

BioVeL – Biodiversity Virtual e-Laboratory

Workflow Documentation

Killer whale demography workflow Portal execution

September 2014

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

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





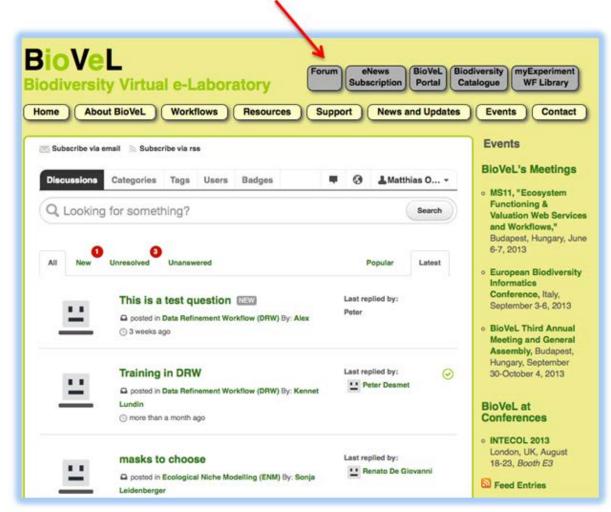
Killer whale demography workflow

Contents 1. Sources of help	3
Killer whale demography	4
2. Input files for tutorial	4
2.1 Input data	4
2.1 Related publications	6
3. Tutorial:	7
3.1 Input Ports	10
3.1.1 Data	10
3.1.2 Parameters	11
3.3 Outputs	12
3.3.1 Results	13
4. References	25
5. Authors	26

1. Sources of help

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

- 1) From the BioVeL documentation website, here: <u>https://wiki.biovel.eu/x/BIBp</u>
- By using the BioVeL community discussion Forum on our website, <u>www.biovel.eu</u>. 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

Killer whale demography

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, two input files are used.

2.1 Input data

To download click here on the file name or they can be downloaded at myExperiment (<u>http://www.myexperiment.org/packs/667.html</u>):

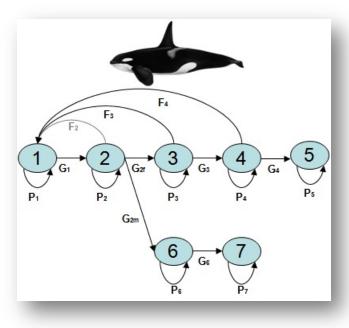
Orcinus orca input data:

- <u>NRKW_R</u> or <u>SRKW_R</u>
- <u>VR_combined</u>

<u>NRKW_R</u> or <u>SRKW_R</u>: 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 \geq 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.

Ceres	From From From O Web Test Source Got External Cat	her Existing Rat	Connection	6 21 22 The Sect A	S Advanced Col	umm Dupicates Valcla	Aa Consolidate Wh dion - Anal a Toolo	192	93 Show De ⇒3 Hote Det p Subtotal Outline	nai bal				
_	A1 • (*					11	1							
1	A	В			E	F	G	Н	I.	J	K	L	M	N-
	and the owner of the	•		Offspring										
2	1973	1		NA	Juv									
3	1973	2			Juv									
4	1973	3			Juv									
5	1973	4		NA	Juv									
6	1973	5		NA	Juv									
7	1973	6		NA	Juv									
8	1973	7		NA	Juv									
9	1973	8		NA	Juv									
10	1973	9 5	10 Th	NA	Juv									
11	1973	10			Male									
12	1973	10 0			Female									
13	1973	11			Male									
14	1973	11 (Female									
15	1973	12			Male									
16	1973	12 0			Female									
17	1973	13			Male									
18	1973	13	0	0) Female				4					

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.

From	n From From		ing Rafrich Al -	Data Review Connections 21 Properties Sidk Leaks \$1 octions		Advanced	a Branove Da		What # What # Group 1		Show Detail Hitle Detail				۵	0 a 2
-	A1		Call surv S		Serie R. Coller					- State II						
	A	В	C	D	E	F	G	н	1	1	к	L	M	N	0	P
	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_
	0,75	1	1	0,993055556	1	1	1	0,970238095	1	0,785714286	1	1	1	1	0,15	0,23684
i.	0	0,857142857	1	0,992647059	1	1	1	0,882051282	1	0,875	0,761904762	1	1	1	0,095238095	0,16470
	1	1	1	0,985078053	1	1	1	1	0,857142857	1	1	1	1	0,974358974	0,05	0,08695
i.	1	1	1	0,973611111	1	1	1	0,948412698	1	0,857142857	1	0,948412698	. 1	0,897435897	0,25	0,1485
5	0,75	0,983333333	0,94444444	0,980298637	1	0,991656667	1	0,987179487	1	0,957380952						0,1443
1	1	1	1	0,941024029	1	0,99	1	1	1	0,9125	1	0,944444444	1	0,909863946	0,111111111	0,1176
3	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	0,0925
)	1	1	1	0,960858294	1	1	1	0,969387755	1	0,967320261	0,857142857	1	0,772727273	0,995192308	0,1	0,1621
0	1	0,857142857	1	0,966741871	1	1	0,875	0,988095238	1	0,824242424	0,833333333	1	0,9	0,985294118	0,181818182	0,0877
1	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	0,1152
2	NA	0,846153846	0,94375	0,970779221	1	0,989472728	1	0,985185185	1	0,939068101	1	0,999029514	0,77777778	0,818796992	0	0,2062
3	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	0,1202
4	0,333333333	1	1	0,983004386	0,955	0,970654319	0,808333333	0,979259259	1	0,689618332	1	0,97963928	0,928571429	0,773148148	0,12	0,1130
5	0,666666667	0,666666667	1	0,922341721	1	0,97	0,857142857	0,9666666667	1	0,875	0,9	0,941666667	0,571428571			0,0774
6	0,666666667	0,875	1	0,969405594	0,975	0,986749049	1	1	1	1	1	0,989015278	1	0,9375	0,170212766	0,1156
7	1	0,9	1	0,97092803	1	1	1	1	0,8	1	1	0,944444444	0,8	0,941176471	0	0,1186
8	0,833333333			0,994565217	1	1	1	1	0,777777778	0,9375	1	1	1	1	0,22727272727	0,0780
9	1	0,971428571	1	0,979707792	1	1	1	0,986111111	1	0,875	1	1	1	1	0,043478261	0,2015
0	0,714285714	0,875		0,94407994		0,969009158		0,981481481	0,875	0,75	1	0,997693316	1	0,921052632	0,1666666667	0,1975
1	0,3333333333			0,973996887								0,942875078		0,98245614		0,2179
2			0,971428571	0,9841536		0,972785639						0,916666667			0,052631579	0,1686
3	0,333333333	0,764705882			0.96959697	0,993197279			0,833333333		1	0,96969697	1	0,825396825	0	0,1770
4	1			0,978250916		0,992592593			0,916666667			0,962121212				
	0,833333333			0,976678475		0,970899471			0,833333333			0,981818182	0,6	0,979166667		
6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0,052631579	0,1139
7																
8																
9																
4	+ H VR comb	ined to								14						

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. 2014. 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. 2014. Relative importance of Chinook salmon abundance on resident killer whale population growth and viability. Aquatic Conservation: Marine and Freshwater Ecosystems. Article first published online: 21 AUG 2014. DOI: 10.1002/aqc.2494

3. Tutorial:

This workflow analyses the demography and population growth of resident killer whale populations. Originally created for comparative studies of North-eastern Pacific populations at risk, Southern Resident Killer Whales (SRKW) and the Northern Resident Killer Whales (NRKW), the workflow can be used for other killer whale populations or cetaceans counting with census data and life cycles that can be represented using the matrix models described in this document.

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

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).

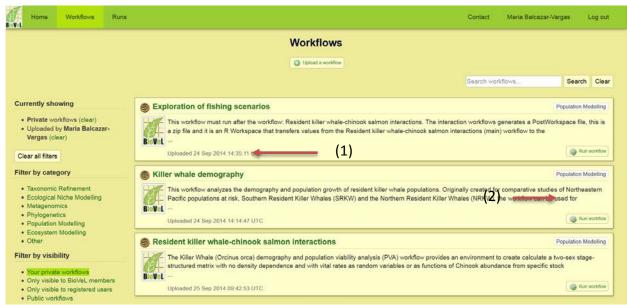
Two distinct populations of resident killer whales (Orcinus orca) in the north-eastern Pacific Ocean have been identified in Canada and the U.S. as being of conservation concern. The Southern Resident Killer Whale (SRKW) population is currently listed as endangered under the U.S. Endangered Species Act 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 prev availability, particularly Chinook salmon abundance levels and (Oncorhvnchus 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.

In your browser (preferably Firefox or Chrome) navigate to the <u>BioVeL Portal</u> page (<u>http://portal.biovel.eu</u>/) 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 *Killer whale demography* (1) you can also directly run the workflow using the 'Run workflow' button at the bottom-right (2).

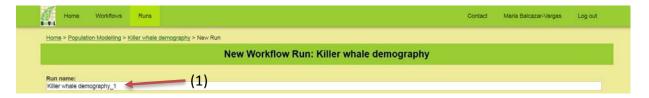


On the resulting page click on the 'Run Workflow' button at the top (1).

Killer whale demography workflow

A BOY	Home	Workflows	Runs						Contact	Maria Balcazar-Vargas	Log out
	Home > Pop	ulation Modelling	> Killer whale demograph	ý							
					Killer	whale demo	graphy				BUVI
		(1)	\longrightarrow	🚳 Run workflow 🛛 🎍 I	Download workflow	Add to Favourites	Janage workflow	O Upload new version			
	Visibility: P	rivate 🔒							F	Related runs	
	🔜 View on	myExperiment								None	
	populations populations This workflor Vital rates Construct Eigen ana	s at risk, Southerm s or cetaceans co ow perform the fo s estimation and p ion of Birth-flow M slysis analysis (determin	demography and population resident Killer Whales (S unting with census data ar illowing analyses: probability distributions Matrix Model nistic and stochastic)	SRKW) and the Northern	Resident Killer	Whales (NRKW), the	workflow can be u	used for other killer wha			
			ma workbench, the users r lattice, betareg, Formula a			Service plugin in Ta	verna. The workflow	/ also requires an Rserv	/e		
			ated by the Biodiversity Vir ca/index-eng.html). BioVe					ins of Canada, BC, Can	ada.		
	Related pul	blications									
	Rishi Sharr	na. 2013. Sensitiv	 Ford, Eric Ward, Chuck vity of resident Killer What tion and Enhancement Fu 	e population dynamics to	o Chinook salmo						

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. *Killer whale demography_1*).



3.1 Input Ports

3.1.1 Data

<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. Here, two files can be used as input: SRKW_R.csv **or** NRKW_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.

b	10. 7	<u>0</u> =	1000		-		4	-	5	RKW_R -	Microsoft 8	anet .		100	-					- 0	×
H	Home I	insett Page	Layour		Data Revie															a 🕢 o	9 E
From	From From s Web Text	From Other Sources *	friday.		Connections Thopentics Collectures	24 (2.5) 34 Son		The Clean To Pencerty Se Advanced	Text to Column		Data Validation	Consolidat	Mue di Analysis -	Group Ung	roup Subto	1 *1 thows "I thick D end	etail				
	Get loda	ensal Data		.co	nhectors.		Sert & Fits	er			Data Too	8			Outline		Gi .				_
_	A1	• (*	fer Ye		200	-	-				1.10			1 0			1 10.555	17 023		100	
4	A	В			D	E		F		G	н		18	1		K	L	M	1	N	-
	Year	Age			Offsprin	and the second se															-1
2	1973		1		NA	Juv															
3	1973		2		NA	Juv															
4	1973		3		NA	Juv															
5	1973		4		NA	Juv															
6	1973		5		NA	Juv															
7	1973		6		NA	Juv															
8	1973		7		NA	Juv															
9	1973		8		NA	Juv															
10	1973		9		NA	Juv															
11	1973		10		NA	Male															
12	1973		10			0 Fema															
13	1973		11			Male															
14	1973		11			0 Fema															
15	1973		12			Male															
16	1973		12			0 Fema Male															
17	1973		13	100	1	1000															
18	1973		13 14			0 Fema Male															
19 20	1973																				
20	1973		14			Male															
	1973		15 15																		
22	1973		15		NA	0 Fema Male															-1
11	F SRKW R	12	in i		N/A	Male							4	.11				(MARK)	1 185 (-)		۶Ē

fome > Population Modelling > Killer whale democ	Indhith > mem creat				
	New Workflow I	Run: Killer whale demography	/		
tun name: Glier whale demography_1					
Data					2
KWDataFile 🕕	(1)	File Upload			
	Or select a file Browse No file selected.	Organize • New folder	VERNA + WF Jon + PACK +	Ap Search PACK	
VR_combined_csv () Enter input here	Or select a file Browse No file selected.	A pownloads Downloads Destop Destop Decements More Recent Places Destop Decements More Recent Places Documents More Recent Places More Recent Place	(2)	Date modified 47747942 1435 15-12-2012 1755 15-12-2012 1755 29-11-2012 1633 23-11-2012 1445 30-11-2012 1528 29-11-2012 1127 29-11-2012 1129 20-6-2014 2223 6-11-2013 1353	Type micro Micro Micro Micro Micro Micro Micro Micro Micro

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

The example value is automatically entered in	he box below. Click to edit or enter a new value directly or choose a file.	
2011 (1)	Or select a file Browse No file selected	
Population ()		
The example value is automatically entered in	he box below. Click to edit or enter a new value directly or choose a file.	
SRKW	Or select a file Browne No file selected	
Sims 🕦		
The example value is automatically entered in	he box below. Click to edit or enter a new value directly or choose a file.	
10000	Or select a file Browse No file selected.	
Standr_Data 🔞		
The example value is automatically entered in	he box below. Click to edit or enter a new value directly or choose a file.	
NO	Or select a file Browne No file selected	
StartYear 📵		
The example value is automatically entered in	he box below. Click to edit or enter a new value directly or choose a file.	
1967	Or select a file. Browse. No file selected.	

EndYear: Last year to be considered in the analysis.

e.g.: 2011

population: It is the name of the analysed population.

e.g.: SRKW

<u>Sims</u>: 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

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** to carry out the analyses.

3.3 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 the PostWorkspace, a zip file that is needed to run the second workflow: Exploration of fishing scenarios workflow.

Home Workflows Runs	Q	ontact Maria Balcazar-Vargas Log out
Run was successfully created.		6
Home > Population Modelling > Killer whale de	mography > Killer whale demography_1	
	Killer whale demography_1	<u>í</u>
	🔹 Download at results 📝 Manage run 🗙 Delete	Bio
ame: Killer whale demography_1	Save	
Visibility: Private 🔒		
Norkflow: Killer whale demography	Created at: 11 Sep 2014 16:14:39 UTC	
Category: Population Modelling	Started at: 11 Sep 2014 16:14:41 UTC	
Status: Finished	Finished at: 11 Sep 2014 16:16:30 UTC	
Outputs		(8
Jump to:		
Results: zipFile		
Results (1)		
zipFile () (application/zip)	(1	Download value
Sorry but we cannot show this type of contra	ant in the browser. Please download it to view it on your local machine.	

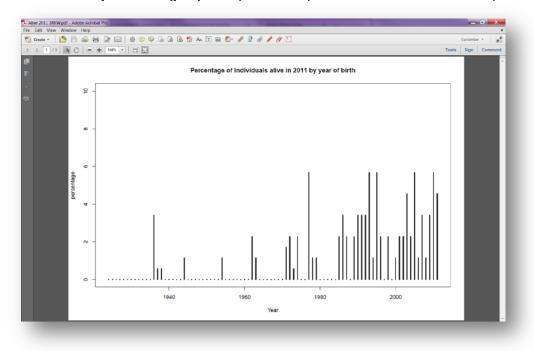
3.3.1 Results

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.

an arm arm	Web Tex	s From Other Sources -	Easting Cornections	Retresh All	Lois S	Sort 18	the company	Text to Remo	the state			Cingroup Subtr	and a second				
	Al	• (*	fe Ye		<u>u</u>	361.6	Pater -		Data 100	3		Quarte		- UK			-
1	A	В			E	F	G	н	1	1	К	L	M	N	0	Р	Q
1 1		Percentage		0	-		0				n.				ÿ		ч
2		4,545455															
3		5,681818															
4		3,409091															
5	2008	1,136364															
6		3,409091															
7	2006	1,136364															
8	2005	5,681818															
9	2004	2,272727															
10	2003	4,545455															
11	2002	2,272727															
12	2001	2,272727															
13	2000	1,136364															
14	1999																
15	1998	2,272727															
16	1997																
17	1996	2,272727															
18	1995	5,681818															
19	1994	1,136364															
20		5,681818															
21		3,409091															
22		3,409091															
23		3,409091															
24		2,272727															
25	1988																
26		2,272727															
27	1986	3.409091 011 SRKW	12								4			-8			1 10
Ready		or contain	-								1.53				111 121 146 1	105 (F)	0 (

Alive 2011 SRKW.csv

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



Alive 2011 SRKW.pdf

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

	Tom From From Other Web Test Sources - Correcti Get Editorial Data	a Retresh	Connections 11 () Properties Edit Unics		The Chever To Presignly See Advanced	Text to Remo Columns Duplic	NV Data	Consolidate A	Kan H Mue H Wyss - Group	Cuttine	2 thdy Detail					
	01 • fr															4
4	A B	с	D	E	F	G	н	1	J	К	L	M	N	0	P	C.
1 Ca	2Names nlastYear pr	opLastYear	The state of the second													
2 3 4	1 calve	4	0,045454545													
3	7 OldMale	5	0,056818182													
4	5 PostRFem	6	0,068181818													
5	4 OldRFem	15	0,170454545													
5	6 YoungMale	15	0,170454545													
7	3 YoungRFem	19	0,215909091													
8 9 10	2 Juvenil	24	0,272727273													
9																
LO																
1																
2																
13																
14																
15																
.6																
7																
8																
9																
0																
1																
2																
13 14 15																
14																
15																
7	Counts and Proportions TO	CDWW PT							14			4				. T

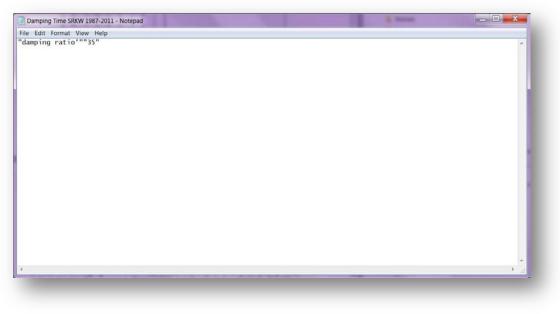
Counts and Proportions T0 Population Start year-End year (csv)

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

00890	Web Ted Git E	From Oth Sources derral Data	Come	form All	eth	2. 3	III II I	- Reapply Ter	to Remove		attbildate.	What W codysis	Clegroup Subl Outline	1 *3 Show De *3 Hide Det Hide							
4	A	• (* B	Ja (Year	D	E	F	G	н	1	1	к	1	М	N	0	P	Q	R	S	1
Ye		calve	Juver					oungMal Ol		otal KW		, A	-								
	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											
5	1991		4	23	20	18	6	9	10	90											
7	1992		3	25	18	20	7	9	9	91											
3	1993		6	26	18	21	7	10	9	97											
	1994		2	25	20	18	9	9	11	94											
C	1995		6	21	22	17	9	11	9	95											
1	1996		5	25	24	15	10	9	9	97											
2	1997		0	30	24	13	7	9	8	91											
3	1998		2	26	24	12	7	10	7	88											
1	1999		3	23	25	11	8	9	6	85											
5	2000		3	21	25	9	8	11	5	82											
5	2001		3	20	23	9	8	13	3	79											
7	2002		2	17	21	12	8	15	4	79											
8	2003		6	17	22	13	8	15	3	84											
9	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											
2	2007		3	18	19	16	9	15	6	87											
5	2008		3	20	19	16	8	15	6	88											
1	2009		3	20	18	15	8	15	6	86											
5	2010		6	21	19	15	7	15	5	88											
5	2011		4	24	19	15	6	15	5	88											1.1

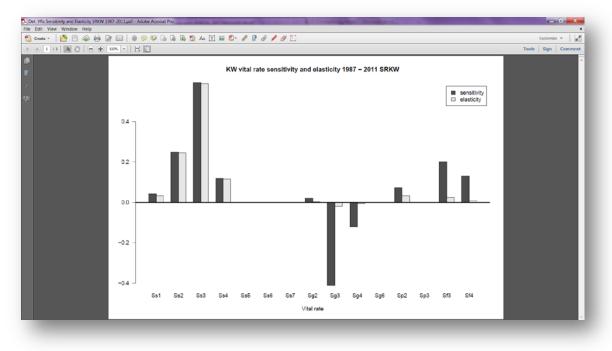
Counts by Year SRKW 1987-2011

Damping Time Population Start year-End year (txt): Damping time (*t*) 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.



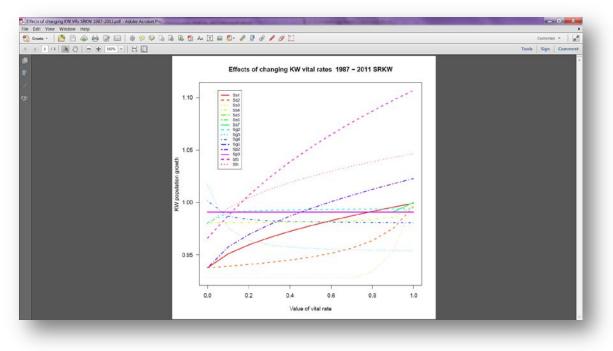
Damping Time SRKW 1987-2011

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.

110		biert Pag			Renew V	Ann Add-Ini	Acrebat		1092914	DORE OF THE	and the second	-								
	n From Fr So Web T Ga	rem From Other Text Sources - It External Data	Existing Connections	Bafresh All - = Edit Connection	ections 21 (renties £1) tinks £1)	Sort & Fil	Th Coar To Reapply To Advanced an	Text to Remove Columns Duplicate	Data Costa Too	Consolidate A	nhut-M Group	Vill 1	*3 Show Det *3 Hidt Det al	ui al						
	A1	• (*	Le Slan	voda1																
	A		С	D	E	F	G	н	1	J	K	L	M	N	0	Ρ	Q	R	S	
	Slambda																			
		0,99083																		
	Sstable.s																			
5	[1]	0,032505	0,216957	0,226552	0,146781	0,112653	0,142007	0,122545												
5																				
	Ssensitivi																			
		CalveMat																		
	[1,]	0,036766	0,21939	0,22909																
	[2,]	0,036766	0,2454	0																
	[3,]	0	0,57539	0,50083	0															- 1
	[4,]	0	0	0,18661																
	[5,]	0	0	0																
		0			0		-													
	17,1	0	0	U	0	0	0	0												
	Selasticit	de c																		
	Selasticit		lunddat	VoEamMa	OlEemMat	DREamMa	VoMalMat	OlMalAdat												
		O																		
		0,032869																		
		0,032003																		
	14.1	0	0	0.00002																
	[5,]	0	0	0,00000																
	[6,]	0	0	0																
	[7.]	0	0		0	1														
	1-11		1		1		-													
		n Analysis 😰										14								100
	¥.																(SHI L)	1 20 120 N (-		9

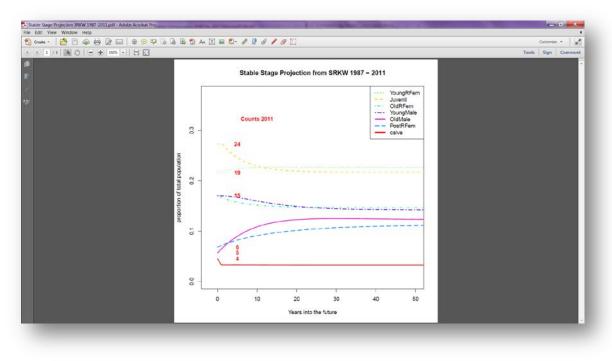
Eigen Analysis (opens in excel)

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).

-	r From From From	other hiding	Connections of Respectuses all a Respectuses	24 <u>25</u> 7 24 sort sine	The Chean and Colored Colored	o Korsow Cata	Consolidate Whard Analysis - In	Nroup Lings	sp Subtracel	hov Detail Ide Detail						
	Get External	Data	Correctors	Sort & Fi	ker	Data Too	h .		Outire	.6						
	A1 •	Je Colv	eMat											-	_	~
4	A						G	н	1.10	1	К	L	M	N	0	-
						YoMalMat 0	O MaiMat 0									
6		0,002858925														
5	0,885821138	0,858113736	0 000700000	0	0	0										
	0	0,055511401	0,93766855	0.010465001	0	0										
5																
7	0	0,067076276	0	0,048540505	0,927843913	0,888350488	0									
	0	0,007070270	0	0	0	0,080759135	0 897243266									
8 9 .0			, č	, in the second s		0,000733235	0,007245200									
0																
1																
2																
13																
4																
5																
.6																
7																
8																
9																
0																
1																
2																
3																
4																
	MeanMatrix	SRXW 2							141			10.2				10
é.	7.												(HP)	1 LUI 132% (C)		

MeanMatrix SRKW

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

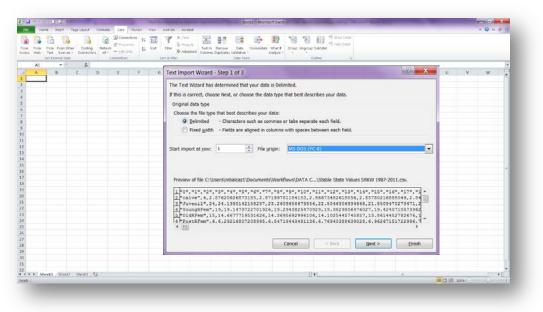
Stable State Values Population Start year – End year (csv): Long-term projections of population size by life stage based on transient dynamics.

Note: If the user used \geq 1850 <u>Sims</u>, you need to open the file as follows:

- 1. Open excel (versions 2007 onwards)
- 2. Go to Data tab
- 3. Click on From text (red oval)
- 4. Open the Folder where the file Stable State Values SRKW 1987-2011.csv is.
- 5. Import the file Stable State Values SRKW 1987-2011.csv (green oval).

Image: Stable State Image:	A CONTRACTOR OF A CONTRACTOR OFTA CONTRACTOR O		e) x
A C D F H F F H F	Home Ing Appe Layout Formulati Data Ferreir View Add-Ins Acrobat	• •	000
Al C D I F G H I C D I F G H I C D I F G H I C D C D I F G H I C D C D C D I F G H I C D C D C D C D C D C D C D C D C D C	The second		
A B C D F G H 1 Image: Antonio Vetez: Espino WF Text, WF_DEmografia, 2014-09-10 4-y Sourch Text WF_DEmogr. P Organize New folder Image: Antonio Vetez: Espino WF Text, WF_DEmografia, 2014-09-10 4-y Sourch Text WF_DEmografia, 2014-09-10 Arrange by: Folder Image: Antonio Vetez: Espino WK New folder Image: Antonio Vetez: Espino New folder Image: Antonio Vetez: Espino Arrange by: Folder * Image: Antonio Vetez: Espino Image: Antonio Vetez: Espino Image: Antonio Vetez: Espino Arrange by: Folder * Image: Antonio Vetez: Espino Arrange by: Folder * Image: Antonio Vetez: Espino Image: Antoni		Import Text File	×
Organize New folder Organize New folder Image: Stable State Image: Stable State Organize New folder Image: Stable State Image: Stable State Image: Stable State Image: Stable State			-
Microsoft Excel Favorites Favo		Search Test_WF_DEmografia_2014-09-10	10g_ P
Favorites Name Downloads Alke 2011 SRXW Recert Places Alke 2011 SRXW Districts Stable State Values SRXW 1987-2011 Music Stable State Values SRXW 1987-2011 Music Stable State Values SRXW 1987-2011 Videos Videos		Organize • New folder	0
Image: Stable State Values SRKW 1987-2011			•
File name: Stable State Values SRKW 1987-2011		Downloads Value Desktop Alive 2011 SRKW Desktop Counts and Proportions T0 SRKW 1987-2011 Ubraries Counts by Year SRKW 1987-2011 Documents MeanMatrix SRKW Alive 2015 SRKW 1987-2011 State State Values SRKW 1987-2011 Main State State Values SRKW 1987-2011 Main State State Values SRKW 1987-2011 Pictures State State Values SRKW 1987-2011 Videos Yuta rates estimates SRKW 1987-2011 Damping Time SRKW 1987-2011 Damping Time SRKW 1987-2011	
Tools Import Cancel		Computer	-
		Tools Tools Can	el
** Sheet) Sheet / Shee			
	(+ + Sheet1_Sheet2_Sheet3_C2 dv		•1

- 6. Follow three steps to open the file
 - a. Text import wizard: step 1:
 - i. Choose Delimited
 - ii. File origin: MS DOS (PC-8)
 - iii. Click next



- b. Text import wizard: step 2:
 - i. Choose Coma delimited
 - ii. Click next

Norme Intert Page Layout Formulas. Data Review View Ad	Book1 - Microsoft Ecel
 Memory Test Sources With Test Sources Control Sources 	Y N. Carrow 🔀 📑 🔯 🎼 🎝 101 101 101 101 101 101 101 101 101 10
A1 • (* fe	
A B C D E F G	Text Import Wizard - Step 2 of 3
	This screen lets you set the delimiters your data contains. You can see how your text is affected in the preview below. Delimiters Delimiters Delimiters Delimiters Delimiters Tgaat consecutive delimiters as one Delimiters Text gualifier: Text gualifier: Delimiters Delimit
	Data greview
	Parte 6 .07620626073105 2.07199701104135 0.66673402610056 2.05700216080049 € Puremail 44 44.188014218837 32.860658679556 22.504630639866 31.860647027847 1 Puremail 6 3.147772201246 1.3408682996106 14.1028445748687 13.861445278247 1 DidFFrem 6 4.2021600720995 4.54719443401136 4.76940388639028 4.96267151722896 1
	Cancel < gack gent > Enioh
N Sheet1 Sheet2 Sheet3 1	

- c. Text import wizard: step 3:
 - i. Click in Advance (red oval) and the Advance Text Import Settings window appears.
 - ii. Decimal separator: decimal numbers must be separated by a period, red oval).
 - iii. Thousands separator: choose empty space (red oval).
 - iv. Click ok

Forme Intert Page Lajout	Book1 - Microsoft Excel Formalis: Data Review View Add-bit: Acrobat			- • • ×
From From Gron Other With Ted Sources - Connecte Git Enternal Cala		ap Ungroup Sabital Outline 5		
		N O P		w
		H 0 F	u	
	Text Import Wizard - Step 3 of 3	? ×		
	This screen lets you select each column and set the Data Format.			
	Column data format			
	General General' converts numeric values to converts date values to dates	N	rt Settings	1
	○ Lext values to text.	Advanced Text Impo	rt Settings	
	Date: DMY	Settings used to recog	nize meno una	
	🗇 Do not import column (skip)	Decimal separator:		
		Thousands separato		
		- ·		
	Data preview	Note: Numbers will I in the Regional Setti	be display.co.comp the numeric settings specified	
	General General General General General	Reset	Trailing minus for negative numbers	
	Salve 4 2.87620626873185 2.87199781184153 2.86673482618056 2.857802 Suvensi 24 24.1380142158257 23.2609658679556 22.5046306934868 21.85094		OK Cancel	
	YoungReen 19 19.1479722701926 19.2943825470929 19.3829806476027 19.42407	105	Cancer	
	DidRFem 15 14.6677719531626 14.3695692996106 14.1025445745057 13.061445 Response 6 6.29216007208995 6.54719443401136 6.76940388639028 6.9626710	1722996 H T		2
	×	,		
	Cancel < gack Hent >	Enish		
H Sheet1 Sheet2 Sheet3		5141		1. 15
		March 1	110 II III 100%	

7. Click in Finish.

Home Intert Rage Layout Formulas Data Review View Add-Ins Art	Book1 = Microsoft Excel	
The second secon	* 🔀 🖬 🗃 🎼 🗱 💔 🗐 🗐 🖓 🖓	
A B C D E F G H	I I K L M N O P Q R S T	U V W
	Text Import Wizard - Step 3 of 3	
	This screen lets you select each column and set the Data Format. Column data format General General Converts numeric values to numbers, date values to dates, and all remaining values to toxt. Data greview Data greview	
	Innersition Baneral Banera Baneral Baneral	

8. Import Data window appears, asking Where do you want to put the data, choose Existing worksheet.

Norme Intert Rage Layout Formulas Data Review Ver-	Booki - Microsoft Excel
From Frem Frem Coher With Test Source- Gra Element Catal	
A1 • (* £4	
	G H I J K L M N O P Q R S T U V W Import Data
	Where do you want to put the data?
	SA\$1 New worksheet
	Properties OK Cancel
H Sheet1 Sheet2 Sheet3 1	

From	n From From So Web Test Got En	Sour cenal D	as - Comections ata	Rofresh Al - Edit Unit Connections	ši sort i	₩ Coar Bar B Rapply Bar B Advanced CA Filter		Data Consolidat raidation - Data Tools	White of George		Show Detail Hige Detail					
1	AI	•	- £ 0 C	D	E	F	G	н	1	J	ĸ	L	M	N	0	10
1		1000	2		- 4	5	6		8		10		12	13	14	1
2	calve			2,871997812										2,715920394		2
	Juvenil			23,26096587												
í.	YoungRFerr	19	19,14797227	19,29438255	19,38298065	19,42407106	19,42631334	19,39683832	19,34151726	19,26518398	19,17181792	19,06469478	18,94651065	18,81948423	18,68544103	1
5	OldRFem	15	14,66777195	14,3695693	14,10254457	13,86144528	13,64193028	13,44041838	13,25395471	13,08010056	12,91684271	12,76251864	12,61575495	12,47541665	12,34056529	1
5	PostRFem	6	6,292168072	6,547194435	6,769403886	6,952571517	7,130338899	7,275296637	7,400053645	7,506794966	7,597430088	7,6736334	7,736878106	7,788464721	7,829545051	
7	YoungMale	15	14,93508794	14,88668075	14,78484907	14,6436547	14,47437795	14,28584468	14,08491043	13,876854	13,66569646	13,45445932	13,24537312	13,04004553	12,83959675	1
3	OldMale	5	5,697603359	6,318281033	6,871270574	7,359212877	7,785613087	8,154527161	8,470307045	8,737411143	8,960266039	9,143168193	9,290216592	9,405269155	9,491917215	9
1																
0																
1																
2																
3																
5																
6																
7																
8																
9																
0																
1																
2																
3																
4																
5																-1
6																1
	N Stable 5	tate \	/elucs SRKW 190	W 2 50										HI 1 11 120%		12

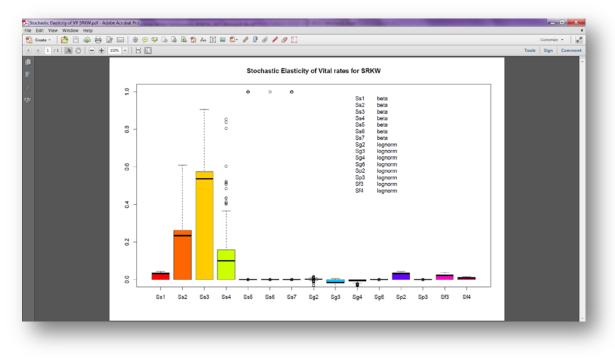
Stable State Values SRKW 1987-2011

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").

ion a	From From Fr	an Other lources - connections al Cata	Rafresh Al - == Edit Links Connections		her Scharced (Text to Remove	- Burn Same	olidate What W Analysis -		100 -T H	iow Detail de Detail						
-		• (- £ C															_
a	A	В	С	D	E	F	G	н	1	J	К	L	М	N	0	р	
	Category	Mean_Surv	Var_Surv	Mean_Offspr	Var_Offspr												
	calve	0,784679089	0,08087138	0	()											
6	Juvenil	0,980701413	0,002173426	0	()											
	YoungRFem	0,984551768	0,00111008	0,116279866	0,005860444	l											
6	OldRFem	0,966806107	0,002933632	0,069369375	0,005502706	5											
5	PostRFem	0,927843915	0.011568907	0	0)											
1	YoungMale	0,969109623	0,004211171	0	0)											
	OldMale	0,897243266	0,020918201	0	()											
D																	
1																	
2																	
3																	
1																	
5																	
5																	
7																	
3																	
9																	
0																	
1																	
2																	
3																	
1																	
ŝ	+ H Stats by C	atogery SRKW 198	7 201 12						5	4			. 10			in the second	15

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"



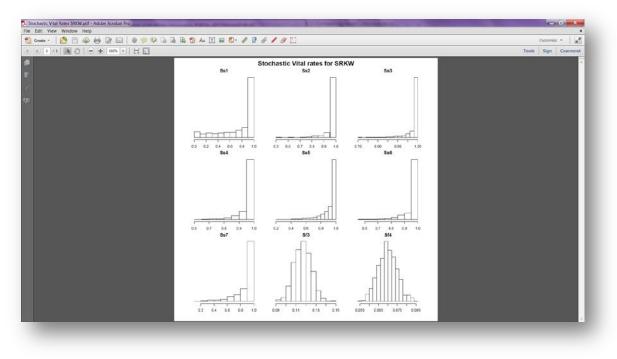
Stochastic Elasticity of VR SRKW

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

		cas Connections	P4	≩i Scet filter	To Reapply Text Column	to Remov	es Validation *	(onsolidate	What-W Analysis	oup Subtotal					
-	Get External C		Connections	Sort & F	नेश		Data Tools			Outline	fi.				
d	A	В	С	D	E	F	G	н	L	J	K	L	N	I N	0
2		Ss1	5s2	Ss3	Ss4	Ss5	Ss6	Ss7	Sg2	Sg3	Sg4	Sg6	Sp2	Sp3	Sf3
1	ElasMean.KW	0,022183746	0,163720251	0,373543704	0,097490997	0,193	0,001	0,138	0,001964245	-0,012095871	-0,005131105	-9,098	-05 0,0221	83746 1,118	-18 0,01591
	ElasMed.KW	0,032155237	0,234138065	0,536273749	0,100133893	0	0	0	0,001317043	-0,015485878	-0,005270205		0 0,0321	55237	0 0,02185
	ElasMin.KW	0	0	0	0	0	0	0	-0,040039163	-0,04363982	-0,044922854	-0,090909	091	0	0
	ElasMax.KW	0,042365953	0,609289144	0,906998555	0,853534229	1	1	1	0,016304561	0,005593261	0	1,128	-17 0,0423	65953 8,168	-17 0,03847
	5%	0	0	0	0	0	0	0	-0,002608308	-0,026597939	-0,01297065	-4,808	-18	0	0
	95%	0,038167718	0,29505899	0,653161727	0,246442351	1	6,01E-17	1	0,00870828	0	0		0 0,0381	67718 6,208	-18 0,0312
)															
Ļ															
2															
3															
ł															
•															
,															
,															
5															
1															
	and a second	asticity Stats SRK	1.000							กษ					



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



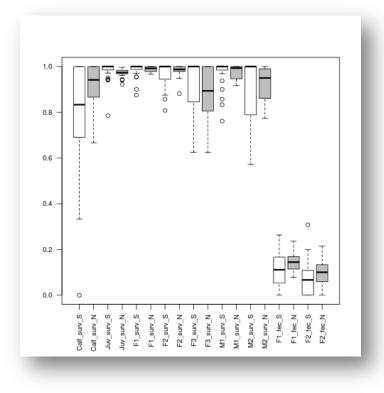
Stochastic Vital Rates SRKW

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

File	Ho	me Insert Page	Layout Formulas Data	Review View	Add-Ins Acrobat									۵	0001
an es	web		Existing Rafresh connections All		Filter Sy Advanced	Text to Remove Columns Dupicates		What-M Analysis - Group U	ngroup Subtotal						
	A1	Get External Data	Connectio fe	ng	Sort & Filter		Data Tools		Outline	5					_
í		B	C	D	E	F	G	н	1	J	К	1	м	N	0
ł		-	Juvenile_Survival	-			-				N		IVI	N .	0
1	1987	0,75	1	1_30111001	-	_	-			0.057142857					
	1988	0,75		1	1	-	0,761904762		0.095238095						
	1989	1	-	1	-	0,857142857				0.055555556					
	1990	1	-	1	1		1	1	-,						
	1991	0,75	0,944444444	1	1	1	1	0,95	,	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					
1	1996	1	1	1	0,915714286	0,625	1	0,9	0,166666667	0,066666667					
2	1997	NA	0,94375	1	1	1	1	0,77777778	0	0					
3	1998	1	0,94047619	0,9	0,953703704	1	1	0,666666667	0,083333333	0					
1	1999	0,333333333	1	0,955	0,808333333	1		0,928571429		0					
		0,666666667	1	1	0,857142857	1	,	0,571428571							
		0,666666667	1	0,975		_	1	-	0,170212766						
	2002	1	1	1		0,0	_	-/-	0	-,					
		0,833333333	1	1	_	0,77777778		_	0,227272727						
	2004	1	-	1	_			_	0,043478261						
		0,714285714		1		0,875			0,166666667						
		0,333333333			0,928571429		-,		0,125						
	2007		-,					-	0,052631579						
		0,333333333	-	0,96969697		0,833333333	_	_	0						
	2009	1		1		0,916666667		0,666666667	0,055555556	0,129032258					
ŧ.	F H VI	tal rates estimates	SRKW 1987 👧						11						► 1

Vital rates estimates SRKW 1987-2011

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



VR_combined

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
- **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. 2014. Relative importance of Chinook salmon abundance on resident killer whale population growth and viability. Aquatic Conservation: Marine and Freshwater Ecosystems, DOI: 10.1002/aqc.2494
- 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.
- 5. *Francisco Quevedo* Cardiff School of Computer Science and Informatics, Cardiff, University, Cardiff CF24 3AA, United Kingdom.