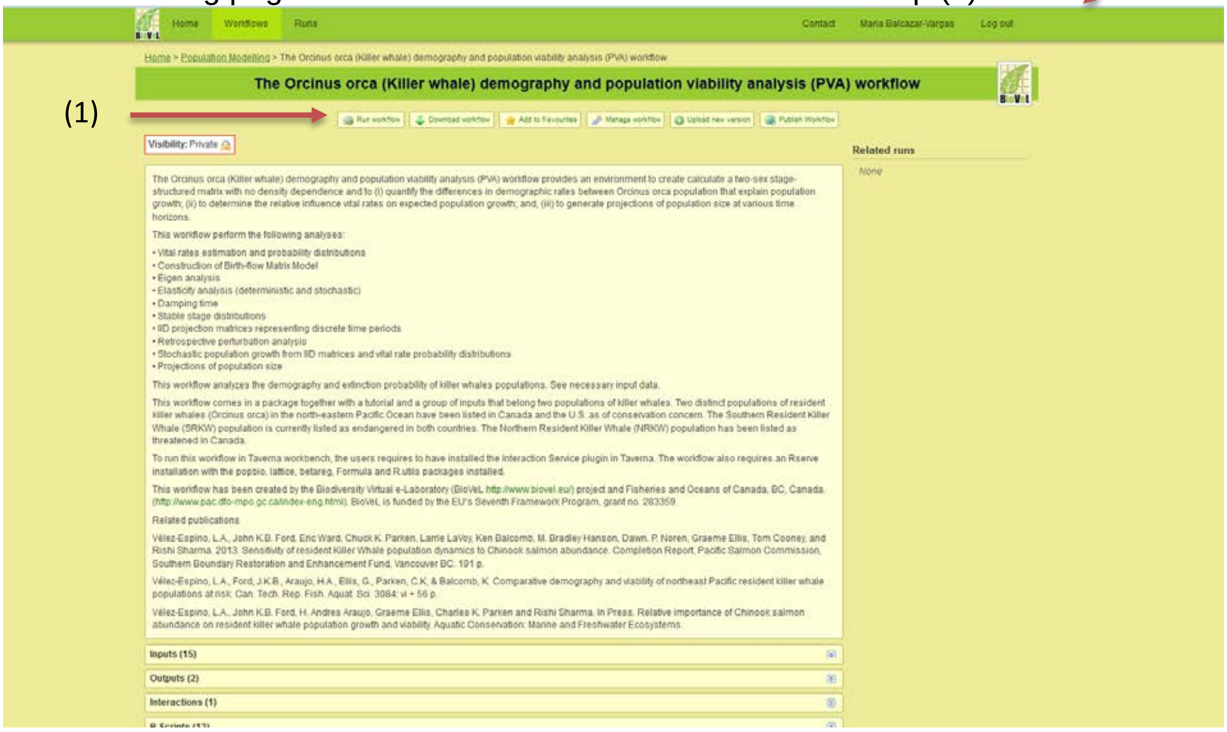


On the resulting page choose the workflow *Orcinus orca* (Killer whale) demography and population viability analysis (PVA) (1) you can also directly run the workflow using the 'Run workflow' button at the bottom-right (2).

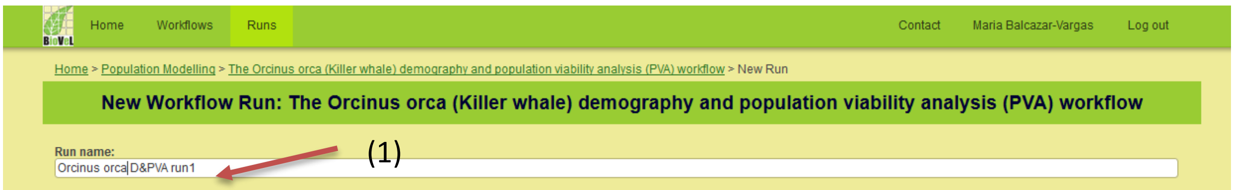
Orcinus orca (Killer whale) demography and population viability analysis (PVA) workflow



On the resulting page click on the 'Run Workflow' button at the top (1).



On the next page you can edit the name of the workflow run to make it easier for you to identify it later (e.g. *Orcinus orca* D&PVA run1).



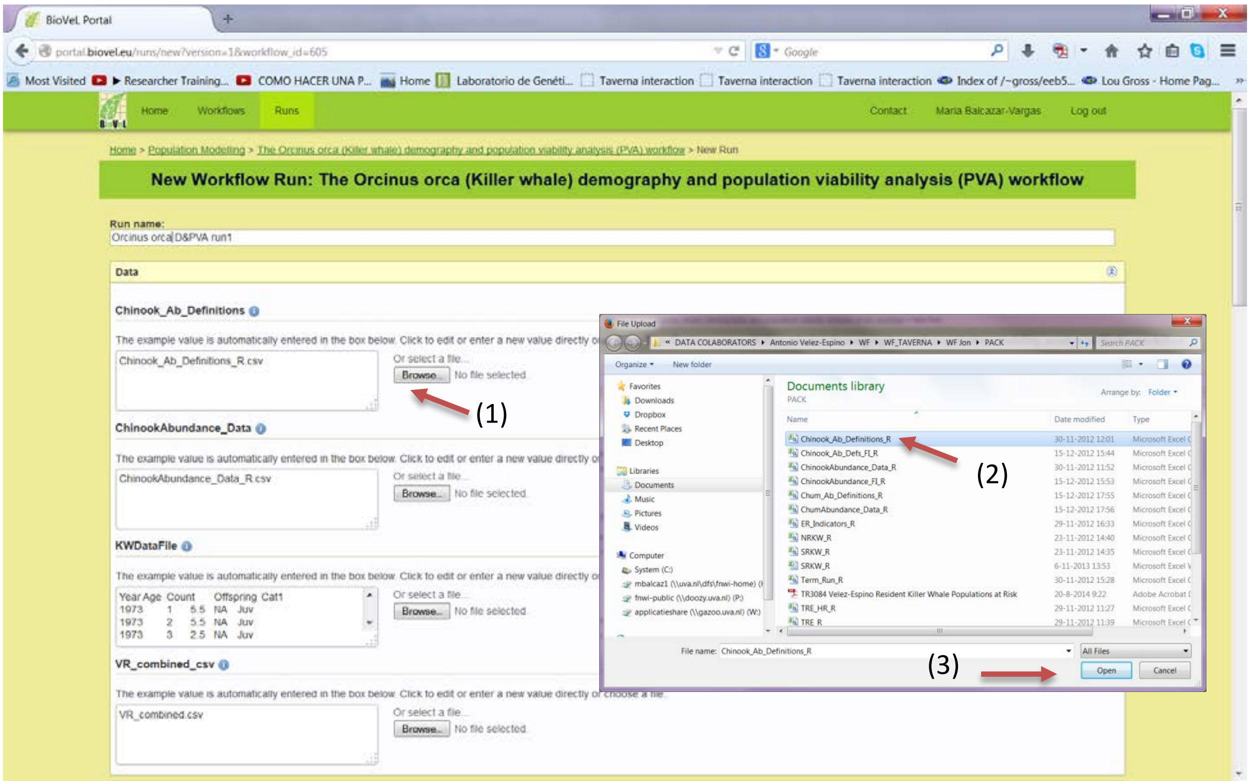
3.1 Input Ports

3.1.1 DATA

<u>Chinook_Ab_Definitions:</u> it's a .csv file. Chinook abundance definitions by stock aggregate, abundance type (TR:Terminal Run; OA: Ocean Abundance), time lag (5YA: 5-year running average), and hypothesis (SR: Southern Resident Killer Whale; NR: Northern Resident Killer Whale) and abundance ID. See below information about hypothesis.

e.g.: Chinook_Ab_Definitions_R.csv

To open the file. Click in Browse (1), a window dialog appears and the user selects the file e.g. Chinook_Ab_Definitions_R.csv, (2) and then clicks the Open button (3). Repeat this action for all the input DATA.

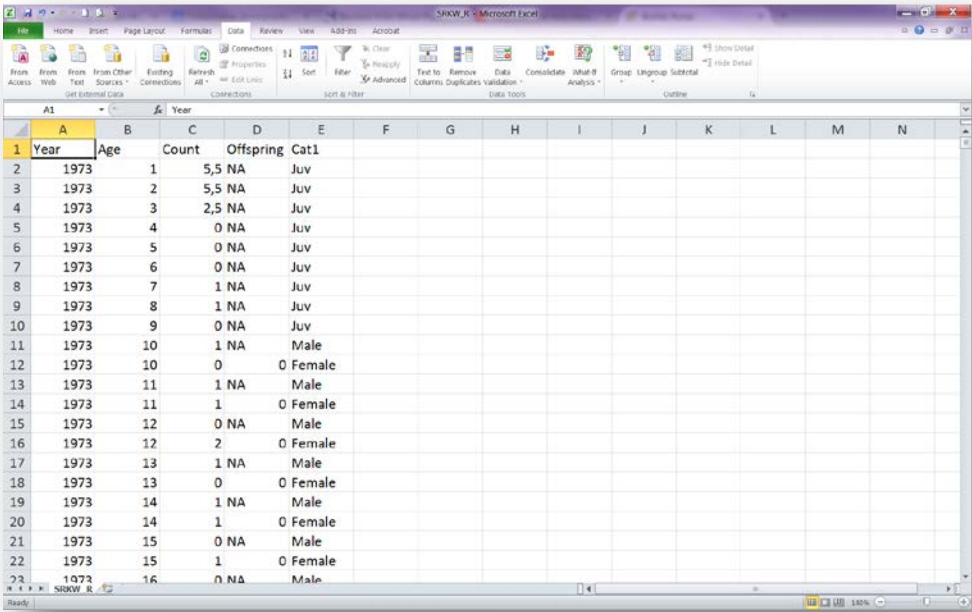


<u>ChinookAbundance_Data:</u> it's a .csv file. Time series of abundance (TR or OA) of all stocks and stock aggregates by time lag used in the analysis.

e.g.: ChinookAbundance_Data_R.csv.

To open the file. Click in choose file, a window dialog appears and the user selects the file e.g. ChinookAbundance_Data_R.csv and then clicks the Open button.

<u>KWDataFile:</u> it's a .csv file. Population File. This is a .csv file with the census data (i.e., counts) by age and group (juvenile, male or female) for the study population. For animals of uncertain year of death, amortized partial values were used. For instance, an animal with probable death over a span of two years was counted as 0.5 for the first year and 0.0 for the second year.



	Year	Age	Count	Offspring	Cat1
2	1973	1	5,5	NA	Juv
3	1973	2	5,5	NA	Juv
4	1973	3	2,5	NA	Juv
5	1973	4	0	NA	Juv
6	1973	5	0	NA	Juv
7	1973	6	0	NA	Juv
8	1973	7	1	NA	Juv
9	1973	8	1	NA	Juv
10	1973	9	0	NA	Juv
11	1973	10	1	NA	Male
12	1973	10	0	0	Female
13	1973	11	1	NA	Male
14	1973	11	1	0	Female
15	1973	12	0	NA	Male
16	1973	12	2	0	Female
17	1973	13	1	NA	Male
18	1973	13	0	0	Female
19	1973	14	1	NA	Male
20	1973	14	1	0	Female
21	1973	15	0	NA	Male
22	1973	15	1	0	Female
23	1973	16	0	NA	Male

e.g.: SRKW_R.csv

To open the file. Click in choose file, a window dialog appears and the user selects the file e.g. SRKW_R.csv and then clicks the Open button.

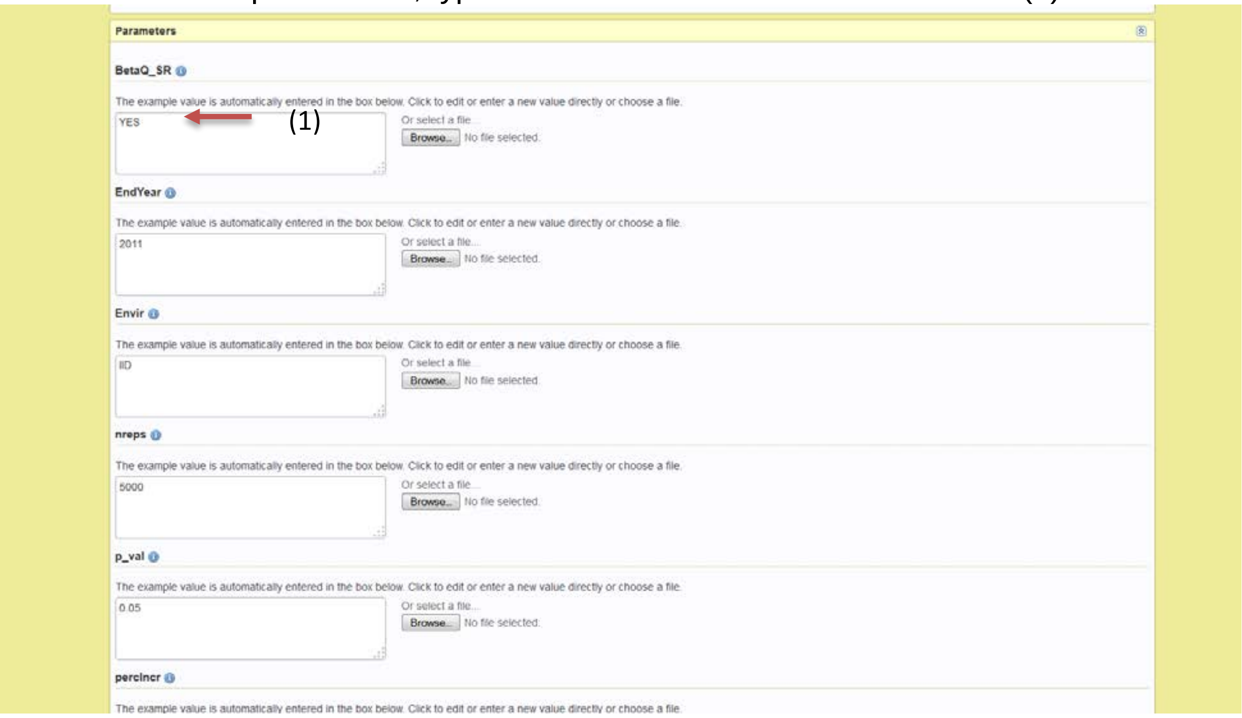
***<u>VR_combined</u>*:** Time series of vital rates (fecundity and survival by life stage) for both populations

e.g.: VR_combined.csv

To open the file. Click in choose file, a window dialog appears and the user selects the file e.g. VR_combined.csv and then clicks the Open button.

3.1.2 PARAMETERS

To determine the parameters, type in each box the value of the variable (1).



***BetaQ_SR*:** defines if the simple regressions should be run with a Beta: YES or Linear model: NO.

e.g.: YES

***EndYear*:** Last year to be considered in the analysis.

e.g.: 2011

ENVIR: Type of environmental stochasticity used for projection of population size. Two types available: IID (identically and independently distributed) or VR_Random (vital rates as random variables). For IID, various matrices are generated from vital rates representative of discrete time periods specified by the user (see “Study_period_year_x”). These matrices are drawn randomly for projections. For VR_Random, vital rates are randomly drawn from their probability distributions parameterized with mean and variances from the entire study time period (see Output Port “Stats_by_Category”).

e.g.: IID

***NREPS*:** Number of replications for projections of population size

e.g.: 5000.

***p.val*:** p- value for the regression.

e.g.: 0.05

***percIncr*:** Percentage increment of Chinook abundance (0.1 = 10%).

e.g.: 0.1

***population*:** It is the name of the analyzed population.

e.g.: SRKW

***Sims*:** Number of simulations that are used for generation of stochastic vital rate elasticities. This input indicates the number of stochastic matrices generated from randomly drawn vital rates. After computing population growth and elasticities for each of these matrices, a bootstrap is used to compute stochastic population growth and mean elasticities and their 95% confidence intervals.

e.g.: 10000

***Standr_Data*:**. Use standardized data? YES or NO

e.g.: NO

***StartYear*:**. First year to be considered in the analysis.

e.g.: 1987

***Variant*:** Using direct perturbations, two computational variants of the elasticity of interactions were explored. Variant 1 (equation 5) completely represents a direct perturbation process whereas variant 2 (equation 6) is a combination of vital rate elasticity and direct perturbation:

$$\varepsilon\left(x_{Chinook\rightarrow v_i}\right)_{DP,\text{variant1}} = \frac{\Delta\lambda}{\Delta x_{Chinook}} = \frac{\left(\left(\lambda_{after}/\lambda_{before}\right)-1\right)}{\left(\left(x_{Chinook,after}/x_{Chinook,before}\right)-1\right)}$$

$$\varepsilon\left(x_{Chinook\rightarrow v_i}\right)_{DP,\text{variant 2}} = \varepsilon\left(v_i\right)\frac{\Delta v_i}{\Delta x_{Chinook}} = \varepsilon\left(v_i\right)\frac{\left(\left(v_{i,after}/v_{i,before}\right)-1\right)}{\left(\left(x_{Chinook,after}/x_{Chinook,before}\right)-1\right)}$$

The term $x_{Chinook,before}$ is the Chinook abundance from a particular stock corresponding to the mean value of the interacting vital rate, $x_{Chinook,after}$ represents the simulated value of Chinook abundance that is used to explore the effect of changes in Chinook abundance (e.g. through changes in harvest rates) on RKW population growth rates. Thus, λ_{before} and λ_{after} represent the population growth rate before and after a perturbation on the vital rate(s) corresponding to a given change in Chinook abundance as per beta regressions, where ($v_{i,after}$) is the vital rate value after the perturbation. For more information see Velez-Espino et al. (Aquatic Conservation: Marine and

Freshwater Ecosystems, *In press*)

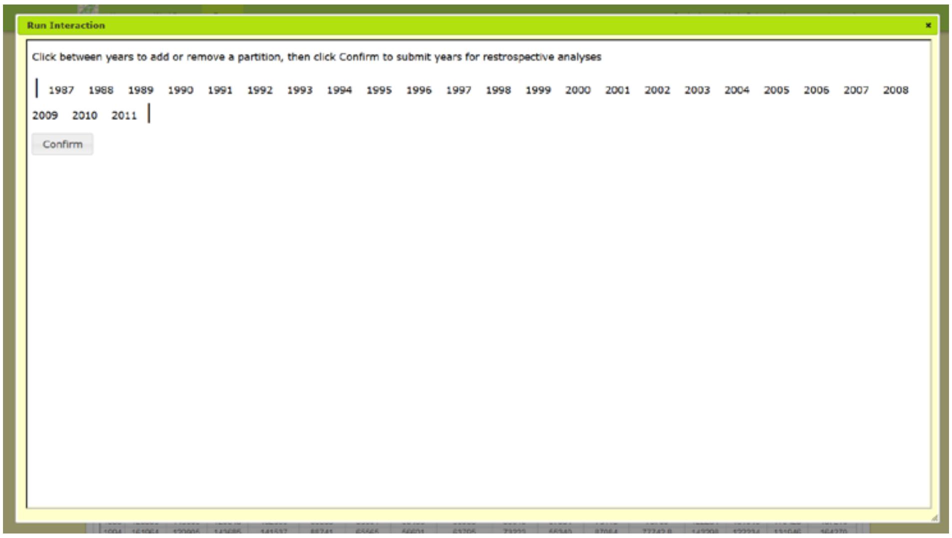
e.g.: 2

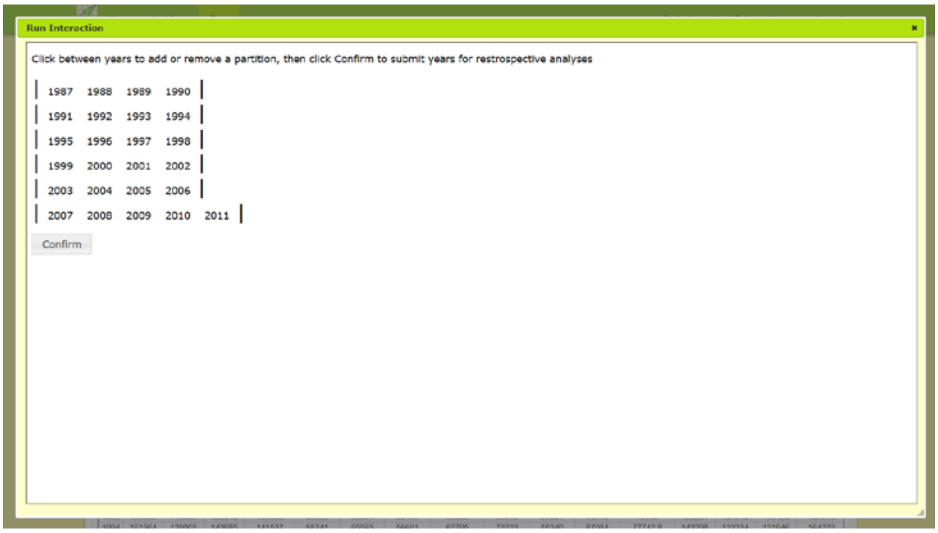
After the user has filled out the input ports and has clicked the ***Start Run***, the workflow performs the analysis. To complete all the analysis may take few minutes, depends on the number of ***Sims*** and ***NREPS*** to carry out the analyses.

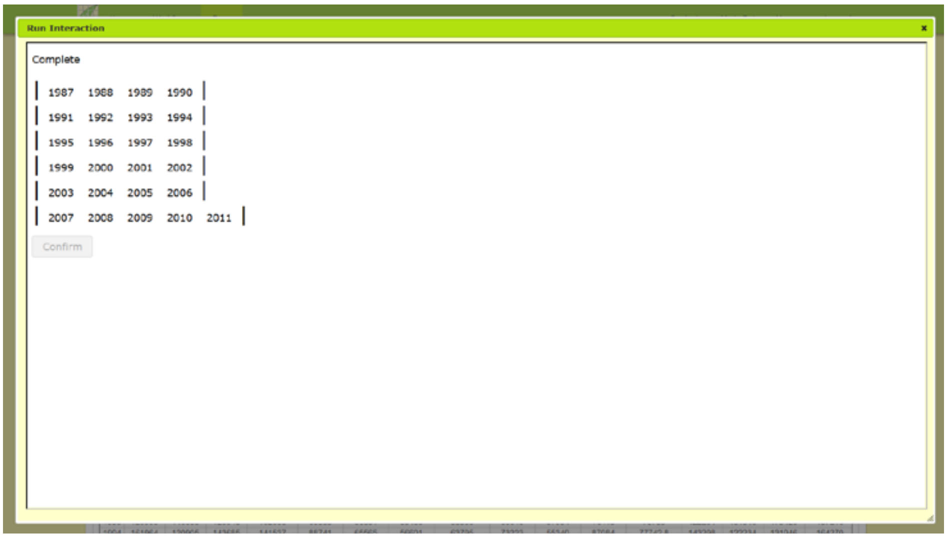
3.2. Dialogue

***Years for retrospective analysis*:** Set the sets for the study period manually. Click after the desired year.

In this tutorial, click every 4 year, (e.g. 1987 1988 1989 1999). Click between 1990 and 1991, repeat the process. The last period will be for 5 years.

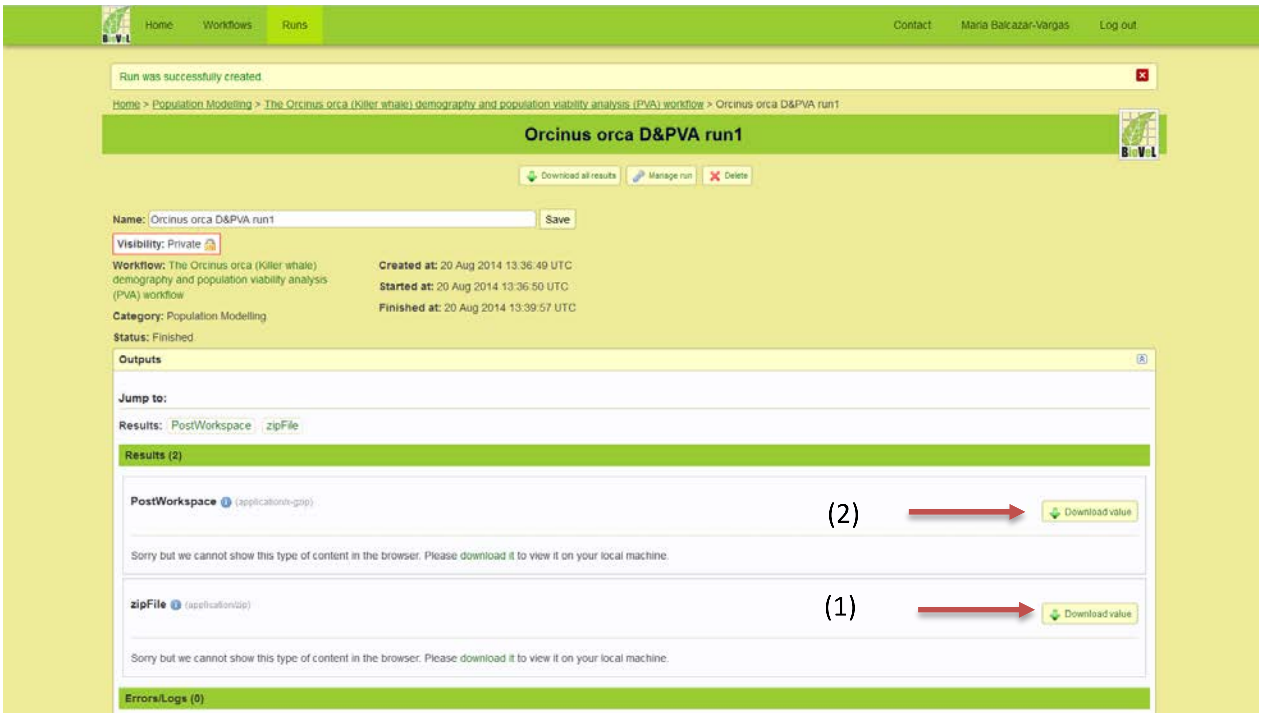






3.2.1 Outputs

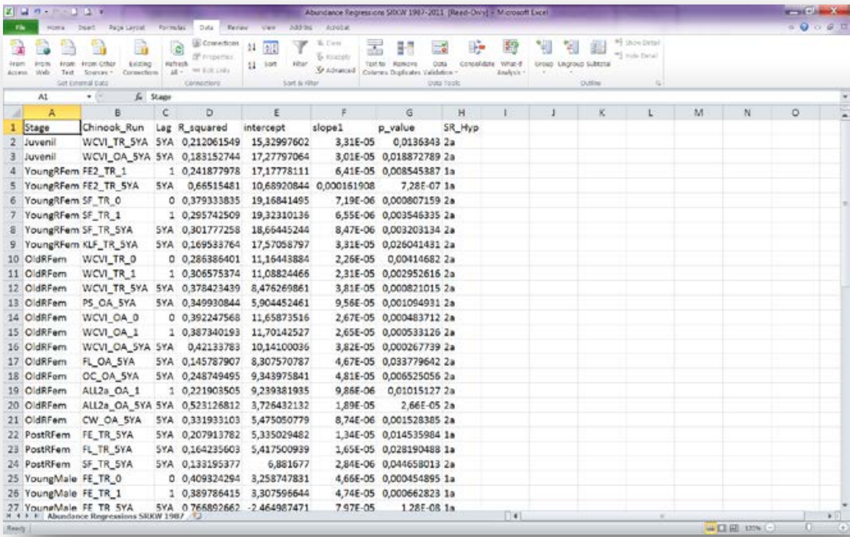
Once the analyses are finished, the user can download all the results by clicking Download value button (1). Numerical and graph results will be download as a zip file that can be save by the user. The numerical results are .csv files than can be opened with Excel and the plot files are .PDF files. A second result is PostWorkspace, a zip file that is needed to run the second workflow: Interaction between killer whale population dynamics and Chinook salmon abundance workflow.



3.3 Results

Zip File

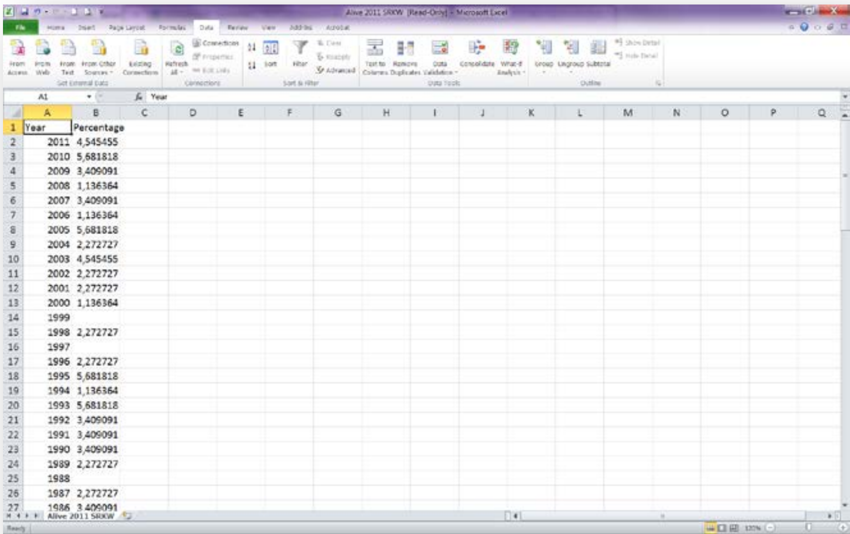
Abundance Regressions Population Start year-End year (csv): Statistics from beta regressions between Chinook abundance and killer whale vital rates.



Stage	Chinook_Run	Lag	R_squared	intercept	slope1	p_value	SR_Hyp
Juvenil	WCVI_TR_5YA	5YA	0,212061549	15,32997602	3,31E-05	0,0136343	2a
Juvenil	WCVI_OA_5YA	5YA	0,183152744	17,27797064	3,01E-05	0,018872789	2a
YoungRFem	FE2_TR_1	1	0,241877978	17,17778111	6,41E-05	0,008545387	1a
YoungRFem	FE2_TR_5YA	5YA	0,66515481	10,68920844	0,000161908	7,28E-07	1a
YoungRFem	SF_TR_0	0	0,379333835	19,16841495	7,19E-06	0,000807159	2a
YoungRFem	SF_TR_1	1	0,295742509	19,32310136	6,55E-06	0,003546335	2a
YoungRFem	SF_TR_5YA	5YA	0,301777258	18,66445244	8,47E-06	0,003203134	2a
YoungRFem	KLF_TR_5YA	5YA	0,169533764	17,57058797	3,31E-05	0,026041431	2a
OldRFem	WCVI_TR_0	0	0,286386401	11,16443884	2,26E-05	0,00414682	2a
OldRFem	WCVI_TR_1	1	0,306575374	11,08824466	2,31E-05	0,002952616	2a
OldRFem	WCVI_TR_5YA	5YA	0,378423439	8,476269861	3,81E-05	0,000821015	2a
OldRFem	PS_OA_5YA	5YA	0,349930844	5,904452461	9,56E-05	0,001094931	2a
OldRFem	WCVI_OA_0	0	0,392247568	11,65873516	2,67E-05	0,000483712	2a
OldRFem	WCVI_OA_1	1	0,387340193	11,70142527	2,65E-05	0,000533126	2a
OldRFem	WCVI_OA_5YA	5YA	0,42133783	10,14100036	3,82E-05	0,000267739	2a
OldRFem	FL_OA_5YA	5YA	0,145787907	8,307570787	4,67E-05	0,033779642	2a
OldRFem	OC_OA_5YA	5YA	0,248749495	9,343975841	4,81E-05	0,006525056	2a
OldRFem	ALL2a_OA_1	1	0,221903505	9,239381935	9,86E-06	0,01015127	2a
OldRFem	ALL2a_OA_5YA	5YA	0,523126812	3,726432132	1,89E-05	2,66E-05	2a
OldRFem	CW_OA_5YA	5YA	0,331933103	5,475050779	8,74E-06	0,001528385	2a
PostRFem	FE_TR_5YA	5YA	0,207913782	5,335029482	1,34E-05	0,014535984	1a
PostRFem	FL_TR_5YA	5YA	0,164235603	5,417500939	1,65E-05	0,028190488	1a
PostRFem	SF_TR_5YA	5YA	0,133195377	6,881677	2,84E-06	0,044658013	2a
YoungMale	FE_TR_0	0	0,409324294	3,258747831	4,66E-05	0,000454895	1a
YoungMale	FE_TR_1	1	0,389786415	3,307596644	4,74E-05	0,000662823	1a
YoungMale	FE_TR_5YA	5YA	0,766892662	-2,464987471	7,97E-05	1,28E-08	1a

Abundance Regressions SRKW 1987-2011

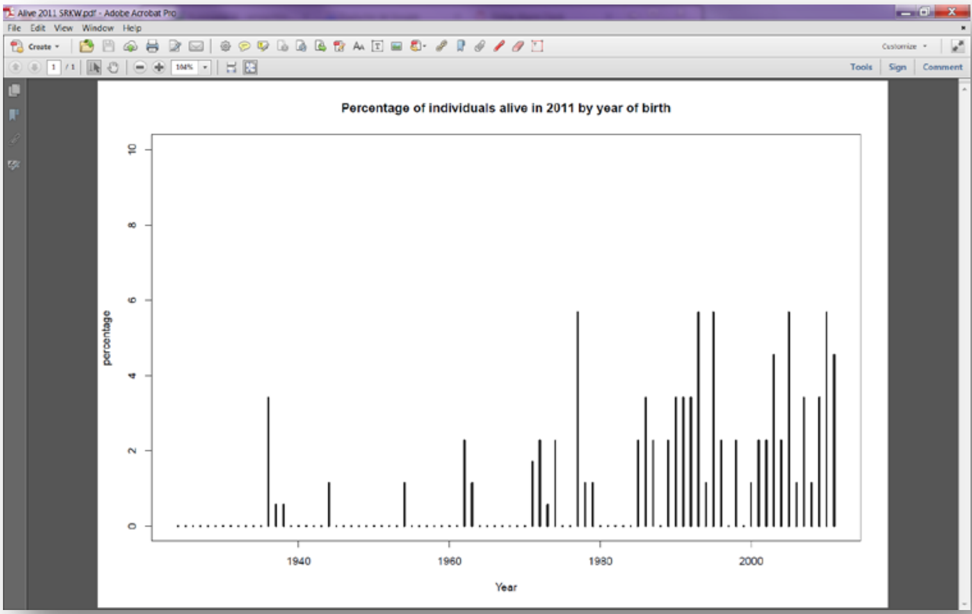
Alive End Year Population (csv): Percentage of individuals alive in the last year of the study by year of birth. The sum of percentages for the selected time period indicates the number of individuals born during the study and alive the last year



Year	Percentage
2011	4,545455
2010	5,681818
2009	3,409091
2008	1,136364
2007	3,409091
2006	1,136364
2005	5,681818
2004	2,272727
2003	4,545455
2002	2,272727
2001	2,272727
2000	1,136364
1999	
1998	2,272727
1997	
1996	2,272727
1995	5,681818
1994	1,136364
1993	5,681818
1992	3,409091
1991	3,409091
1990	3,409091
1989	2,272727
1988	
1987	2,272727
1986	3,409091

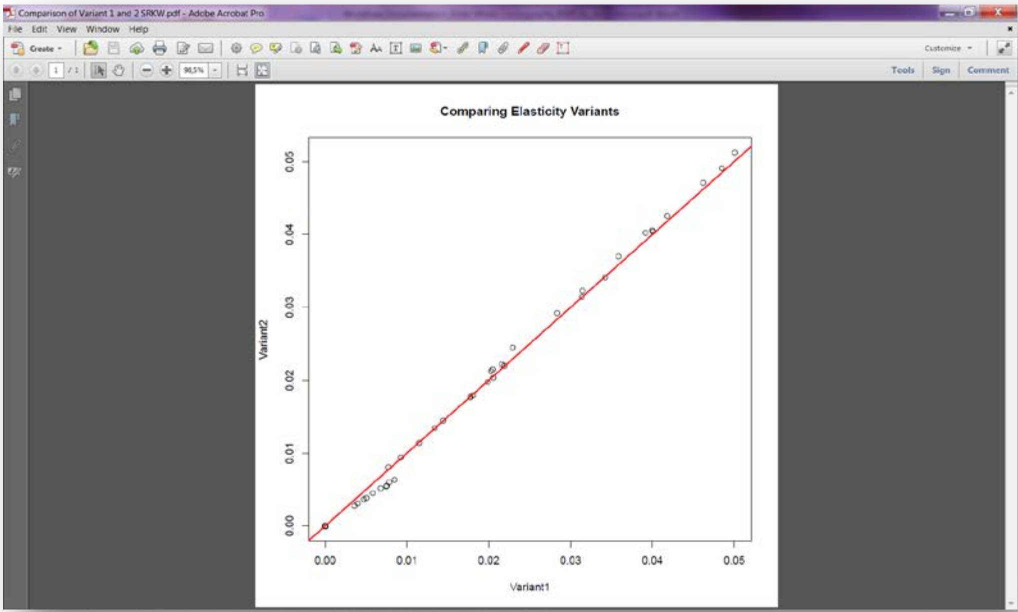
Alive 2011 SRKW.csv

Alive End Year Population (pdf): Graphical output for "Alive End Year Population"



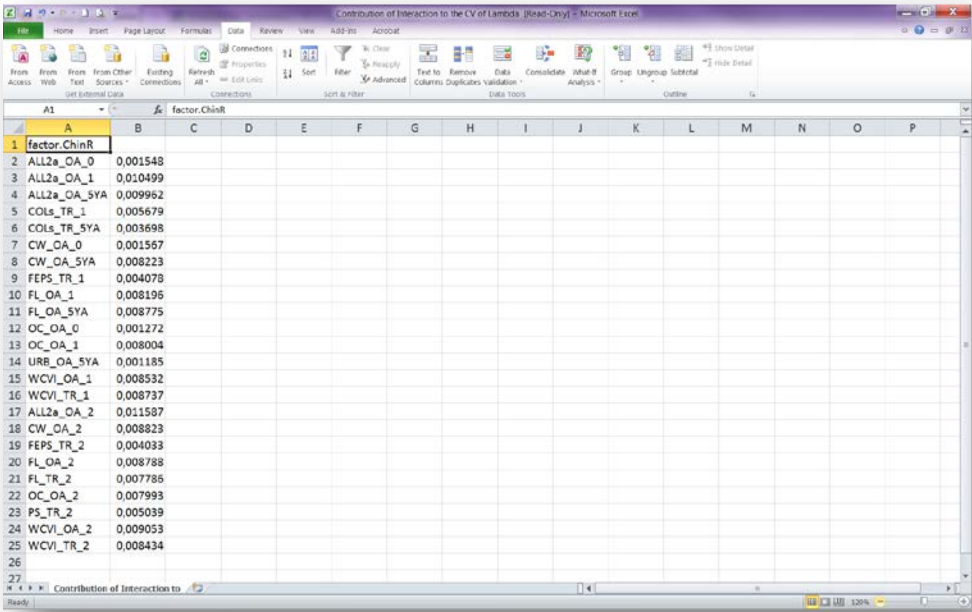
Alive 2011 SRKW.pdf

Comparison of Variant 1 and 2 Population (pdf): Plot showing the relationship between the two computational variants of the elasticity of interactions



Comparison of Variant 1 and 2 SRKW

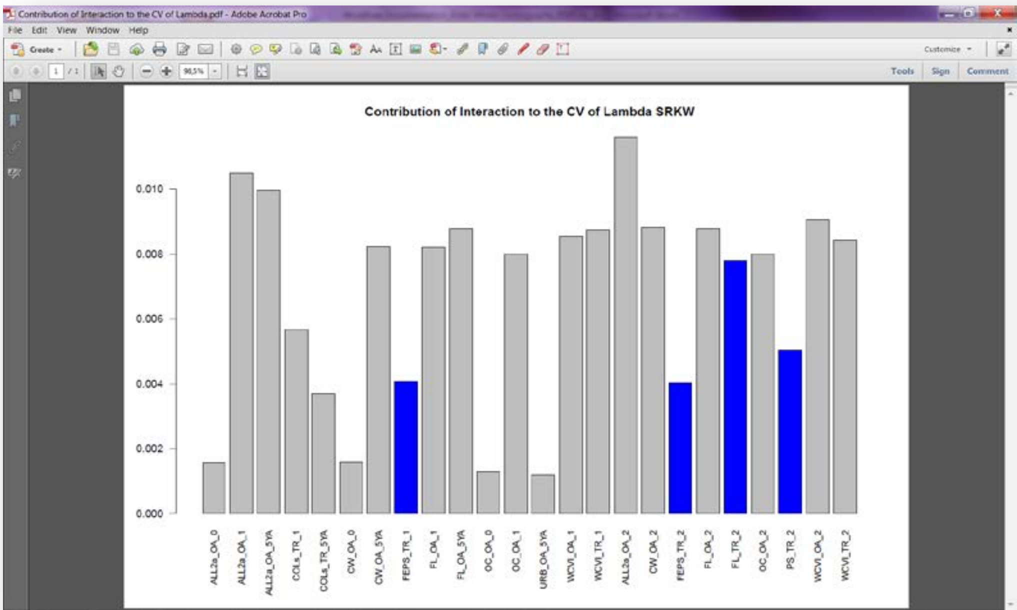
Contribution of Interaction to the CV of Lambda (csv): This file shows the proportion of the CV in population growth due to specific interactions between Chinook salmon stocks and abundance type and killer whale vital rates as explained by retrospective perturbation analysis.



factor.ChinR	
ALL2a_OA_0	0,001548
ALL2a_OA_1	0,010499
ALL2a_OA_5YA	0,009962
COLs_TR_1	0,005679
COLs_TR_5YA	0,003698
CW_OA_0	0,001567
CW_OA_5YA	0,008223
FEPS_TR_1	0,004078
FL_OA_1	0,008196
FL_OA_5YA	0,008775
OC_OA_0	0,001272
OC_OA_1	0,008004
URB_OA_5YA	0,001185
WCVI_OA_1	0,008532
WCVI_TR_1	0,008737
ALL2a_OA_2	0,011587
CW_OA_2	0,008823
FEPS_TR_2	0,004033
FL_OA_2	0,008788
FL_TR_2	0,007786
OC_OA_2	0,007993
PS_TR_2	0,005039
WCVI_OA_2	0,009053
WCVI_TR_2	0,008434

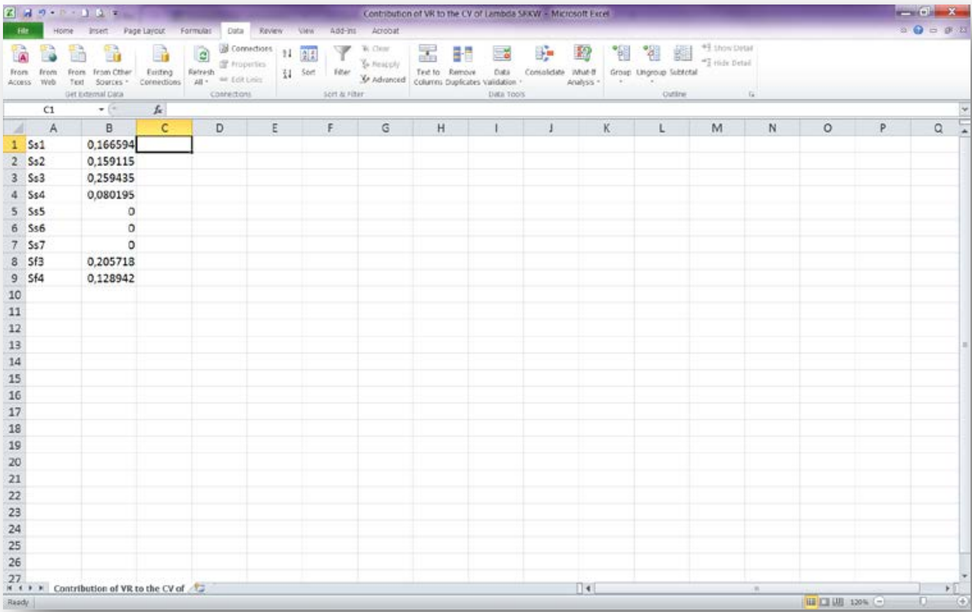
Contribution of Interaction to the CV of Lambda (csv)

Contribution of Interaction to the CV of Lambda (pdf): Graphical representation of Contribution of Interaction to the CV of Lambda (csv)



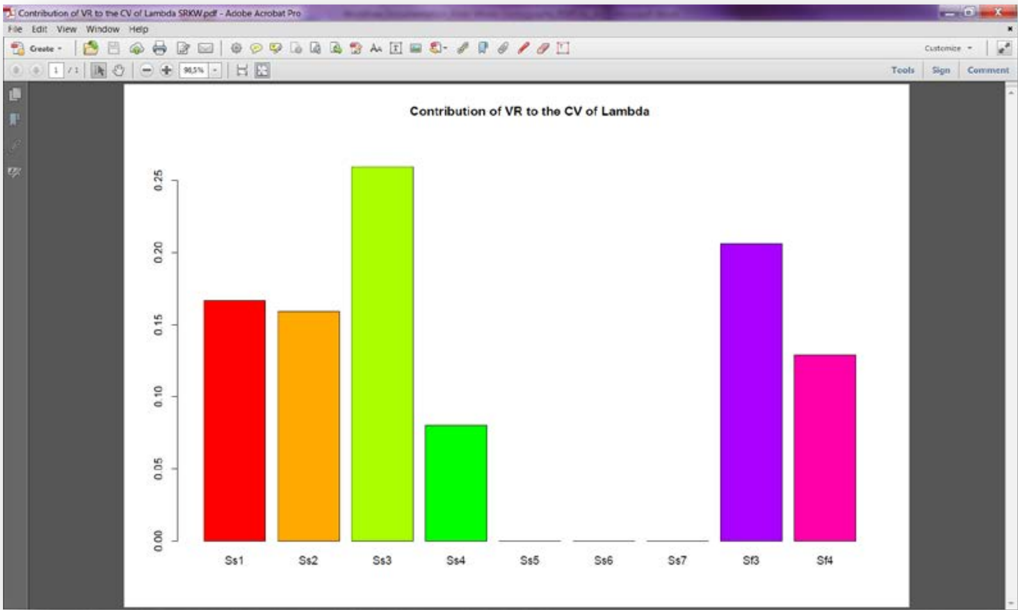
Contribution of Interaction to the CV of Lambda (pdf)

Contribution of VR to the CV of Lambda Population (.cvs): Results of retrospective perturbation analysis showing the contribution of past (observed) vital rate variation to the coefficient of variation of population growth rate (details in Vélez-Espino et al. 2013) e.g.: Contribution of VR to the CV of Lambda SRKW



Contribution of VR to the CV of Lambda Population (cvs)

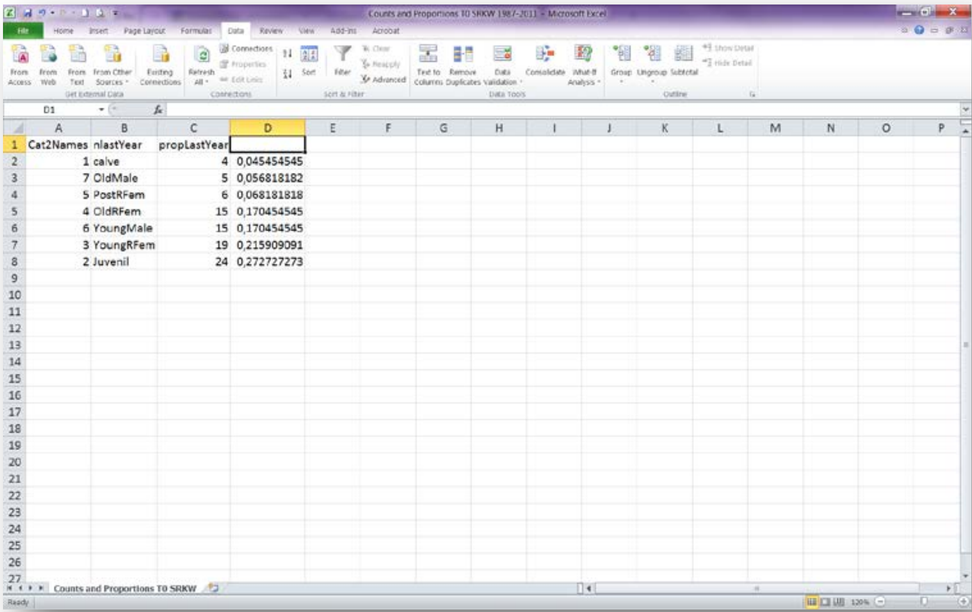
Contribution of VR to the CV of Lambda Population (pdf): Graphical representation of “Contribution_of_VR_to_CV_of_Lambda.csv”.



Contribution of VR to the CV of Lambda Population (pdf)

Orcinus orca (Killer whale) demography and population viability analysis (PVA) workflow

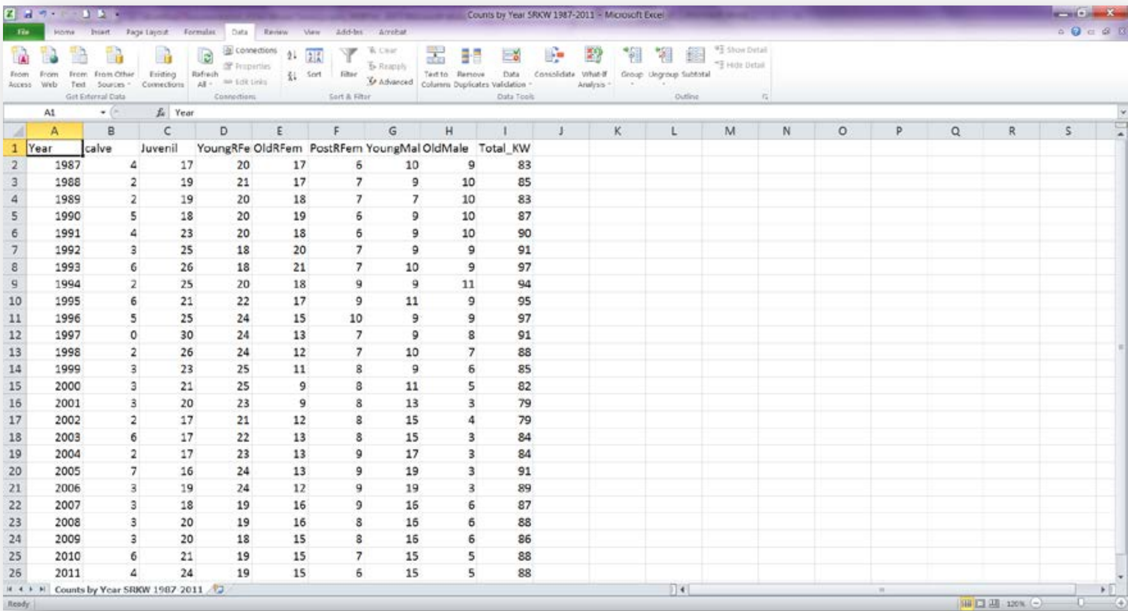
Counts and Proportions T0 Population Start year-End year (csv): Number of individuals and relative proportion by stage in the last year of the selected time period. These proportions are used to represent initial conditions for projections



Cat2Names	nlastYear	propLastYear	
1	calve	4	0,045454545
7	OldMale	5	0,056818182
5	PostRFem	6	0,068181818
4	OldRFem	15	0,170454545
6	YoungMale	15	0,170454545
3	YoungRFem	19	0,215909091
2	Juvenil	24	0,272727273

Counts and Proportions T0 Population Start year-End year (csv)

Counts by Year Population Start year-End year (csv): Number of individuals by life stage (calves, juveniles, young reproductive females, old reproductive females, post-reproductive females, young mature males, and old mature males) and year through the selected time period. Last column represents total population size

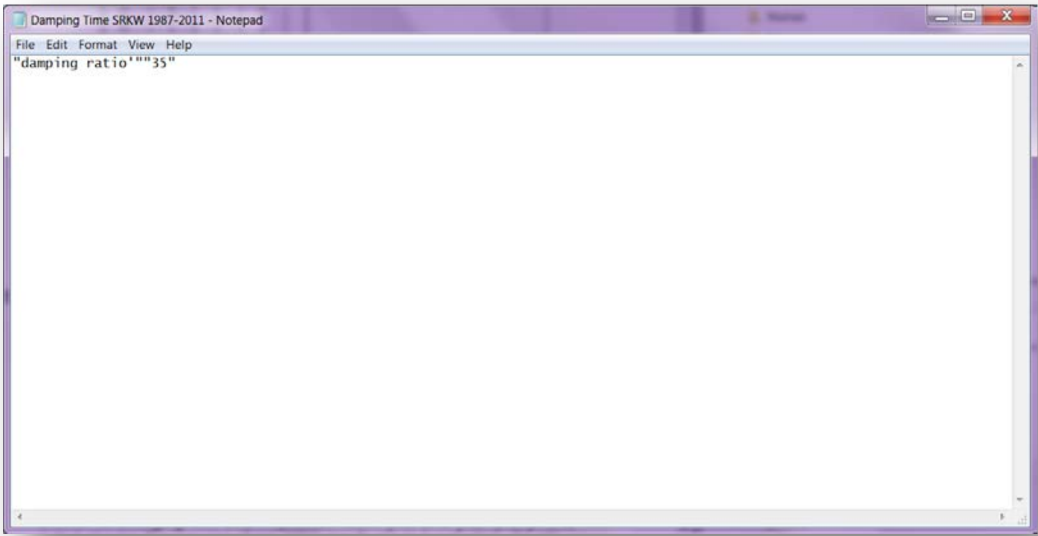


Year	calve	Juvenil	YoungRFe	OldRFem	PostRFem	YoungMal	OldMale	Total_KW
1987	4	17	20	17	6	10	9	83
1988	2	19	21	17	7	9	10	85
1989	2	19	20	18	7	7	10	83
1990	5	18	20	19	6	9	10	87
1991	4	23	20	18	6	9	10	90
1992	3	25	18	20	7	9	9	91
1993	6	26	18	21	7	10	9	97
1994	2	25	20	18	9	9	11	94
1995	6	21	22	17	9	11	9	95
1996	5	25	24	15	10	9	9	97
1997	0	30	24	13	7	9	8	91
1998	2	26	24	12	7	10	7	88
1999	3	23	25	11	8	9	6	85
2000	3	21	25	9	8	11	5	82
2001	3	20	23	9	8	13	3	79
2002	2	17	21	12	8	15	4	79
2003	6	17	22	13	8	15	3	84
2004	2	17	23	13	9	17	3	84
2005	7	16	24	13	9	19	3	91
2006	3	19	24	12	9	19	3	89
2007	3	18	19	16	9	16	6	87
2008	3	20	19	16	8	16	6	88
2009	3	20	18	15	8	16	6	86
2010	6	21	19	15	7	15	5	88
2011	4	24	19	15	6	15	5	88

Counts by Year SRKW 1987-2011

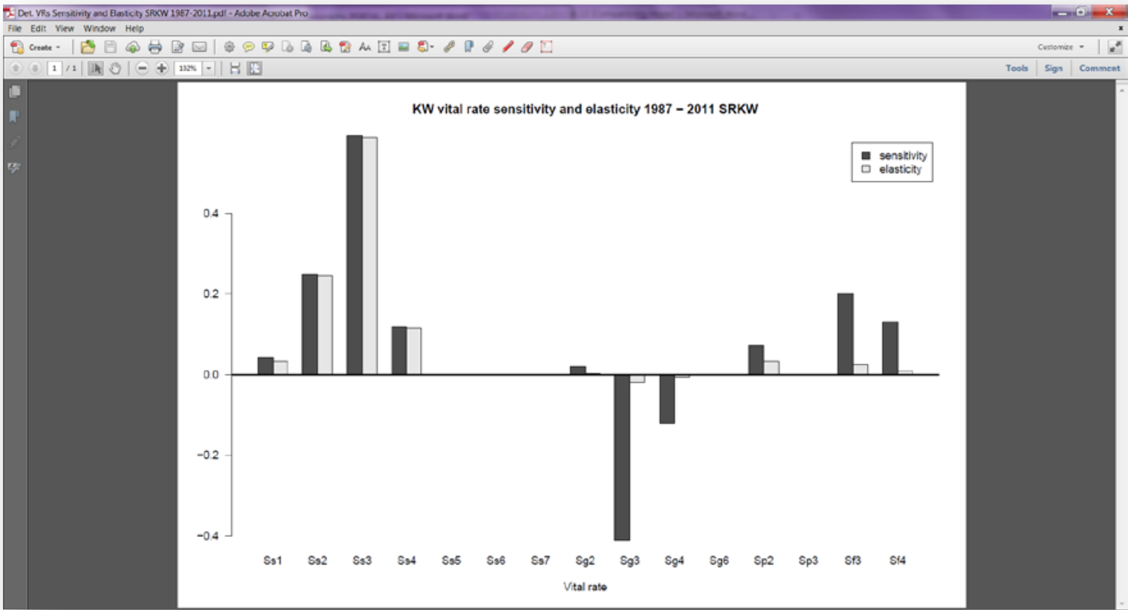
Orcinus orca (Killer whale) demography and population viability analysis (PVA) workflow

Damping Time Population Start year-End year (txt): Damping time (τ) is defined as $\tau = \ln(z)/\ln(\rho)$, where ρ is the damping ratio and z is the number of times the contribution of λ_1 (dominant eigenvalue) becomes as great as that of λ_2 (subdominant eigenvalue). Damping times at z = 10 were used to define minimum time horizons for projections of population size.



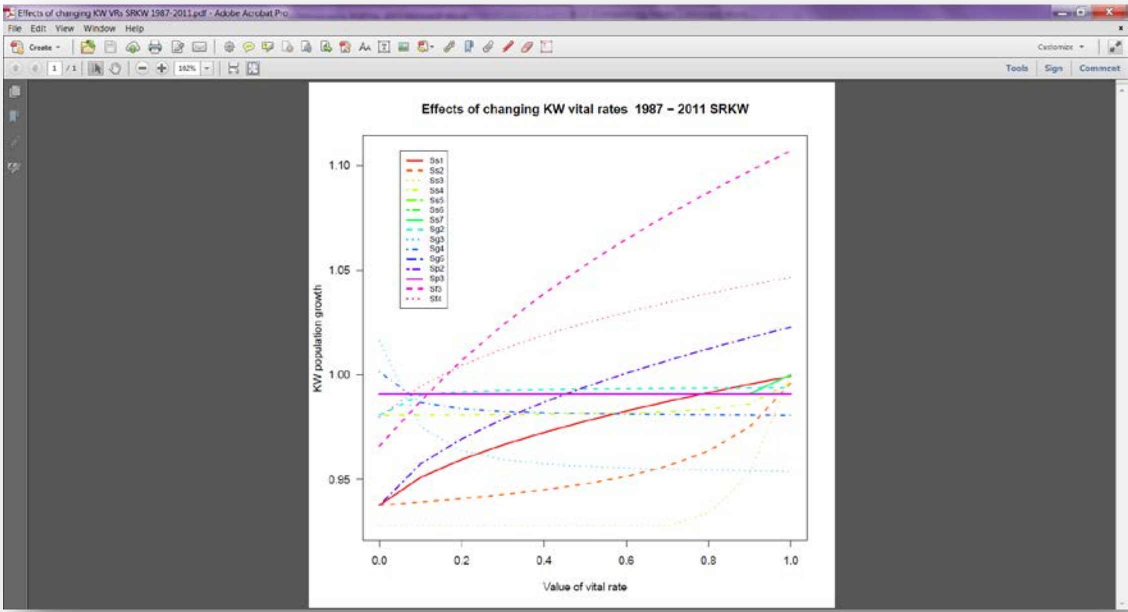
Damping Time SRKW 1987-2011

Det. VRs Sensitivity and Elasticity Population Start year-End year (pdf): Graphical output for sensitivities and elasticities of vital rates (survival, fecundity and stage transition probabilities)



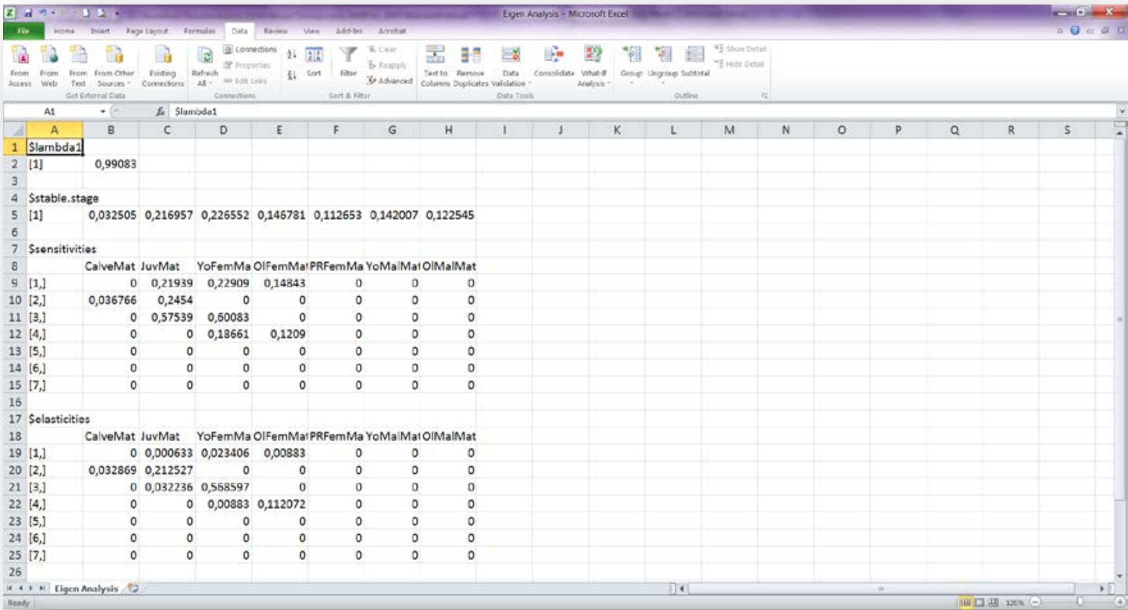
Det. VRs Sensitivity and Elasticity SRKW 1987-2011

Effects of changing KW VRs Population Start year-End year (pdf): Graphical output showing the response of population growth rate to hypothetical vital rate values ranging from 0.0 to 1.0. Some of these values could be biologically unfeasible (e.g., a fecundity rate of 1.0 would indicate every year all females in the stage produce a viable calf)



Effects of changing KW VRs SRKW 1987-2011

Eigen Analysis (txt): Dominant eigenvalue (asymptotic population growth rate), stable stage distribution, sensitivities, elasticities, reproductive value, and damping ratio based on mean matrix of selected population.

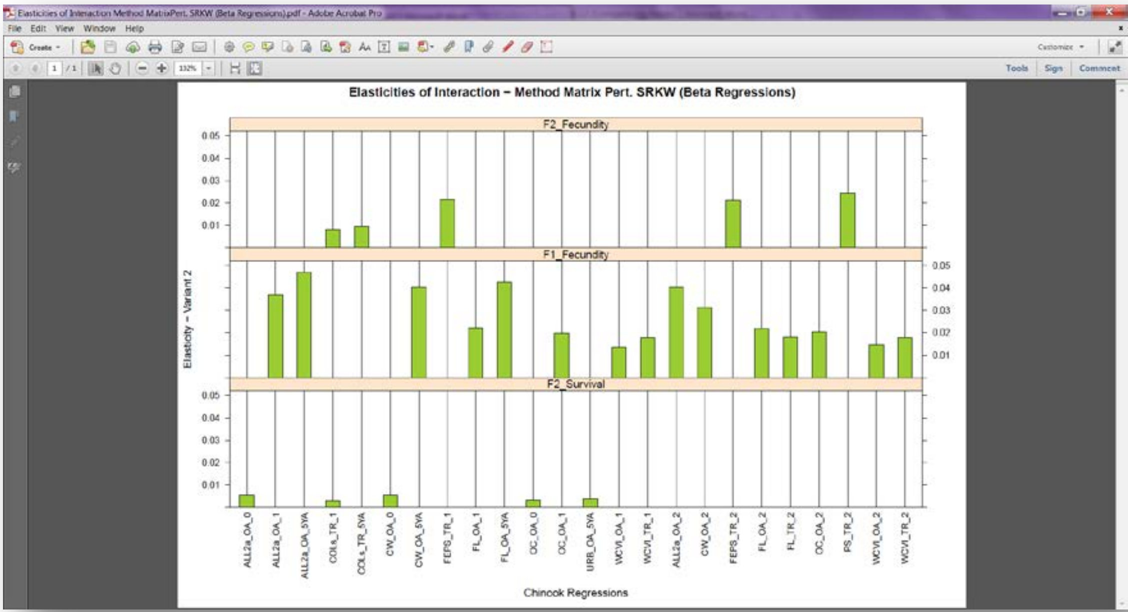


	A	B	C	D	E	F	G	H
1	$lambda1							
2	[1]	0,99083						
3								
4	$stable.stage							
5	[1]	0,032505	0,216957	0,226552	0,146781	0,112653	0,142007	0,122545
6								
7	$sensitivities							
8		CalveMat	JuvMat	YoFemMa	OlFemMat	PRFemMa	YoMalMat	OlMalMat
9	[1,]	0	0,21939	0,22909	0,14843	0	0	0
10	[2,]	0,036766	0,2454	0	0	0	0	0
11	[3,]	0	0,57539	0,60083	0	0	0	0
12	[4,]	0	0	0,18661	0,1209	0	0	0
13	[5,]	0	0	0	0	0	0	0
14	[6,]	0	0	0	0	0	0	0
15	[7,]	0	0	0	0	0	0	0
16								
17	$elasticities							
18		CalveMat	JuvMat	YoFemMa	OlFemMat	PRFemMa	YoMalMat	OlMalMat
19	[1,]	0	0,000633	0,023406	0,00883	0	0	0
20	[2,]	0,032869	0,212527	0	0	0	0	0
21	[3,]	0	0,032236	0,568597	0	0	0	0
22	[4,]	0	0	0,00883	0,112072	0	0	0
23	[5,]	0	0	0	0	0	0	0
24	[6,]	0	0	0	0	0	0	0
25	[7,]	0	0	0	0	0	0	0

Eigen Analysis (opens in excel)

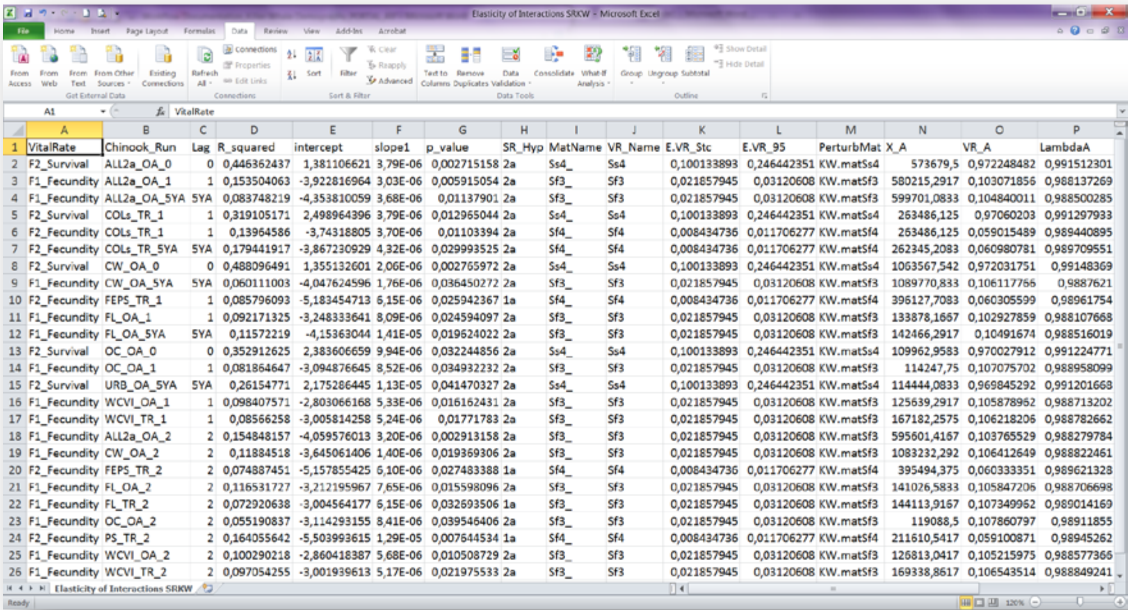
Orcinus orca (Killer whale) demography and population viability analysis (PVA) workflow

Elasticities of Interaction Method MatrixPert. Population (Type of Regressions) (pdf): This plot shows the elasticities (as determined by variant 2) of all significant interactions (as determined by beta regressions) between Chinook stock/abundance type/lag and killer whale vital rates



Elasticities of Interaction Method MatrixPert. SRKW (Beta Regressions)

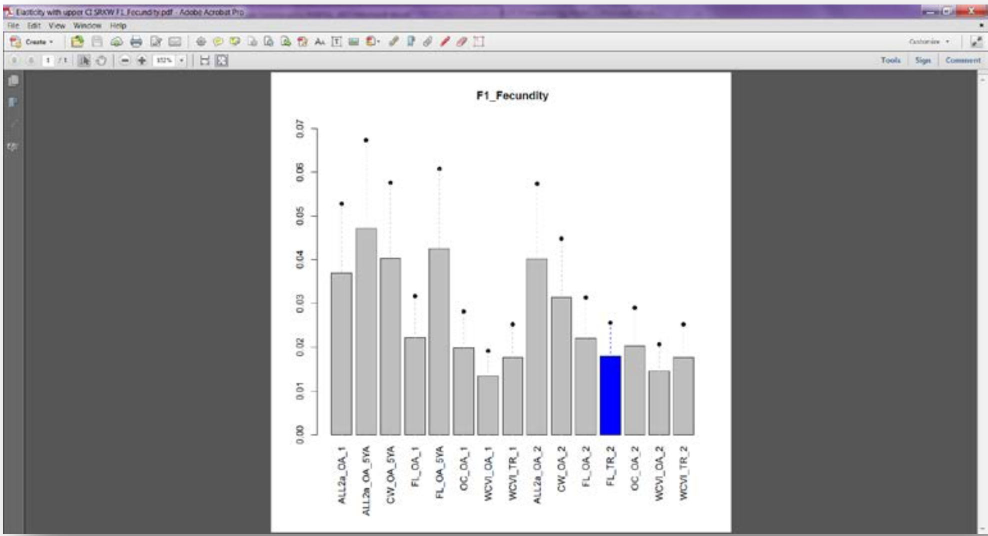
Elasticity of Interactions Population (csv): This file shows the beta regression statistics and the value of variables involved in the direct perturbations used to compute the elasticities of all significant interactions.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	VitalRate	Chinook_Run	Lag	R_squared	intercept	slope1	p_value	SR_Hyp	MatName	VR_Name	E.VR_Stc	E.VR_95	PerturbMat	X_A	VR_A	LambdaA
2	F2_Survival	ALL2a_OA_0	0	0,446362437	1,381106621	3,79E-06	0,002715158	2a	Ss4_	Ss4	0,100133893	0,246442351	KW.matSs4	573679,5	0,972248482	0,991512301
3	F1_Fecundity	ALL2a_OA_1	1	0,153504063	-3,922816964	3,03E-06	0,005915054	2a	Sf3_	Sf3	0,021857945	0,03120608	KW.matSf3	580215,2917	0,103071856	0,988137269
4	F1_Fecundity	ALL2a_OA_5YA	5YA	0,083748219	-4,353810059	3,68E-06	0,01137901	2a	Sf3_	Sf3	0,021857945	0,03120608	KW.matSf3	599701,0833	0,104840011	0,988500285
5	F2_Survival	COLs_TR_1	1	0,319105171	2,498964396	3,79E-06	0,012965044	2a	Ss4_	Ss4	0,100133893	0,246442351	KW.matSs4	263486,125	0,97060203	0,991297933
6	F2_Fecundity	COLs_TR_1	1	0,13964586	-3,74318805	3,70E-06	0,01103394	2a	Sf4_	Sf4	0,008434736	0,011706277	KW.matSf4	263486,125	0,059015489	0,989440895
7	F2_Fecundity	COLs_TR_5YA	5YA	0,179441917	-3,867230929	4,32E-06	0,029993525	2a	Sf4_	Sf4	0,008434736	0,011706277	KW.matSf4	262345,2083	0,060980781	0,989709551
8	F2_Survival	CW_OA_0	0	0,488096491	1,355132601	2,06E-06	0,002765972	2a	Ss4_	Ss4	0,100133893	0,246442351	KW.matSs4	1063567,542	0,972031751	0,99148369
9	F1_Fecundity	CW_OA_5YA	5YA	0,060111003	-4,047624596	1,76E-06	0,036450272	2a	Sf3_	Sf3	0,021857945	0,03120608	KW.matSf3	1089770,833	0,106117766	0,9887621
10	F2_Fecundity	FEPS_TR_1	1	0,085796093	-5,183454713	6,15E-06	0,025942367	1a	Sf4_	Sf4	0,008434736	0,011706277	KW.matSf4	396127,7083	0,060305599	0,98961754
11	F1_Fecundity	FL_OA_1	1	0,092171325	-3,248333641	8,09E-06	0,024594097	2a	Sf3_	Sf3	0,021857945	0,03120608	KW.matSf3	133878,1667	0,102927859	0,988107668
12	F1_Fecundity	FL_OA_5YA	5YA	0,11572219	-4,15363044	1,41E-05	0,019624022	2a	Sf3_	Sf3	0,021857945	0,03120608	KW.matSf3	142466,2917	0,10491674	0,988516019
13	F2_Survival	OC_OA_0	0	0,352912625	2,383606659	9,94E-06	0,032244856	2a	Ss4_	Ss4	0,100133893	0,246442351	KW.matSs4	109962,9583	0,970027912	0,991224771
14	F1_Fecundity	OC_OA_1	1	0,081864647	-3,094876645	8,52E-06	0,034932232	2a	Sf3_	Sf3	0,021857945	0,03120608	KW.matSf3	114247,75	0,107075702	0,988958099
15	F2_Survival	URB_OA_5YA	5YA	0,26154771	2,175286445	1,13E-05	0,041470327	2a	Ss4_	Ss4	0,100133893	0,246442351	KW.matSs4	114444,0833	0,969845292	0,991201668
16	F1_Fecundity	WCVI_OA_1	1	0,098407571	-2,803066168	5,33E-06	0,016162431	2a	Sf3_	Sf3	0,021857945	0,03120608	KW.matSf3	125639,2917	0,105878962	0,988713202
17	F1_Fecundity	WCVI_TR_1	1	0,08566258	-3,005814258	5,24E-06	0,01771783	2a	Sf3_	Sf3	0,021857945	0,03120608	KW.matSf3	167182,2575	0,106218206	0,988782662
18	F1_Fecundity	ALL2a_OA_2	2	0,154848157	-4,059576013	3,20E-06	0,002913158	2a	Sf3_	Sf3	0,021857945	0,03120608	KW.matSf3	595601,4167	0,103765529	0,988279784
19	F1_Fecundity	CW_OA_2	2	0,11884518	-3,645061406	1,40E-06	0,019369306	2a	Sf3_	Sf3	0,021857945	0,03120608	KW.matSf3	1083232,292	0,106412649	0,988822461
20	F2_Fecundity	FEPS_TR_2	2	0,074887451	-5,157855425	6,10E-06	0,027483388	1a	Sf4_	Sf4	0,008434736	0,011706277	KW.matSf4	395494,375	0,060333351	0,989621328
21	F1_Fecundity	FL_OA_2	2	0,116531727	-3,212195967	7,65E-06	0,015598096	2a	Sf3_	Sf3	0,021857945	0,03120608	KW.matSf3	141026,5833	0,105847206	0,988706698
22	F1_Fecundity	FL_TR_2	2	0,072920638	-3,004564177	6,15E-06	0,032693506	1a	Sf3_	Sf3	0,021857945	0,03120608	KW.matSf3	144113,9167	0,107349962	0,989014169
23	F1_Fecundity	OC_OA_2	2	0,055190837	-3,114293155	8,41E-06	0,039546406	2a	Sf3_	Sf3	0,021857945	0,03120608	KW.matSf3	119088,5	0,107860797	0,98911855
24	F2_Fecundity	PS_TR_2	2	0,164055642	-5,503993615	1,29E-05	0,007644534	1a	Sf4_	Sf4	0,008434736	0,011706277	KW.matSf4	211610,5417	0,059100871	0,98945262
25	F1_Fecundity	WCVI_OA_2	2	0,100290218	-2,860418387	5,68E-06	0,010508729	2a	Sf3_	Sf3	0,021857945	0,03120608	KW.matSf3	126813,0417	0,105215975	0,988577366
26	F1_Fecundity	WCVI_TR_2	2	0,097054255	-3,001939613	5,17E-06	0,021975533	2a	Sf3_	Sf3	0,021857945	0,03120608	KW.matSf3	169338,8617	0,106543514	0,988849241

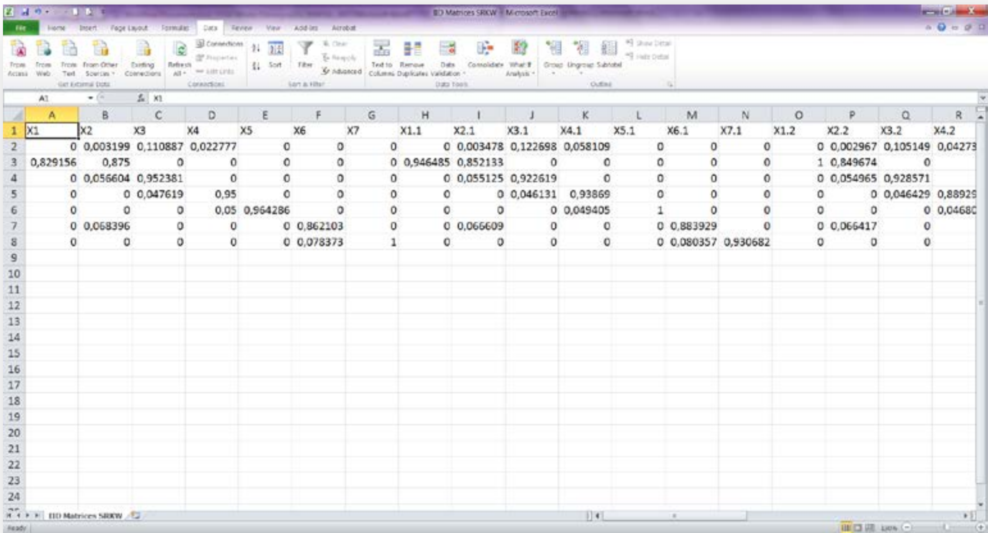
Elasticity of Interactions SRKW

Elasticity with upper CI Population Stage_Vital rate (pdf): These plots show the mean upper 95% confidence limit of elasticities of interactions by population (SRKW or NRKW) and vital rate. Interactions characterizing strong hypotheses 1a or 1b are highlighted in blue for SRKW and in green for NRKW. For example, using the 1987-2011 killer whale data, three vital rates exhibited significant interactions with Chinook salmon stocks: F1_Fecundity, F2_Fecundity, and F2_Survival.



Elasticity with upper CI SRKW F1_Fecundity

IID Matrices Population (csv): Projection matrices produced by discrete time periods within the study period (see Input Port "ENVIR"). Each of these matrices represents population dynamics for discrete temporal strata. Default is six time periods (see Input Ports "Study_period_year_x"). These matrices are used for projections of population size if ENVIR is set to "IID"

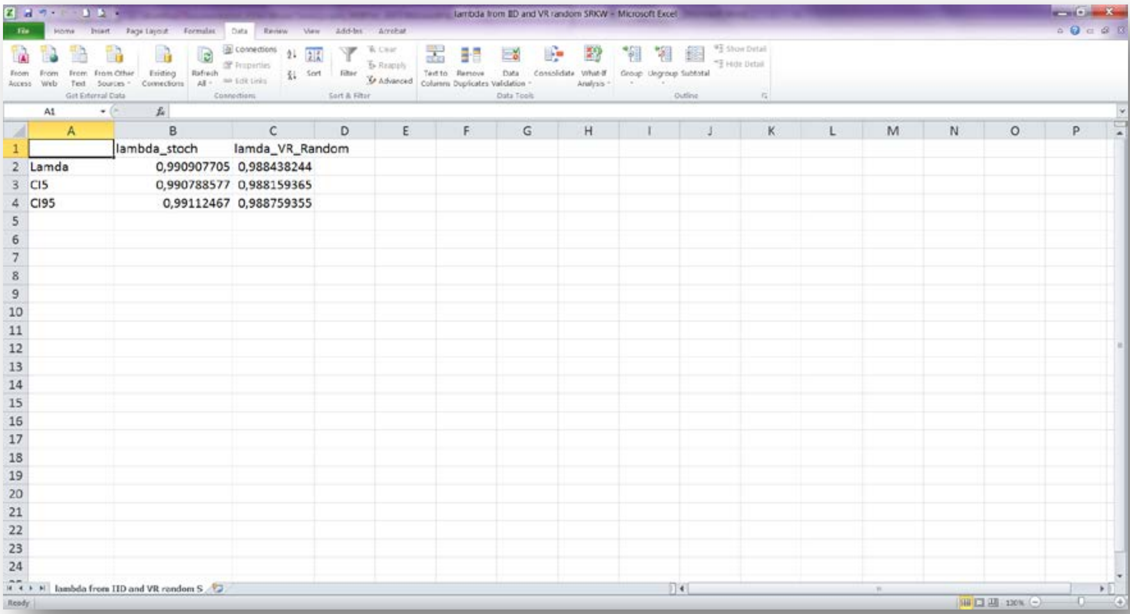


	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	X1	X2	X3	X4	X5	X6	X7	X1.1	X2.1	X3.1	X4.1	X5.1	X6.1	X7.1	X1.2	X2.2	X3.2	X4.2
2	0	0,003199	0,110887	0,022777	0	0	0	0	0,003478	0,122698	0,058109	0	0	0	0	0,002967	0,105149	0,04273
3	0,829156	0,875	0	0	0	0	0	0,946485	0,852133	0	0	0	0	0	1	0,849674	0	
4	0	0,056604	0,952381	0	0	0	0	0	0,055125	0,922619	0	0	0	0	0	0,054965	0,928571	
5	0	0	0,047619	0,95	0	0	0	0	0	0,046131	0,93869	0	0	0	0	0	0,046429	0,88929
6	0	0	0	0,05	0,964286	0	0	0	0	0	0,049405	1	0	0	0	0	0	0,04680
7	0	0,068396	0	0	0	0,862103	0	0	0,066609	0	0	0	0,883929	0	0	0,066417	0	
8	0	0	0	0	0	0,078373	1	0	0	0	0	0	0,080357	0,930682	0	0	0	

IID Matrices SRKW

Orcinus orca (Killer whale) demography and population viability analysis (PVA) workflow

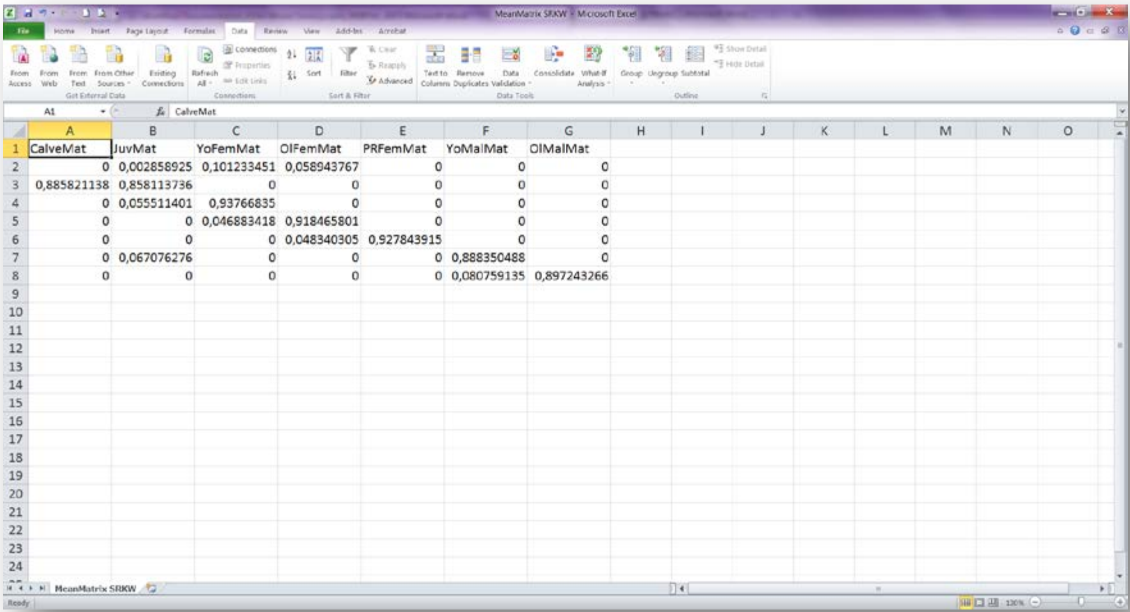
lambda from IID and VR random Population (csv): Stochastic population growth rate computed from IID matrices and from vital rates as random variables (see Input Port "ENVIR")



	lambda_stoch	lamda_VR_Random
Lamda	0,990907705	0,988438244
CI5	0,990788577	0,988159365
CI95	0,99112467	0,988759355

lambda from IID and VR random SRKW

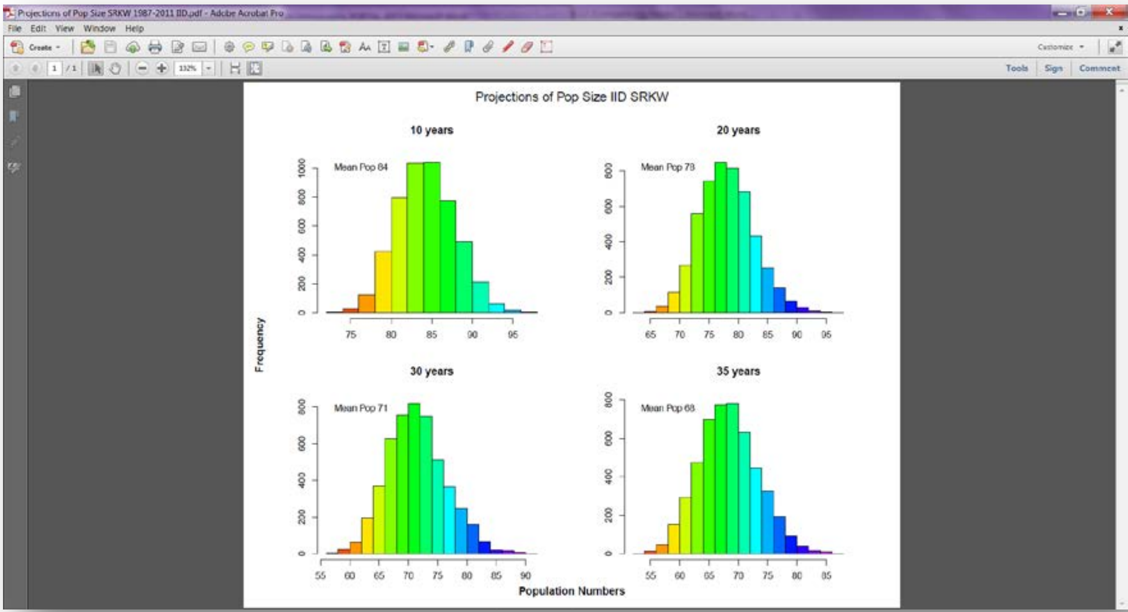
MeanMatrix Population (csv): Two-sex, stage structured matrix based on mean vital rate (survival and fecundity) values for the selected time period. A birth-flow matrix model is used with seven life stages and fixed transition probabilities based on stage duration (details in Vélez-Espino et al. 2014).



CalveMat	JuvMat	YoFemMat	OlFemMat	PRFemMat	YoMalMat	OlMalMat
0	0,002858925	0,101233451	0,058943767	0	0	0
0,885821138	0,858113736	0	0	0	0	0
0	0,055511401	0,93766835	0	0	0	0
0	0	0,046883418	0,918465801	0	0	0
0	0	0	0,048340305	0,927843915	0	0
0	0,067076276	0	0	0	0,888350488	0
0	0	0	0	0	0,080759135	0,897243266

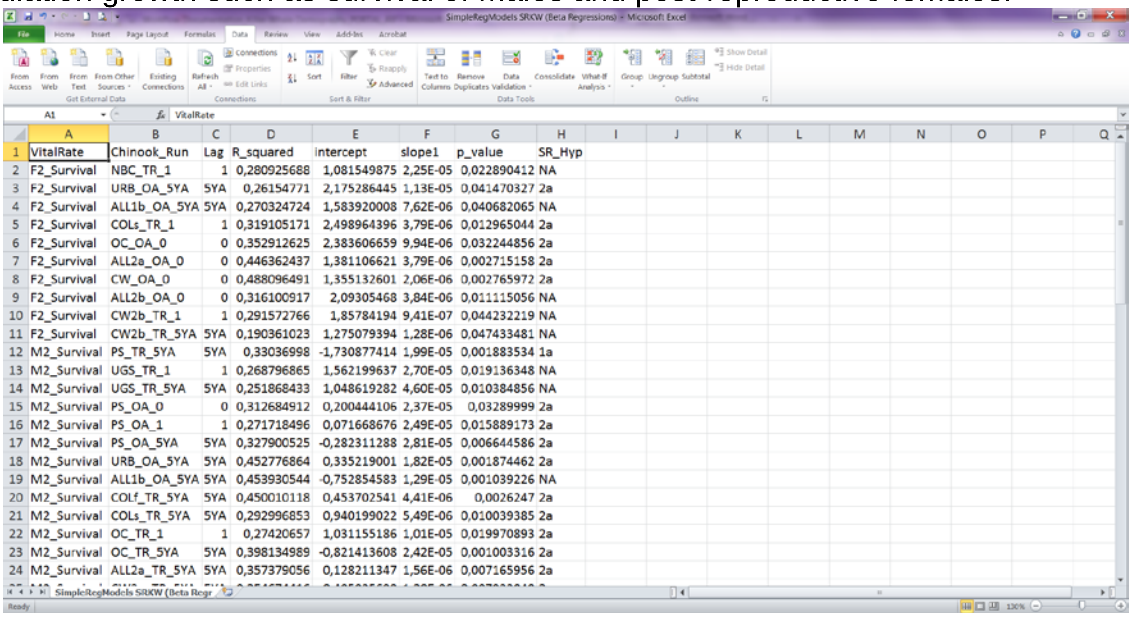
MeanMatrix SRKW

Projections of Pop Size Population Start year – End year IID (pdf): Graphical output showing frequency distributions for projections of population size at the four time horizons specified in Input Ports "Time_horizons_x". Along with stochastic population growth "Lambda_from_IID_and_VR_random", these outputs are the components of the analysis showing expected future population dynamics. Therefore, these two outputs can be seen as components of a PVA



Projections of Pop Size SRKW 1987-2011 IID

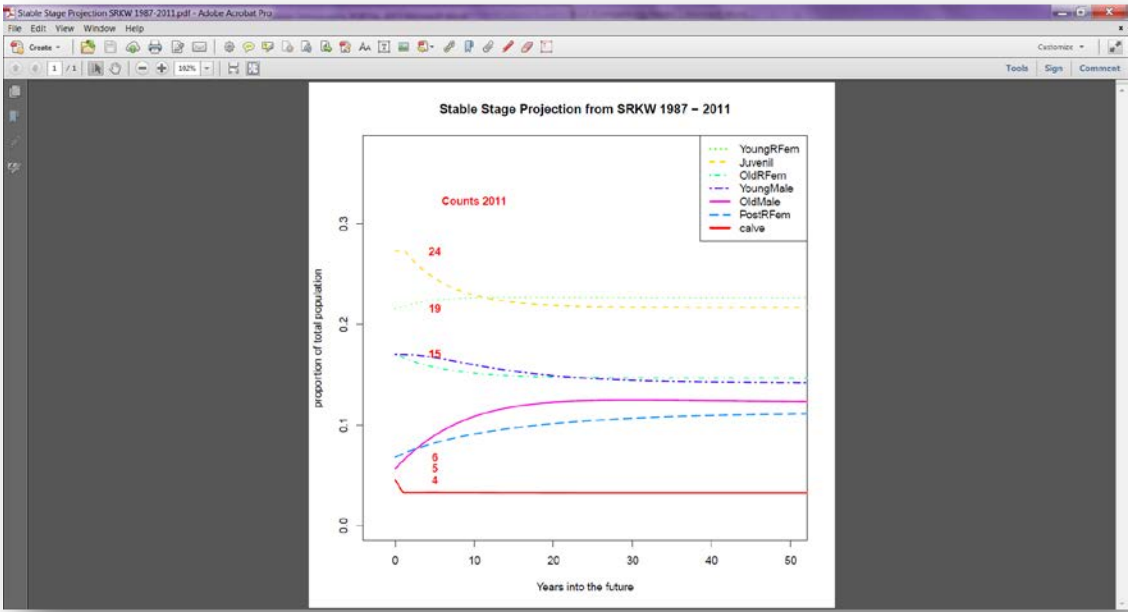
SimpleRegModels Population (Type of Regressions) (csv): Statistics for all significant regressions (beta or linear) between killer whale vital rates and Chinook salmon stocks. The list of regressions includes vital rates not contributing directly to population growth such as survival of males and post-reproductive females.



	A	B	C	D	E	F	G	H
1	VitalRate	Chinook_Run	Lag	R_squared	intercept	slope1	p_value	SR_Hyp
2	F2_Survival	NBC_TR_1	1	0,280925688	1,081549875	2,25E-05	0,022890412	NA
3	F2_Survival	URB_OA_5YA	5YA	0,26154771	2,175286445	1,13E-05	0,041470327	2a
4	F2_Survival	ALL1b_OA_5YA	5YA	0,270324724	1,583920008	7,62E-06	0,040682065	NA
5	F2_Survival	COLs_TR_1	1	0,319105171	2,498964396	3,79E-06	0,012965044	2a
6	F2_Survival	OC_OA_0	0	0,352912625	2,383606659	9,94E-06	0,032244856	2a
7	F2_Survival	ALL2a_OA_0	0	0,446362437	1,381106621	3,79E-06	0,002715158	2a
8	F2_Survival	CW_OA_0	0	0,488096491	1,355132601	2,06E-06	0,002765972	2a
9	F2_Survival	ALL2b_OA_0	0	0,316100917	2,09305468	3,84E-06	0,011115056	NA
10	F2_Survival	CW2b_TR_1	1	0,291572766	1,85784194	9,41E-07	0,044232219	NA
11	F2_Survival	CW2b_TR_5YA	5YA	0,190361023	1,275079394	1,28E-06	0,047433481	NA
12	M2_Survival	PS_TR_5YA	5YA	0,33036998	-1,730877414	1,99E-05	0,001883534	1a
13	M2_Survival	UGS_TR_1	1	0,268796865	1,562199637	2,70E-05	0,019136348	NA
14	M2_Survival	UGS_TR_5YA	5YA	0,251868433	1,048619282	4,60E-05	0,010384856	NA
15	M2_Survival	PS_OA_0	0	0,312684912	0,200444106	2,37E-05	0,03289999	2a
16	M2_Survival	PS_OA_1	1	0,271718496	0,071668676	2,49E-05	0,015889173	2a
17	M2_Survival	PS_OA_5YA	5YA	0,327900525	-0,282311288	2,81E-05	0,006644586	2a
18	M2_Survival	URB_OA_5YA	5YA	0,452776864	0,335219001	1,82E-05	0,001874462	2a
19	M2_Survival	ALL1b_OA_5YA	5YA	0,453930544	-0,752854583	1,29E-05	0,001039226	NA
20	M2_Survival	COLf_TR_5YA	5YA	0,450010118	0,453702541	4,41E-06	0,0026247	2a
21	M2_Survival	COLs_TR_5YA	5YA	0,292996853	0,940199022	5,49E-06	0,010039385	2a
22	M2_Survival	OC_TR_1	1	0,27420657	1,031155186	1,01E-05	0,019970893	2a
23	M2_Survival	OC_TR_5YA	5YA	0,398134989	-0,821413608	2,42E-05	0,001003316	2a
24	M2_Survival	ALL2a_TR_5YA	5YA	0,357379056	0,128211347	1,56E-06	0,007165956	2a

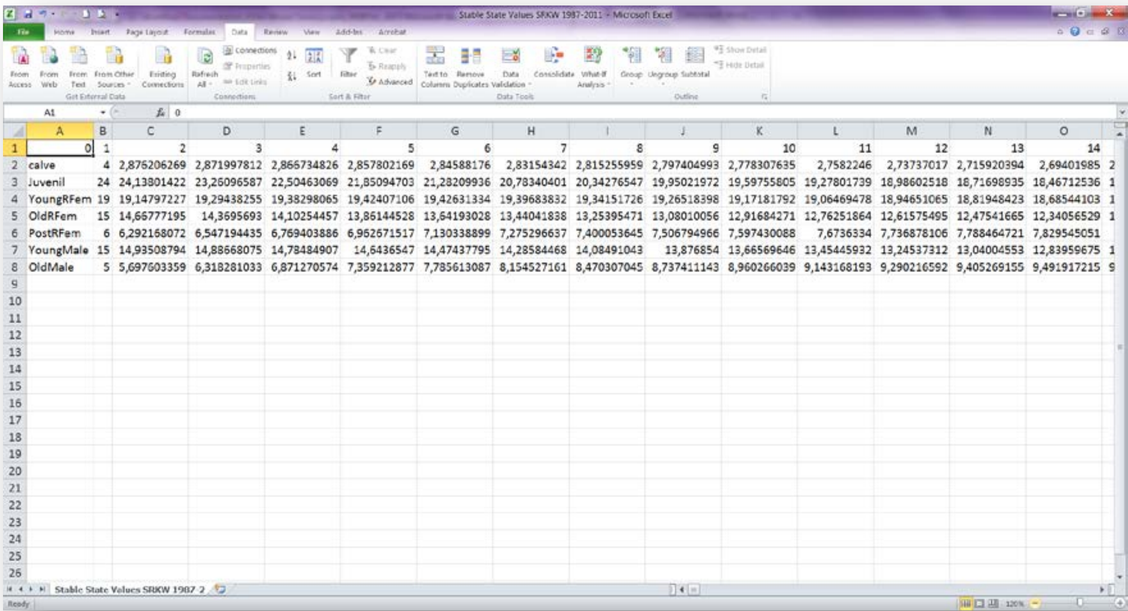
SimpleRegModels SRKW (Beta Regressions)

Stable Stage Projection Population Start year – End year (pdf): Graphical output showing the change in stage composition with time towards stable stage distribution. Initial values correspond to counts and proportions in the last year of the study



Stable Stage Projection SRKW 1987-2011

Stable State Values Population Start year – End year (csv): Long-term projections of population size by life stage based on transient dynamics.

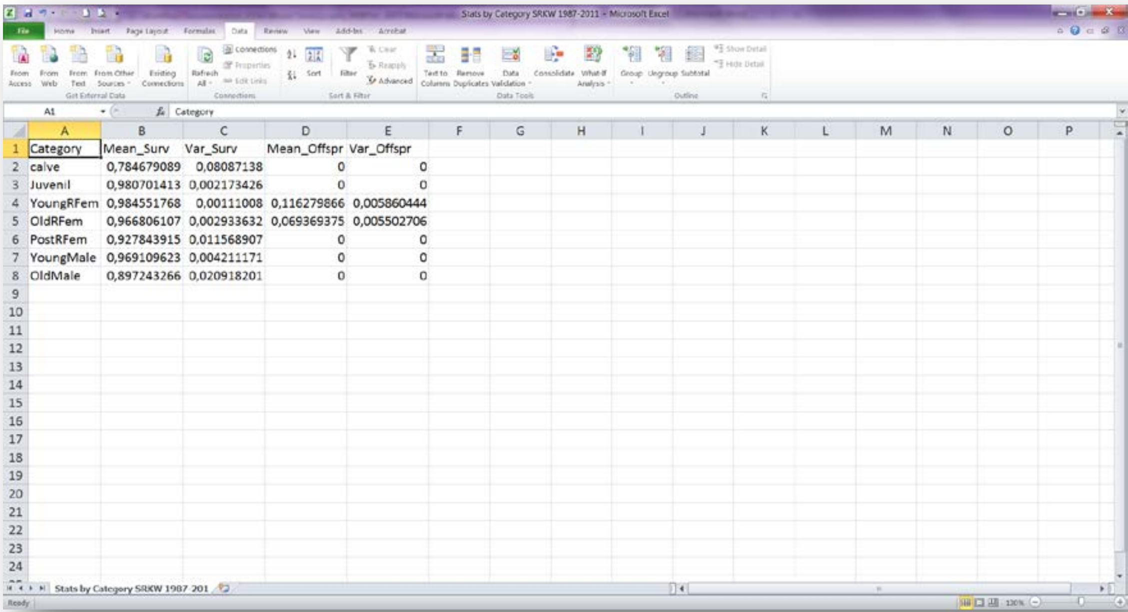


	A	B	C	D	E	F	G	H
1	0	1	2	3	4	5	6	7
2	calve	4	2,876206269	2,871997812	2,866734826	2,857802169	2,84588176	2,83154342
3	Juvenil	24	24,13801422	23,26096587	22,50463069	21,85094703	21,28209936	20,78340401
4	YoungRFem	19	19,14797227	19,29438255	19,38298065	19,42407106	19,42631334	19,39683832
5	OldRFem	15	14,66777195	14,3695693	14,10254457	13,86144528	13,64193028	13,44041838
6	PostRFem	6	6,292168072	6,547194435	6,769403886	6,962671517	7,130338899	7,275296637
7	YoungMale	15	14,93508794	14,88668075	14,78484907	14,6436547	14,47437795	14,28584468
8	OldMale	5	5,697603359	6,318281033	6,871270574	7,359212877	7,785613087	8,154527161

	I	J	K	L	M	N	O
1	8	9	10	11	12	13	14
2	2,815255959	2,797404993	2,778307635	2,7582246	2,73737017	2,715920394	2,69401985
3	20,34276547	19,95021972	19,59755805	19,27801739	18,98602518	18,71698935	18,46712536
4	19,34151726	19,26518398	19,17181792	19,06469478	18,94651065	18,81948423	18,68544103
5	13,25395471	13,08010056	12,91684271	12,76251864	12,61575495	12,47541665	12,34056529
6	7,400053645	7,506794966	7,597430088	7,6736334	7,736878106	7,788464721	7,829545051
7	14,08491043	13,876854	13,66569646	13,45445932	13,24537312	13,04004553	12,83959675
8	8,470307045	8,737411143	8,960266039	9,143168193	9,290216592	9,405269155	9,491917215

Stable State Values SRKW 1987-2011

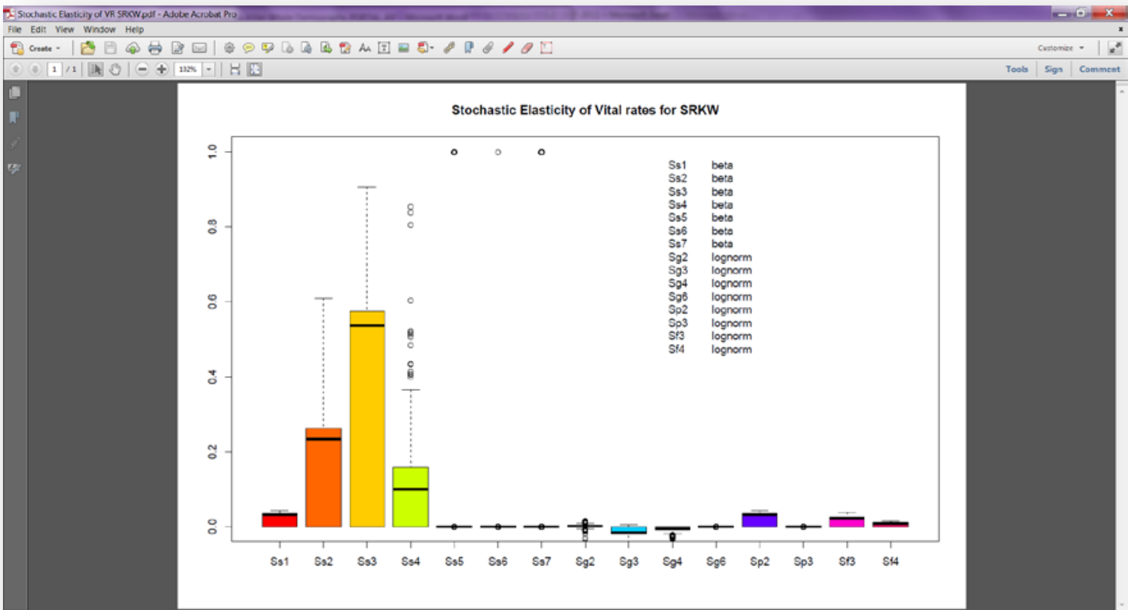
Stats by Category Population Start year – End year (csv): Mean and variance of vital rates (survival and fecundity) by life stage. Mean and variance generated from annual values during the selected time period are used to generate vital rate probability distributions (see “Stochastic_Vital_rates”).



Category	Mean_Surv	Var_Surv	Mean_Offspr	Var_Offspr
calve	0,784679089	0,08087138	0	0
Juvenil	0,980701413	0,002173426	0	0
YoungRFem	0,984551768	0,00111008	0,116279866	0,005860444
OldRFem	0,966806107	0,002933632	0,069369375	0,005502706
PostRFem	0,927843915	0,011568907	0	0
YoungMale	0,969109623	0,004211171	0	0
OldMale	0,897243266	0,020918201	0	0

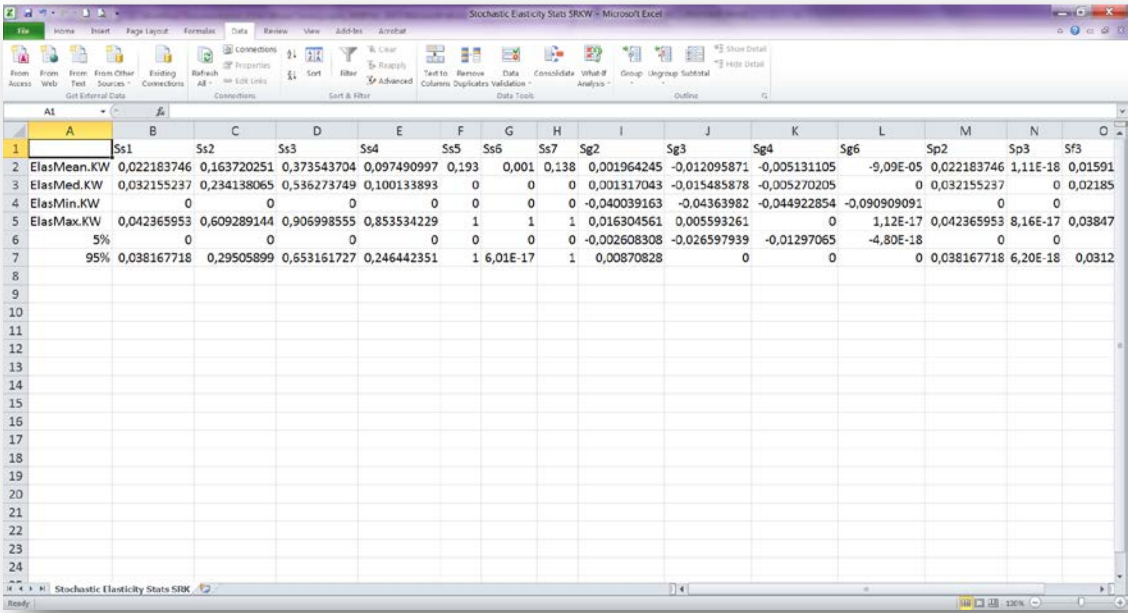
Stats by Category SRKW 1987-2011

Stochastic Elasticity of VR Population (pdf): Graphical output for stochastic elasticities of vital rates based on “Stochastic_Vital_rates”



Stochastic Elasticity of VR SRKW

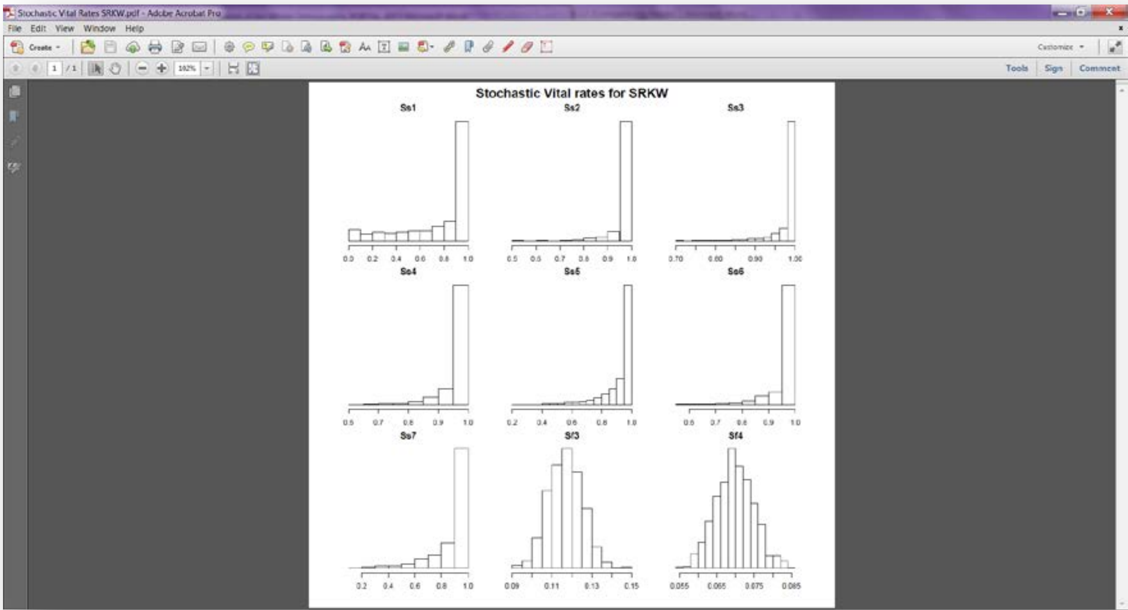
Stochastic Elasticity Stats Population (csv): Mean, median, minimum, maximum, and 95% confidence limits of stochastic elasticities of vital rates.



	Ss1	Ss2	Ss3	Ss4	Ss5	Ss6	Ss7	Sg2	Sg3	Sg4	Sg6	Sp2	Sp3	Sf3
ElasMean.KW	0,022183746	0,163720251	0,373543704	0,097490997	0,193	0,001	0,138	0,001964245	-0,012095871	-0,005131105	-9,09E-05	0,022183746	1,11E-18	0,01591
ElasMed.KW	0,032155237	0,234138065	0,536273749	0,100133893	0	0	0	0,001317043	-0,015485878	-0,005270205	0	0,032155237	0	0,02185
ElasMin.KW	0	0	0	0	0	0	0	-0,040039163	-0,04363982	-0,044922854	-0,090909091	0	0	
ElasMax.KW	0,042365953	0,609289144	0,906998555	0,853534229	1	1	1	0,016304561	0,005593261	0	1,12E-17	0,042365953	8,16E-17	0,03847
5%	0	0	0	0	0	0	0	-0,002608308	-0,026597939	-0,01297065	-4,80E-18	0	0	
95%	0,038167718	0,29505899	0,653161727	0,246442351	1	6,01E-17	1	0,00870828	0	0	0	0,038167718	6,20E-18	0,0312

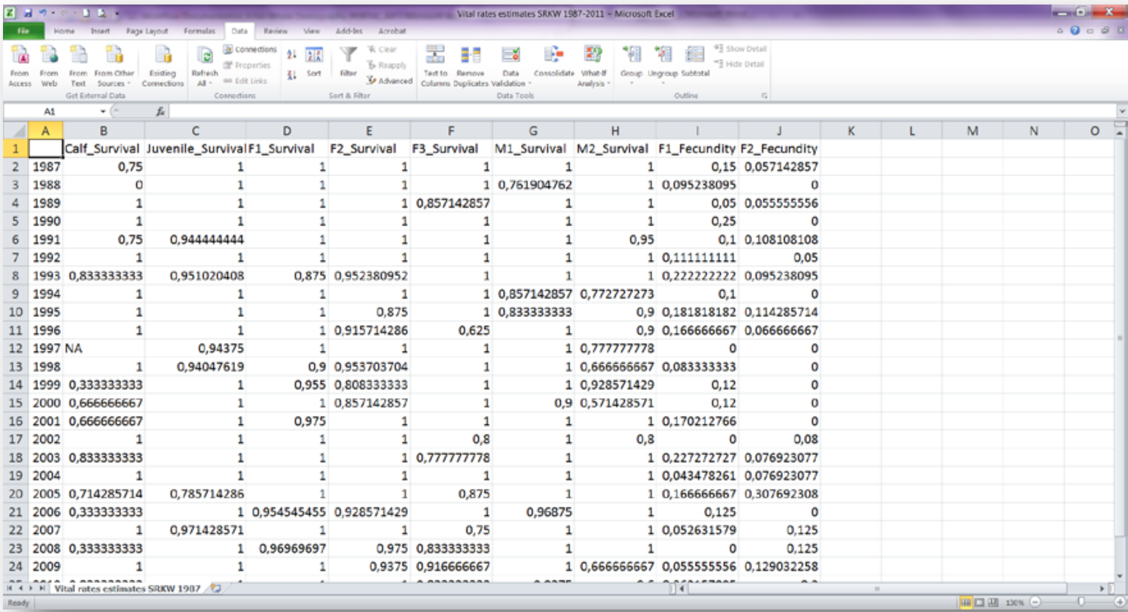
Stochastic Elasticity Stats SRKW

Stochastic Vital Rates Population (pdf): Graphical output for vital rate probability distributions. Beta distribution used for survival; lognormal distribution used for fecundity.



Stochastic Vital Rates SRKW

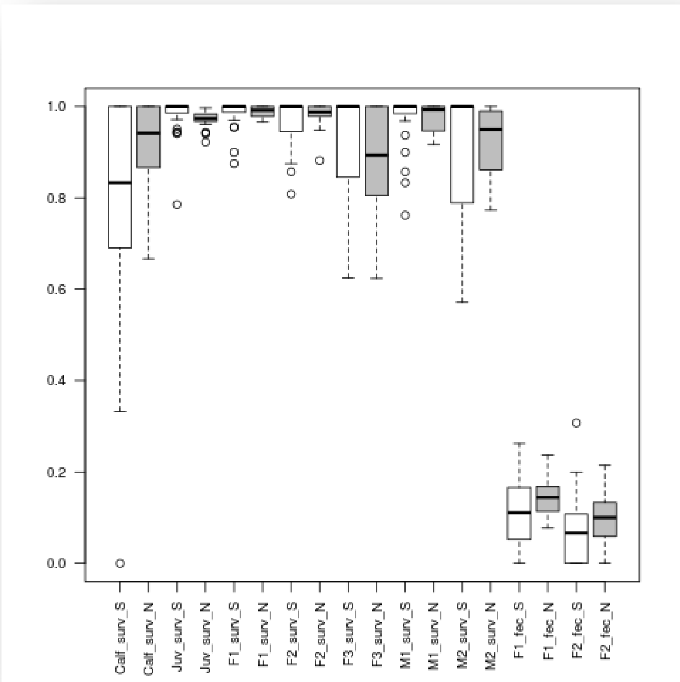
Vital rates estimates Population Start year – End year (csv): Vital rate (survival and fecundity) values by year and life stage through the selected time period



	Calf_Survival	Juvenile_Survival	F1_Survival	F2_Survival	F3_Survival	M1_Survival	M2_Survival	F1_Fecundity	F2_Fecundity
1987	0,75	1	1	1	1	1	1	0,15	0,057142857
1988	0	1	1	1	1	0,761904762	1	0,095238095	0
1989	1	1	1	1	0,857142857	1	1	0,05	0,055555556
1990	1	1	1	1	1	1	1	0,25	0
1991	0,75	0,944444444	1	1	1	1	0,95	0,1	0,108108108
1992	1	1	1	1	1	1	1	0,111111111	0,05
1993	0,833333333	0,951020408	0,875	0,952380952	1	1	1	0,222222222	0,095238095
1994	1	1	1	1	1	0,857142857	0,772727273	0,1	0
1995	1	1	1	0,875	1	0,833333333	0,9	0,181818182	0,114285714
1996	1	1	1	0,915714286	0,625	1	0,9	0,166666667	0,066666667
1997	NA	0,94375	1	1	1	1	0,777777778	0	0
1998	1	0,94047619	0,9	0,953703704	1	1	0,666666667	0,083333333	0
1999	0,333333333	1	0,955	0,808333333	1	1	0,928571429	0,12	0
2000	0,666666667	1	1	0,857142857	1	0,9	0,571428571	0,12	0
2001	0,666666667	1	0,975	1	1	1	1	0,170212766	0
2002	1	1	1	1	0,8	1	0,8	0	0,08
2003	0,833333333	1	1	1	0,777777778	1	1	0,227272727	0,076923077
2004	1	1	1	1	1	1	1	0,043478261	0,076923077
2005	0,714285714	0,785714286	1	1	0,875	1	1	0,166666667	0,307692308
2006	0,333333333	1	0,954545455	0,928571429	1	0,96875	1	0,125	0
2007	1	0,971428571	1	1	0,75	1	1	0,052631579	0,125
2008	0,333333333	1	0,96969697	0,975	0,833333333	1	1	0	0,125
2009	1	1	1	0,9375	0,916666667	1	0,666666667	0,055555556	0,129032258

Vital rates estimates SRKW 1987-2011

VR_combined (.png): Box plot with the survival and fecundity probabilities of each stage.



VR_combined

Orcinus orca (Killer whale) demography and population viability analysis (PVA) workflow

PostWorkspace (zip file): An R Workspace that transfers values from the main workflow to the post-processing workflow. This file must be provided as an input to the post-processing workflow (Orcinus orca (Killer whale) interaction with Chinook (Oncorhynchus tshawytscha) workflow) in order for it to have access to values generated in the main workflow.

4. References

This workflow was created using and based on Packages '*popbio'* in R. (Stubben & Milligan 2007; Stubben, Milligan & Nantel 2011), lattice and betareg.

Bigg MA, Olesiuk PF, Ellis GM, Ford JKB, Balcomb KC (1990) Social organizations and genealogy of resident killer whales (Orcinus orca) in the coastal waters of British Columbia and Washington State. Report of the International Whaling Commission, Special Issue 12:383-405

Brault S, Caswell H (1993) Pod-specific demography of killer whales (Orcinus orca). Ecology 74:1444-1454

Bruna EM, Oli MK (2005) Demographic effects of habitat fragmentation on a tropical herb: life table response experiments. Ecology 86:1816-1824

Caswell H (1989) The analysis of life table response experiments. I. Decomposition of effects on population growth rate. Ecological Modeling 46:221-237

Caswell H (2000) Prospective and retrospective perturbation analyses: their roles in conservation biology. Ecology 81:619-627

Caswell H (2001) Matrix population models: construction, analysis, and interpretation. Sinauer Associates, Inc. Publishers, Sunderland, Massachusetts

Cooch E, Rockwell RF, Brault S (2001) Retrospective analysis of demographic responses to environmental change: a Lesser Snow Goose example. Ecological Monographs 71:377-400

COSEWIC (2008) COSEWIC assessment and update status report on the killer whale Orcinus orca, Southern Resident population, Northern Resident population, West Coast Transient population, Offshore population and Northwest Atlantic / Eastern Arctic population, in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. (www.sararegistry.gc.ca/status/status_e.cfm)

Crouse DT, Crowder LB, Caswell H (1987) A stage-based population model for loggerhead turtles and implications for conservation. Ecology 68:1412-1423

Ford JKB, Ellis GM, Barrett-Lennard LG, Morton AB, Palm RS, Balcomb KC (1998) Dietary specialization in two sympatric population of Killer Whales (Orcinus orca) in coastal British Columbia and adjacent waters. Canadian Journal of Zoology 76:1456-1471

Ford JKB, Ellis GM, Balcomb KC (2000) Killer whales: the natural history and genealogy of Orcinus orca in British Columbia and Washington State, second ed. UBC Press, Vancouver, British Columbia

Ford JKB (2006) An assessment of critical habitats of resident killer whales in waters off the Pacific Coast of Canada. CSAS Research Document 2006/ 72

Ford JKB, Wright BM, Ellis, GM, Candy JR (2010a) Chinook salmon predation by resident killer whales: seasonal and regional selectivity, stock identity of prey, and consumption rates. DFO Canadian Science Advisory Secretariat Research Document 2009/101

Ford JKB, Ellis GM, Oleisuk PF, Balcomb KC (2010b) Linking killer whale survival and prey abundance: food limitation in the oceans' apex predator? Biology Letters 6:139-142

Ford MJ, Hanson MB, Hempelmann JA, Ayres KL, Emmons CK, Schorr GS, Baird RW, Balcomb KC, Wasser SK, Parsons KM, Balcomb-Bartok K (2011) Inferred paternity and male reproductive success in a killer whale (Orcinus orca) population. Journal of Heredity doi: 10.1093/jhered/esr067

Haridas CV, Tuljapurkar S (2007) Time, transients and elasticity. Ecology Letters 10:1143-1153.

Krahn MM, Ford MJ, Perrin WF, Wade PR, Angliss RB, Hanson MB, Taylor BL, Ylitalo GM, Dahlheim ME, Stein JE, Waples RS (2004) 2004 Status review of Southern Resident Killer Whales (Orcinus orca) under the Endangered Species Act, U.S. Dept. of Commerce, NOAA Tech. Memo., NMFS-NWFSC-62

Lefkovitch LP (1971) Some comments on the invariants of population growth, in: Patil GP, Pielou EC, Walters WE (Eds.). Statistical Ecology, Volume 2. Pennsylvania State University Press, Pennsylvania, pp. 337-360.

Levin LA, Caswell H, Bridges T, DiBacco C, Cabrera D, Plaia G (1996) Demographic response of estuarine polychaetes to pollutants: life table response experiments. Ecological Applications 6:1295-1313

NMFS (2008) Recovery Plan for Southern Resident Killer Whales (Orcinus orca). National Marine Fisheries Service, Northwest Region, Seattle, Washington.

Olesiuk PF, Bigg MA, Ellis GM (1990) Life history and population dynamics of resident killer whales (Orcinus orca) in the coastal waters of British Columbia and Washington State. Report of the International Whaling Community, Special Issue 12:209-243

Vélez-Espino, L.A., John K.B. Ford, Eric Ward, Chuck K. Parken, Larrie LaVoy, Ken Balcomb, M. Bradley Hanson, Dawn. P. Noren, Graeme Ellis, Tom Cooney, and Rishi Sharma. 2013. Sensitivity of resident Killer Whale population dynamics to Chinook salmon abundance. Completion Report, Pacific Salmon Commission, Southern Boundary Restoration and Enhancement Fund, Vancouver BC. 191 p.

Vélez-Espino, L.A., Ford, J.K.B., Araujo, H.A., Ellis, G., Parken, C.K, & Balcomb, K. Comparative demography and viability of northeast Pacific resident killer whale populations at risk. Can. Tech. Rep. Fish. Aquat. Sci. 3084: vi + 56 p.

Vélez-Espino, L.A., John K.B. Ford, H. Andres Araujo, Graeme Ellis, Charles K. Parken and Rishi Sharma. *In Press*. Relative importance of Chinook salmon abundance on resident killer whale population growth and viability. Aquatic Conservation: Marine and Freshwater Ecosystems.

Ward EJ, Parsons K, Holmes EE, Balcomb KC, Ford JKB (2010) The role of menopause and reproductive senescence in a long-lived social mammal. Frontiers in Zoology 6:4, doi:10.1186/1742-9994-6-4

Zuidema PA, Franco M (2001) Integrating vital rate variability into perturbation analysis: an evaluation for matrix population models of six plant species. Journal of Ecology 89:995-1005

5. Authors

1. ***L. Antonio Vélez-Espino*** Fisheries and Oceans of Canada, BC, Canada (Nanaimo).
2. ***H. Andres Araujo*** Fisheries and Oceans of Canada, BC, Canada (Nanaimo).
3. ***Maria Paula Balcazar-Vargas*** Instituut voor Biodiversiteit en Ecosysteem, Dynamica (IBED), Universiteit van Amsterdam.
4. ***Jonathan Giddy*** Cardiff School of Computer Science and Informatics, Cardiff, University, Cardiff CF24 3AA, United Kingdom.