BioVeL – Biodiversity Virtual e-Laboratory

Workflow Documentation

Relative importance of Chinook salmon abundance on resident Killer whale population viability pack for execution in the BioVeL Portal

September 2014

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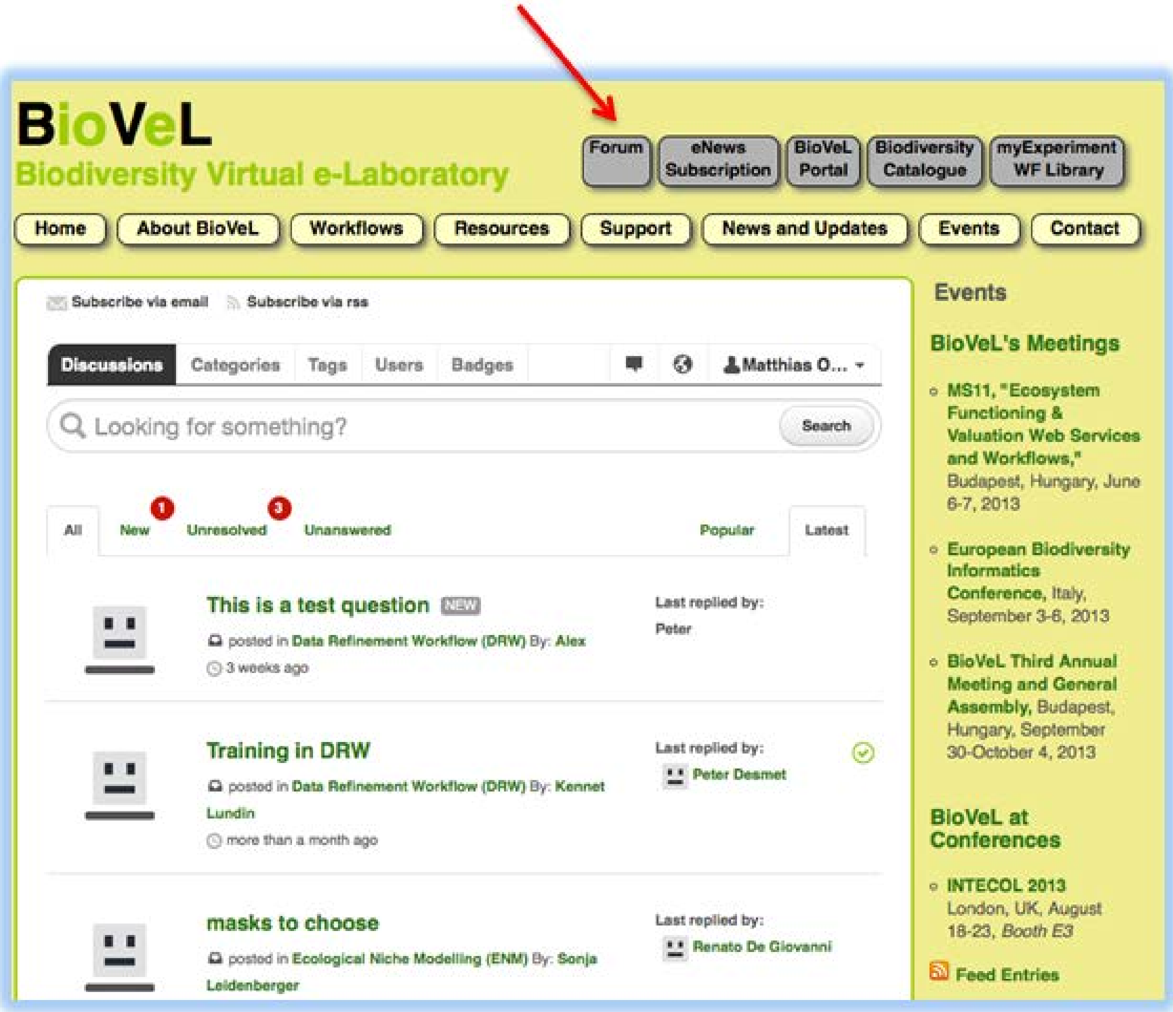
***Relative importance of Chinook salmon abundance on resident Killer whale population viability* pack**

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

This documentation contains the tutorial to run two related workflows.

1. Resident killer whale-chinook salmon interactions workflow

The *Resident killer whale-chinook salmon interactions* workflow provides an environment to create calculate a two-sex stage-structured matrix with no density dependence and with vital rates as random variables or as functions of Chinook abundance from specific stock aggregates and to (i) quantify the differences in demographic rates between Orcinus orca population that explain population growth; (ii) to determine the relative influence of vital rates and Chinook abundance-vital rate interactions on expected population growth; (iii) to generate projections of population size at various time horizons.

2. Exploration of fishing scenarios workflow

This workflow cannot be run without running first the Resident killer whale-chinook salmon interactions workflow. The Exploration of fishing scenarios workflow needs the PostWorkspace, a zip file generated by the first workflow. See details page 39, PostWorkspace (zip file).

This workflow merges statistical inference derived from linkages between resident killer whale (RKW) vital rates (survival probability and fecundity rates) and chinook salmon abundance with demographic perturbation analysis and population viability analysis to address some of the pressing questions that have recently engaged the efforts of scientists and managers interested in: (1) the role of chinook salmon abundance in the population dynamics of RKW; and (2) how RKW population viability is expected to respond to changes in chinook mortality owing to harvest.

This workflow can be used to analyse interactions between Chinook salmon abundance from specific stock aggregates and killer whale vital rates, the effect of these interactions on killer whale population growth, and the exploration of Chinook salmon fishing scenarios on killer whale population growth and short term projections of population size. See necessary input data.

For more details about the analyses, please download:

- ***Sensitivity of resident killer whale population dynamics to Chinook salmon abundance (http://www.myexperiment.org/files/1307.html)***
- ***Comparative Demography and Viability of North-eastern Pacific Resident Killer Whale Populations at Risk (http://www.myexperiment.org/files/1306.html)***
- ***Relative importance of chinook salmon abundance on resident killer whale population growth and viability (http://onlinelibrary.wiley.com/doi/10.1002/aqc.2494/abstract)***

Resident killer whale-chinook salmon interactions.

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 on the file name or they can be downloaded at myExperiment (http://www.myexperiment.org/packs/667.html):

Orcinus orca input data:

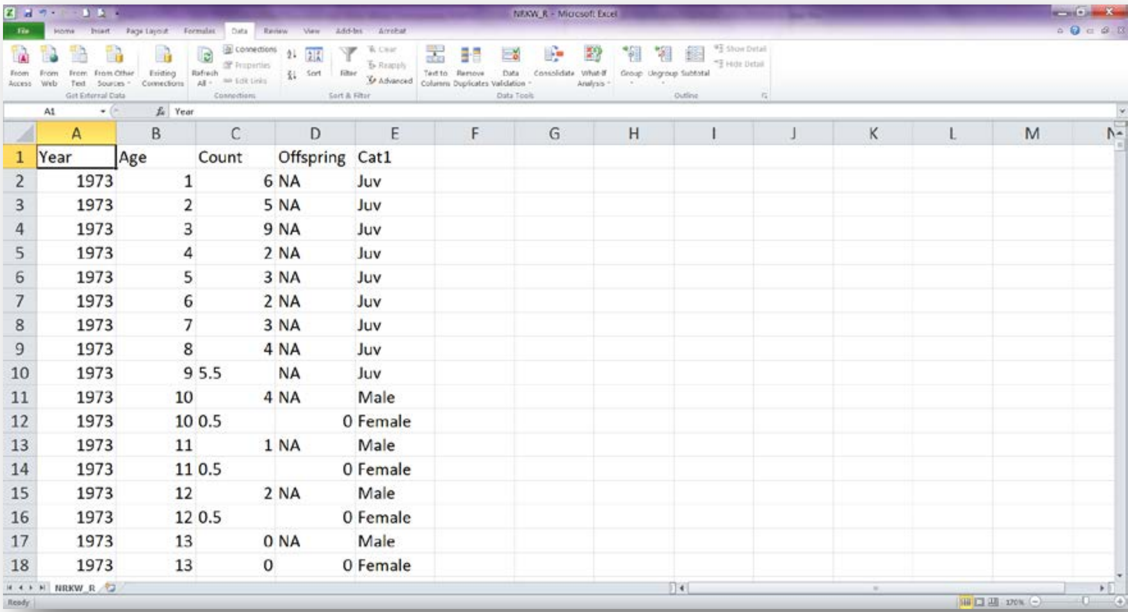
- NRKW_R or SRKW_R
- VR_combined

The following files are needed in order to get some necessary results to run (a second workflow), Exploration of fishing scenarios workflow.

Chinook input data:

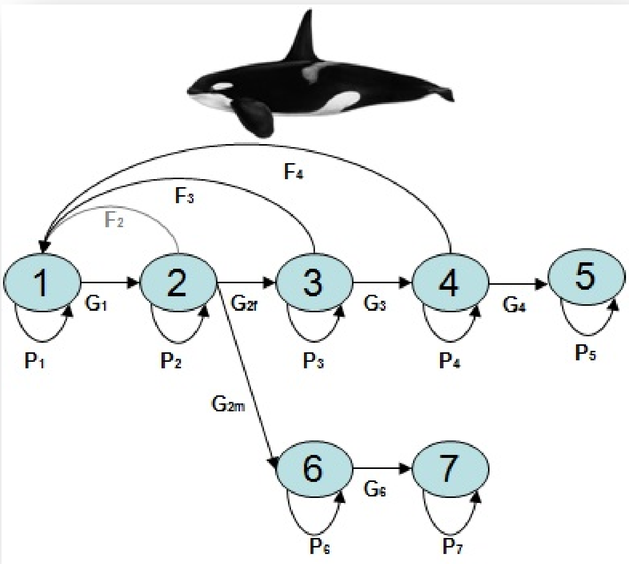
- Chinook_Ab_Definitions_R or Chinook_Ab_Defs_FI_R
- ChinookAbundance_Data_R or ChinookAbundance_FI_R

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

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.

	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																

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.

	A	B	C	D	E	F	G
1	TimeSeries	Stock	Ab.Type	lag	SR_Hyp	NR_Hyp	Ab_ID
2	FE_TR_0	Fraser Early (Spring and Summer)	Terminal run	0	1a	2b	1
3	FE_TR_1	Fraser Early (Spring and Summer)	Terminal run	1	1a	2b	1
4	FE_TR_2	Fraser Early (Spring and Summer)	Terminal run	2	1a	2b	1
5	FE_TR_5YA	Fraser Early (Spring and Summer)	Terminal run	5YA	1a	2b	1
6	FE2_TR_0	Fraser Early (Spring)	Terminal run	0	1a	2b	1
7	FE2_TR_1	Fraser Early (Spring)	Terminal run	1	1a	2b	1
8	FE2_TR_2	Fraser Early (Spring)	Terminal run	2	1a	2b	1
9	FE2_TR_5YA	Fraser Early (Spring)	Terminal run	5YA	1a	2b	1
10	FE3_TR_0	Fraser Early (Summer)	Terminal run	0	1a	2b	1
11	FE3_TR_1	Fraser Early (Summer)	Terminal run	1	1a	2b	1
12	FE3_TR_2	Fraser Early (Summer)	Terminal run	2	1a	2b	1
13	FE3_TR_5YA	Fraser Early (Summer)	Terminal run	5YA	1a	2b	1
14	PS_TR_0	Puget Sound (Summer and Fall)	Terminal run	0	1a	2b	1
15	PS_TR_1	Puget Sound (Summer and Fall)	Terminal run	1	1a	2b	1
16	PS_TR_2	Puget Sound (Summer and Fall)	Terminal run	2	1a	2b	1
17	PS_TR_5YA	Puget Sound (Summer and Fall)	Terminal run	5YA	1a	2b	1
18	FEPS_TR_0	Fraser Early + Puget Sound	Terminal run	0	1a	2b	1
19	FEPS_TR_1	Fraser Early + Puget Sound	Terminal run	1	1a	2b	1
20	FEPS_TR_2	Fraser Early + Puget Sound	Terminal run	2	1a	2b	1
21	FEPS_TR_5YA	Fraser Early + Puget Sound	Terminal run	5YA	1a	2b	1

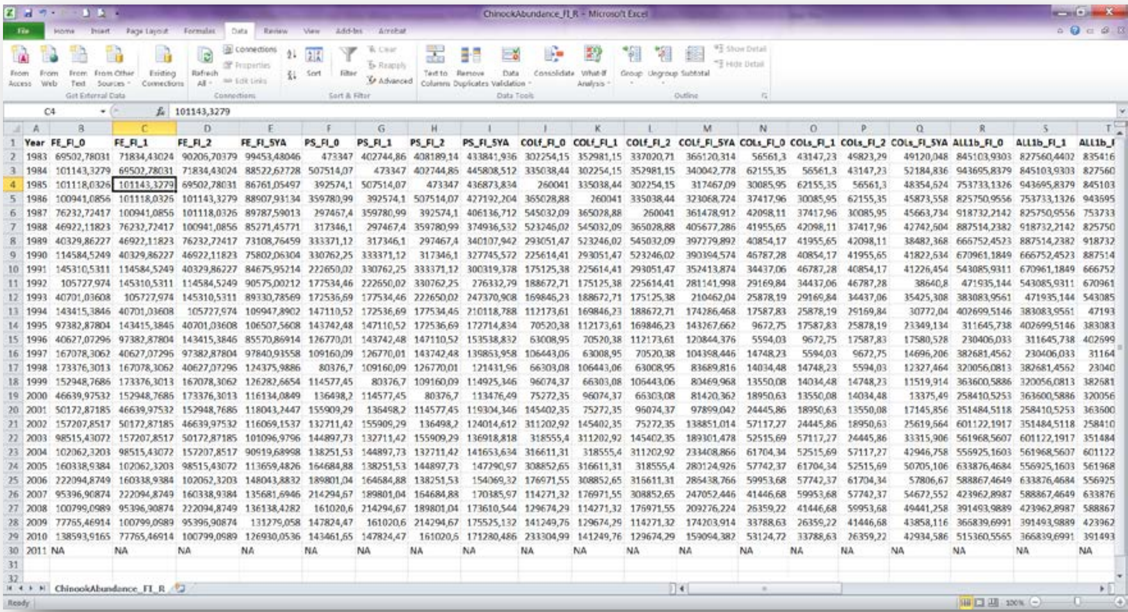
<u>Chinook_Ab_Defs_FI_R:</u> Table used to define fishery impacts (FI) on Chinook abundance by stock aggregate, time lag (5YA: 5-year running average), and hypothesis (SR: Southern Resident Killer Whale; NR: Northern Resident Killer Whale) and abundance ID. FI represent ocean catch of specific Chinook 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

<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.

Year	FE_TR_0	FE_TR_1	FE_TR_2	FE_TR_5YA	FE2_TR_0	FE2_TR_1	FE2_TR_2	FE2_TR_5YA	FE3_TR_0	FE3_TR_1	FE3_TR_2	FE3_TR_5YA	PS_TR_0	PS_TR_1	PS_TR_2	PS_TR_5YA	FEPS_TR_0	FEPS_TR_1	FEPS_TR_2	FEPS_TR_5YA	FL_TR_0	FL_TR_
1983	82641	90670	73741	89780	38371	34783	26931	36512	44270	55887	46810	53267,8	216003	217280	220024	236867	298644	307950	293765	326646	120000	1200
1984	112697	82641	90670	89484	48496	38371	34783	36549	64201	44270	55887	52934,2	229833	216003	217280	223827	342530	298644	307950	313311	131962	1200
1985	136405	112697	82641	99231	65710	48496	38371	42858	70695	64201	44270	56372,6	262880	229833	216003	229204	399285	342530	298644	328435	183104	1319
1986	160271	136405	112697	116537	73805	65710	48496	52233	86466	70695	64201	64303,8	235049	262880	229833	232209	395320	399285	342530	348746	182545	1831
1987	144071	160271	136405	127217	70157	73805	65710	59308	73914	86466	70695	67909,2	225725	235049	262880	233898	369796	395320	399285	361115	99673	1825
1988	149717	144071	160271	140632	62085	70157	73805	64051	87632	73914	85466	76581,6	229522	225725	235049	236602	379239	369796	395320	377234	54401	996
1989	117553	149717	144071	141603	54099	62085	70157	65171	63454	87632	73914	76432,2	258029	229522	225725	242241	375582	379239	369796	383844	79699	544
1990	152585	117553	149717	144839	57633	54099	62085	63556	94952	63454	87632	81283,6	244442	258029	229522	238553	397027	375582	379239	383393	182667	796
1991	128548	152585	117553	138495	50433	57633	54099	58881	78115	94952	63454	79613,4	179428	244442	258029	227429	307976	397027	375582	365924	104572	1826
1992	143685	128548	152585	138418	56601	50433	57633	56170	87084	78115	94952	82247,4	131946	179428	244442	208673	275631	307976	397027	347091	175744	1045
1993	120905	143685	128548	132655	65565	56601	50433	56856	55340	87084	78115	75789	122234	131946	179428	187216	243139	275631	307976	319871	143554	1757
1994	161964	120905	143685	141537	88741	65565	56601	63795	73223	55340	87084	77742,8	143298	122234	131946	164270	305262	243139	275631	305807	111286	1435
1995	157329	161964	120905	142486	77732	88741	65565	67814	79597	73223	55340	74671,8	160858	143298	122234	147553	318187	305262	243139	290039	67026	1112
1996	216402	157329	161964	160057	84519	77732	88741	74632	131883	79597	73223	85425,4	168474	160858	143298	145362	384876	318187	305262	305419	65141	670
1997	233918	216402	157329	178104	86827	84519	77732	80677	147091	131883	79597	97426,8	165835	168474	160858	152140	399753	384876	318187	330243	157189	651
1998	204364	233918	216402	194795	67175	86827	84519	80999	137189	147091	131883	113796,6	186992	165835	168474	165091	391356	399753	384876	359887	271502	1571
1999	154677	204364	233918	193338	47867	67175	85827	72824	106810	137189	147091	120514	203006	186992	165835	177033	357683	391356	399753	370371	196182	2715
2000	169405	154677	204364	195753	68834	47867	67175	71044	100571	106810	137189	124708,8	216738	203006	186992	188209	386143	357683	391356	383962	125667	1961
2001	223299	169405	154677	197133	75634	68834	47867	69267	147665	100571	106810	127865,2	248039	216738	203006	204122	471338	386143	357683	401255	151916	1256
2002	262677	223299	169405	202884	87314	75634	68834	69365	175363	147665	100571	133519,6	252778	248039	216738	221511	515455	471338	386143	424395	163359	1519
2003	283475	262677	223299	218707	106848	87314	75634	77299	176627	175363	147665	141407,2	230683	252778	248039	230249	514158	515455	471338	448955	307182	1633
2004	234716	283475	262677	234714	84903	106848	87314	84707	149813	176627	175363	150007,8	222835	230683	252778	234215	457551	514158	515455	468929	199621	3071
2005	197047	234716	283475	240243	47036	84903	106848	80347	150011	149813	176627	159895,8	233125	222835	230683	237492	430172	457551	514158	477735	135817	1996
2006	285212	197047	234716	252625	50552	47036	84903	75331	234660	150011	149813	177294,8	262552	233125	222835	240395	547764	430172	457551	493020	104629	1358
2007	151099	285212	197047	230310	22410	50552	47036	62350	128689	234660	150011	167960	256930	262552	233125	241225	408029	547764	430172	471535	112468	1046
2008	223888	151099	285212	218392	41909	22410	50552	49362	181979	128689	234660	169030,4	237255	256930	262552	242539	461143	408029	547764	460932	83790	1124
2009	207228	223888	151099	212895	43750	41909	22410	41131	163478	181979	128689	171763,4	207257	237255	256930	239424	414485	461143	408029	452319	98742	837
2010	263036	207228	223888	226093	36561	43750	41909	39036	226475	163478	181979	187056,2	224380	207257	237255	237675	487416	414485	461143	463767	191231	987
2011	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

__**ChinookAbundance_FI_R:**__ Table showing the time series of Fishery Impacts of all stocks by time lag used in the analysis.



Year	FE_FI_0	FE_FI_1	FE_FI_2	FE_FI_5YA	PS_FI_0	PS_FI_1	PS_FI_2	PS_FI_5YA
1983	69502,78031	71834,43024	90206,70379	99453,48046	473347	402744,86	408189,14	433841,936
1984	101143,3279	69502,78031	71834,43024	88522,62728	507514,07	473347	402744,86	445808,512
1985	101118,0326	101143,3279	69502,78031	86761,05497	392574,1	507514,07	473347	436873,834
1986	100941,0856	101118,0326	101143,3279	88907,93134	359780,99	392574,1	507514,07	427192,204
1987	76232,72417	100941,0856	101118,0326	89787,59013	297467,4	359780,99	392574,1	406136,712
1988	46922,11823	76232,72417	100941,0856	85271,45771	317346,1	297467,4	359780,99	374936,532
1989	40329,86227	46922,11823	76232,72417	73108,76459	333371,12	317346,1	297467,4	340107,942
1990	114584,5249	40329,86227	46922,11823	75802,06304	330762,25	333371,12	317346,1	327745,572
1991	145310,5311	114584,5249	40329,86227	84675,95214	222650,02	330762,25	333371,12	300319,378
1992	105727,974	145310,5311	114584,5249	90575,00212	177534,46	222650,02	330762,25	276332,79
1993	40701,03608	105727,974	145310,5311	89330,78569	172536,69	177534,46	222650,02	247370,908
1994	143415,3846	40701,03608	105727,974	109947,8902	147110,52	172536,69	177534,46	210118,788
1995	97382,87804	143415,3846	40701,03608	106507,5608	143742,48	147110,52	172536,69	172714,834
1996	40627,07296	97382,87804	143415,3846	85570,86914	126770,01	143742,48	147110,52	153538,832
1997	167078,3062	40627,07296	97382,87804	97840,93558	109160,09	126770,01	143742,48	139863,958
1998	173376,3013	167078,3062	40627,07296	124375,9886	80376,7	109160,09	126770,01	121431,96
1999	152948,7686	173376,3013	167078,3062	126282,6654	114577,45	80376,7	109160,09	114925,346
2000	46639,97532	152948,7686	173376,3013	116134,0849	136498,2	114577,45	80376,7	113476,49
2001	50172,87185	46639,97532	152948,7686	118043,2447	155909,29	136498,2	114577,45	119304,346
2002	157207,8517	50172,87185	46639,97532	116069,1537	132711,42	155909,29	136498,2	124014,612
2003	98515,43072	157207,8517	50172,87185	101096,9796	144897,73	132711,42	155909,29	136918,818
2004	102062,3203	98515,43072	157207,8517	90919,68998	138251,53	144897,73	132711,42	141653,634
2005	160338,9384	102062,3203	98515,43072	113659,4826	164684,88	138251,53	144897,73	147290,97
2006	222094,8749	160338,9384	102062,3203	148043,8832	189801,04	164684,88	138251,53	154069,32
2007	95396,90874	222094,8749	160338,9384	135681,6946	214294,67	189801,04	164684,88	170385,97
2008	100799,0989	95396,90874	222094,8749	136138,4282	161020,6	214294,67	189801,04	173610,544
2009	77765,46914	100799,0989	95396,90874	131279,058	147824,47	161020,6	214294,67	175525,132
2010	138593,9165	77765,46914	100799,0989	126930,0536	143461,65	147824,47	161020,6	171280,486
2011	NA	NA	NA	NA	NA	NA	NA	NA

Year	COLf_FI_0	COLf_FI_1	COLf_FI_2	COLf_FI_5YA	COLs_FI_0	COLs_FI_1	COLs_FI_2	COLs_FI_5YA	ALL1b_FI_0	ALL1b_FI_1	ALL1b_F
1983	302254,15	352981,15	337020,71	366120,314	56561,3	43147,23	49823,29	49120,048	845103,9303	827560,4402	835416
1984	335038,44	302254,15	352981,15	340042,778	62155,35	56561,3	43147,23	52184,836	943695,8379	845103,9303	827560
1985	260041	335038,44	302254,15	317467,09	30085,95	62155,35	56561,3	48354,624	753733,1326	943695,8379	845103
1986	365028,88	260041	335038,44	323068,724	37417,96	30085,95	62155,35	45873,558	825750,9556	753733,1326	943695
1987	545032,09	365028,88	260041	361478,912	42098,11	37417,96	30085,95	45663,734	918732,2142	825750,9556	753733
1988	523246,02	545032,09	365028,88	405677,286	41955,65	42098,11	37417,96	42742,604	887514,2382	918732,2142	825750
1989	293051,47	523246,02	545032,09	397279,892	40854,17	41955,65	42098,11	38482,368	666752,4523	887514,2382	918732
1990	225614,41	293051,47	523246,02	390394,574	46787,28	40854,17	41955,65	41822,634	670961,1849	666752,4523	887514
1991	175125,38	225614,41	293051,47	352413,874	34437,06	46787,28	40854,17	41226,454	543085,9311	670961,1849	666752
1992	188672,71	175125,38	225614,41	281141,998	29169,84	34437,06	46787,28	38640,8	471935,144	543085,9311	670961
1993	169846,23	188672,71	175125,38	210462,04	25878,19	29169,84	34437,06	35425,308	383083,9561	471935,144	543085
1994	112173,61	169846,23	188672,71	174286,468	17587,83	25878,19	29169,84	30772,04	402699,5146	383083,9561	47193
1995	70520,38	112173,61	169846,23	143267,662	9672,75	17587,83	25878,19	23349,134	311645,738	402699,5146	383083
1996	63008,95	70520,38	112173,61	120844,376	5594,03	9672,75	17587,83	17580,528	230406,033	311645,738	402699
1997	106443,06	63008,95	70520,38	104398,446	14748,23	5594,03	9672,75	14696,206	382681,4562	230406,033	31164
1998	66303,08	106443,06	63008,95	83689,816	14034,48	14748,23	5594,03	12327,464	320056,0813	382681,4562	23040
1999	96074,37	66303,08	106443,06	80469,968	13550,08	14034,48	14748,23	11519,914	363600,5886	320056,0813	382681
2000	75272,35	96074,37	66303,08	81420,362	18950,63	13550,08	14034,48	13375,49	258410,5253	363600,5886	320056
2001	145402,35	75272,35	96074,37	97899,042	24445,86	18950,63	13550,08	17145,856	351484,5118	258410,5253	363600
2002	311202,92	145402,35	75272,35	138851,014	57117,27	24445,86	18950,63	25619,664	601122,1917	351484,5118	258410
2003	318555,4	311202,92	145402,35	189301,478	52515,69	57117,27	24445,86	33315,906	561968,5607	601122,1917	351484
2004	316611,31	318555,4	311202,92	233408,866	61704,34	52515,69	57117,27	42946,758	556925,1603	561968,5607	601122
2005	308852,65	316611,31	318555,4	280124,926	57742,37	61704,34	52515,69	50705,106	633876,4684	556925,1603	561968
2006	176971,55	308852,65	316611,31	285438,766	59953,68	57742,37	61704,34	57806,67	588867,4649	633876,4684	556925
2007	114271,32	176971,55	308852,65	247052,446	41446,68	59953,68	57742,37	54672,552	423962,8987	588867,4649	633876
2008	129674,29	114271,32	176971,55	209276,224	26359,22	41446,68	59953,68	49441,258	391493,9889	423962,8987	588867
2009	141249,76	129674,29	114271,32	174203,914	33788,63	26359,22	41446,68	43858,116	366839,6991	391493,9889	423962
2010	233304,99	141249,76	129674,29	159094,382	53124,72	33788,63	26359,22	42934,586	515360,5565	366839,6991	391493
2011	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

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:

The resident killer whale-chinook salmon interactions workflow provides an environment to create calculate a two-sex stage-structured matrix with no density dependence and with vital rates as random variables or as functions of Chinook abundance from specific stock aggregates and to (i) quantify the differences in demographic rates between Orcinus orca population that explain population growth; (ii) to determine the relative influence of vital rates and Chinook abundance-vital rate interactions on expected population growth; (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.
- Regressions between Killer Whale vital rates and stock-specific Chinook abundance.
- Elasticities of interactions between Killer Whale vital rates and stock-specific Chinook abundance.
- Retrospective perturbation analysis.
- Stochastic population growth from IID matrices and vital rate probability distributions.
- Projections of population size.

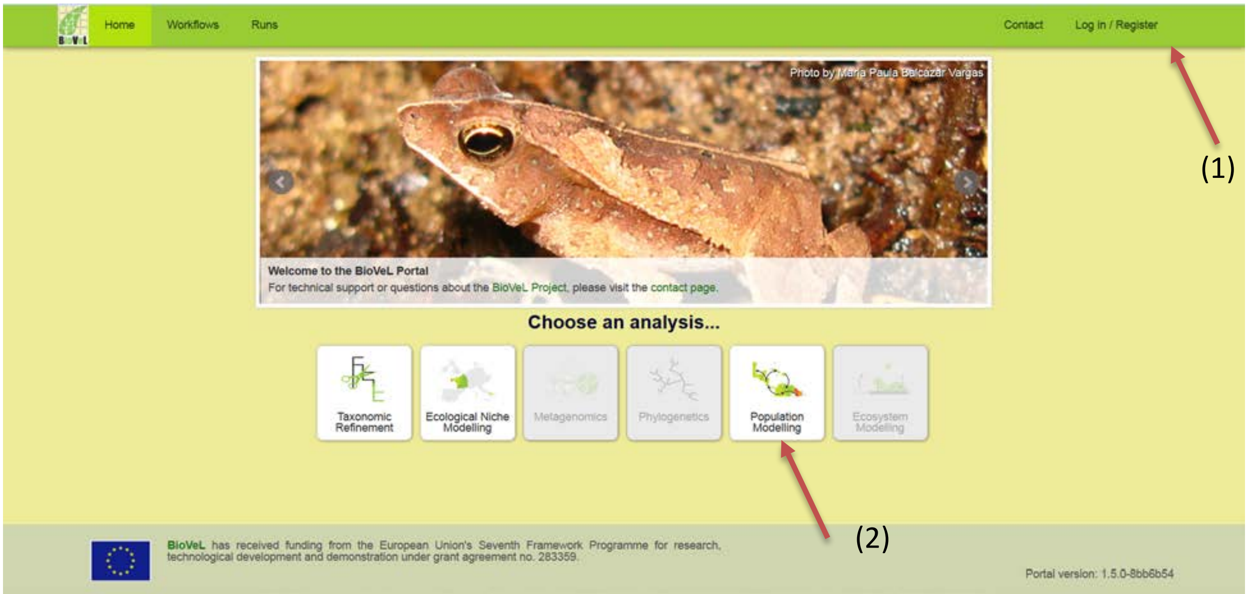
This tutorial explains the type of input data needed to run the workflow. The corresponding analysis use data from two distinct *O. orca* populations in Canada, Southern Resident Killer Whales (SRKW) and the Northern Resident Killer Whales (NRKW).

Two distinct populations of resident killer whales (*Orcinus orca*) in the 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 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.

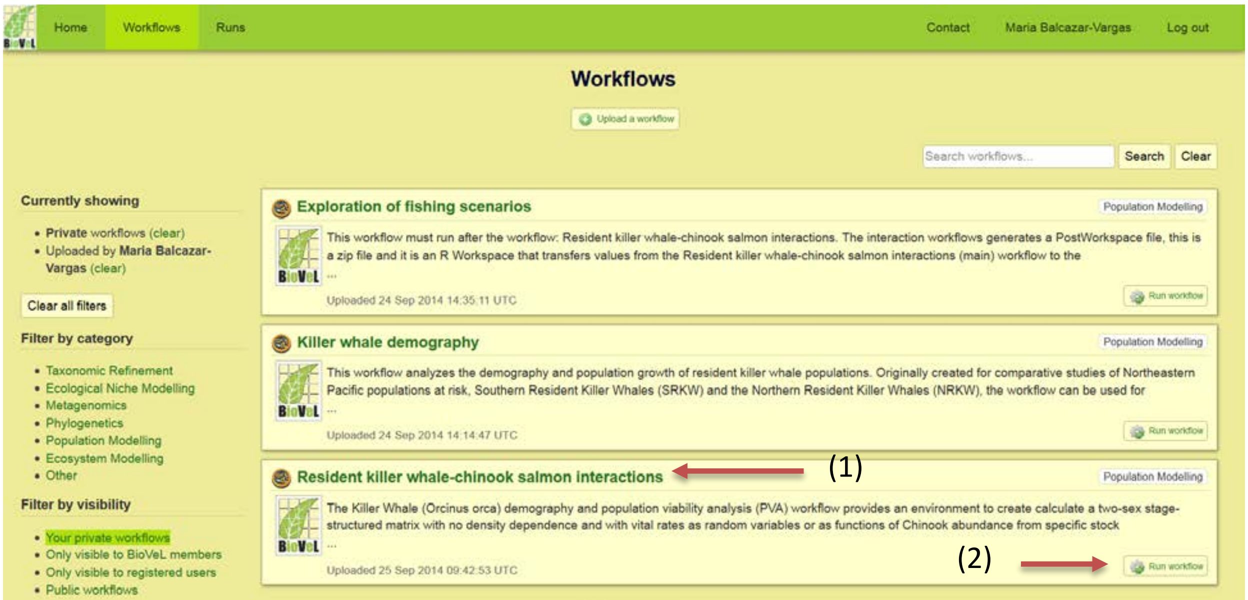
***Relative importance of Chinook salmon abundance on resident Killer whale population viability* pack**

In your browser (preferably Firefox or Chrome) navigate to the BioVeL Portal 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:

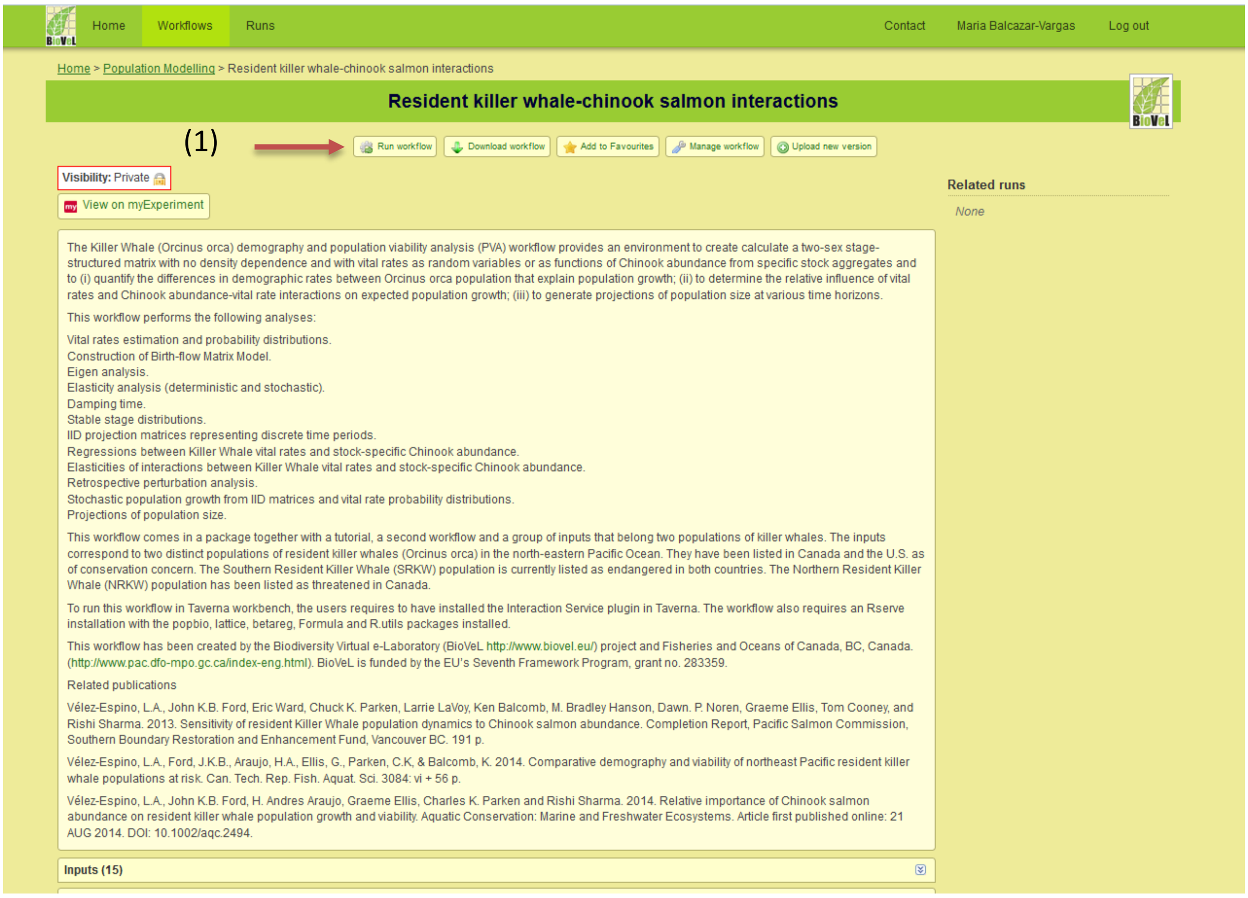


On the resulting page choose the workflow *Resident killer whale-chinook salmon interactions* (1) you can also directly run the workflow using the 'Run workflow' button at the bottom-right (2).

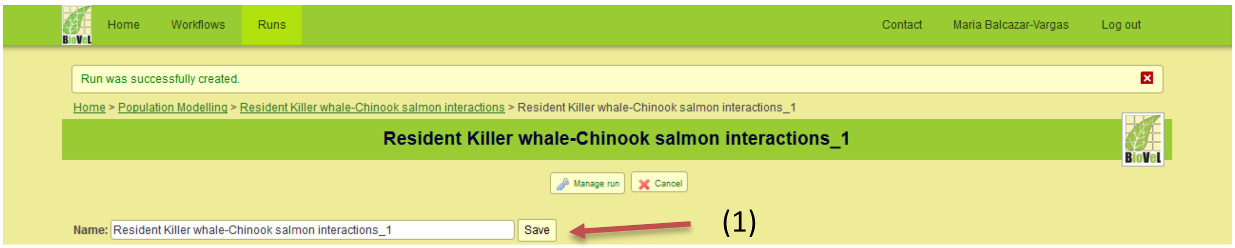


On the resulting page click on the 'Run Workflow' button at the top (1).

***Relative importance of Chinook salmon abundance on resident Killer whale population viability* pack**



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. *Resident Killer whale-Chinook salmon interactions_1*).

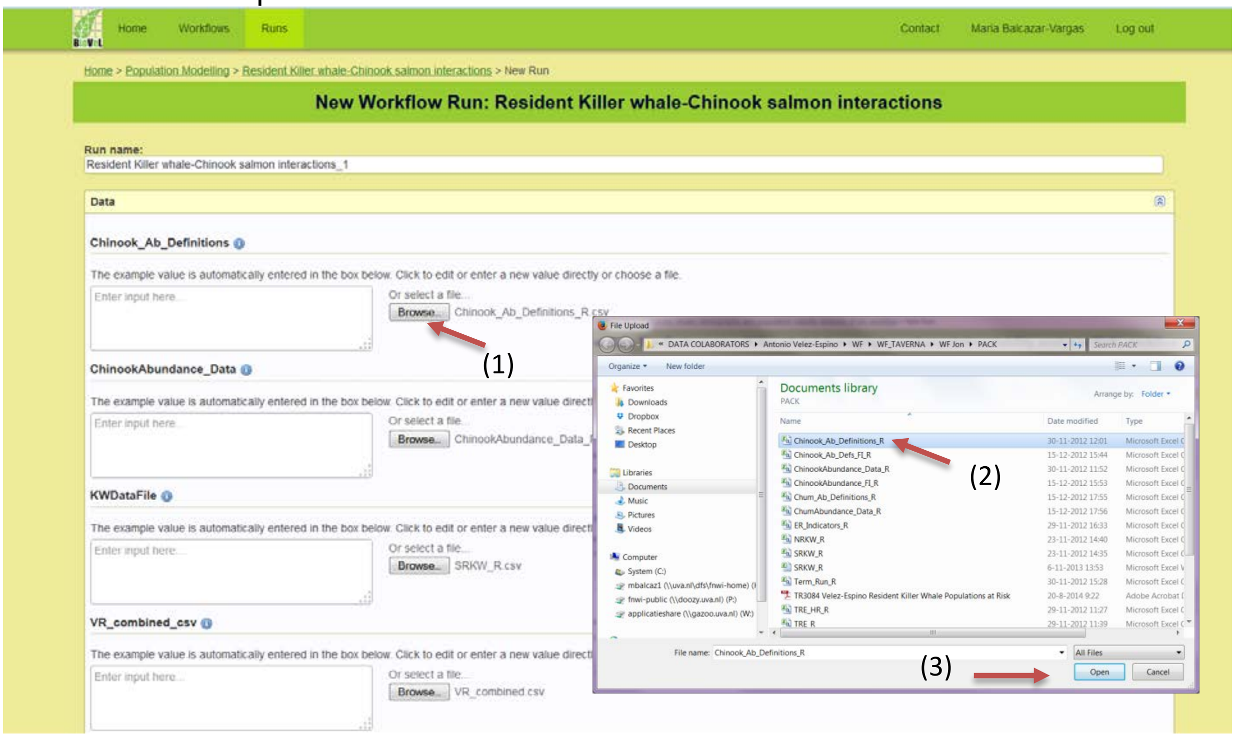


3.1 Input Ports

3.1.1 Data

Chinook_Ab_Definitions: 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. Here, two files can be used as input: Chinook_Ab_Definitions_R.csv ***or*** Chinook_Ab_Defs_FI_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.

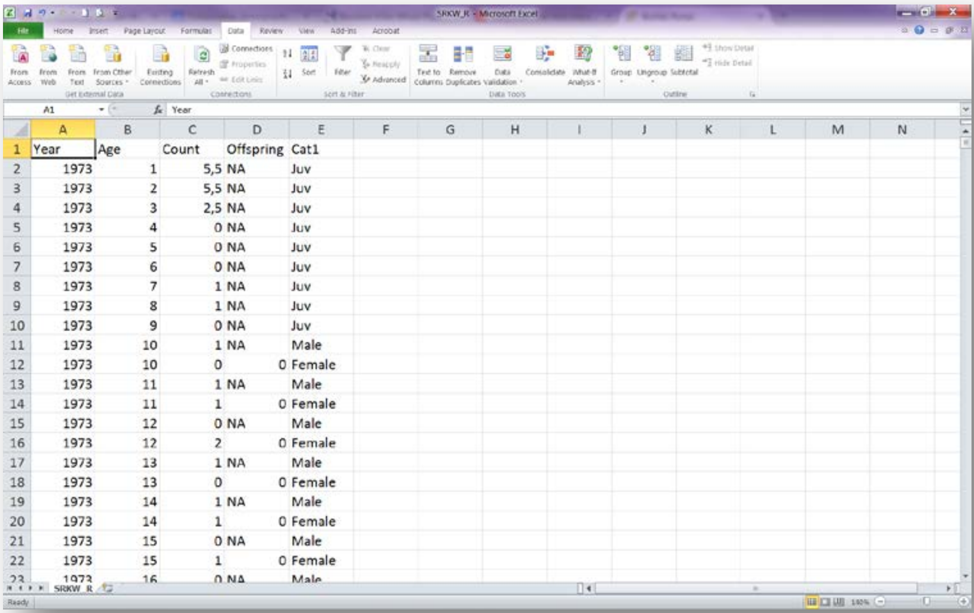


ChinookAbundance_Data: it's a .csv file. Time series of abundance (TR or OA) of all stocks and stock aggregates by time lag used in the analysis. Here, two files can be used as input: ChinookAbundance_Data_R.csv ***or*** ChinookAbundance_FI_R.csv

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.

KWDataFile: 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.



	A	B	C	D	E
1	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

***VR_combined*:** 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).

***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 analysed 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:

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

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

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

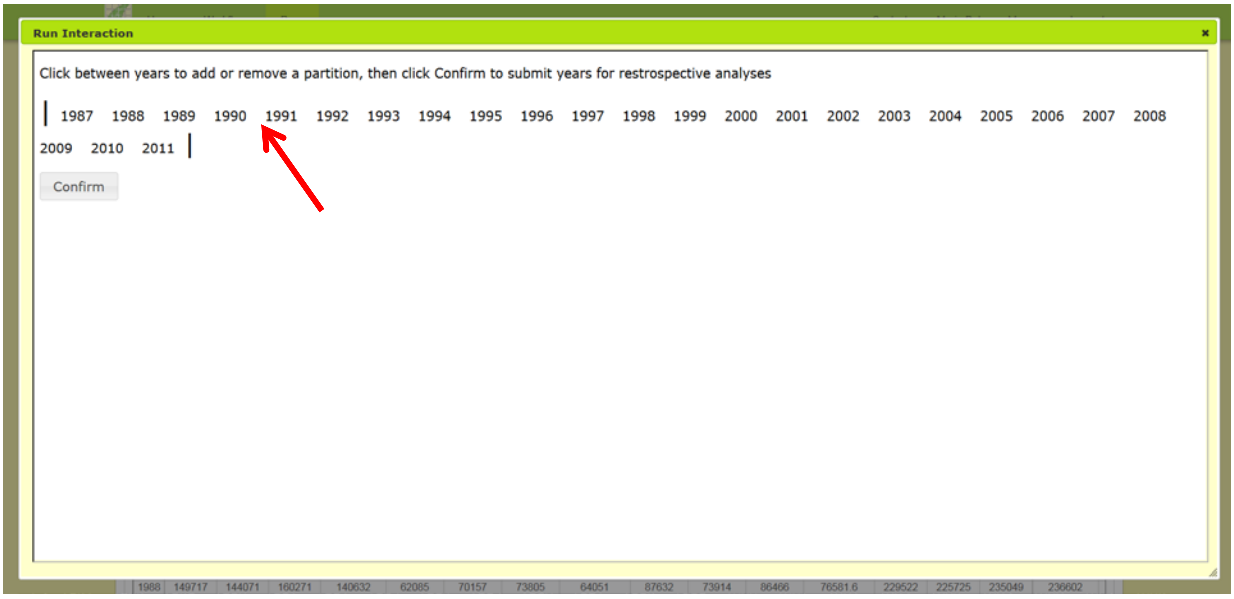
After the user has filled out the input ports and has clicked the ***Start Run***, the workflow performs the analysis. To complete all the analysis may take few minutes, depends on the number of ***Sims*** and ***NREPS*** to carry out the analyses.

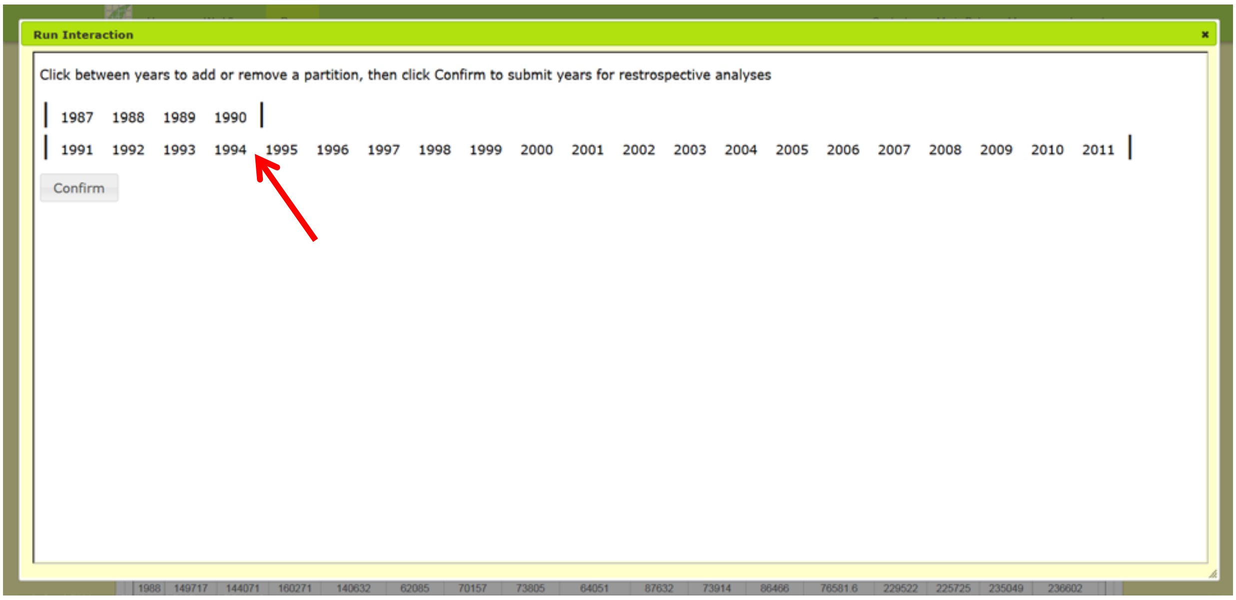
3.2. Dialogue

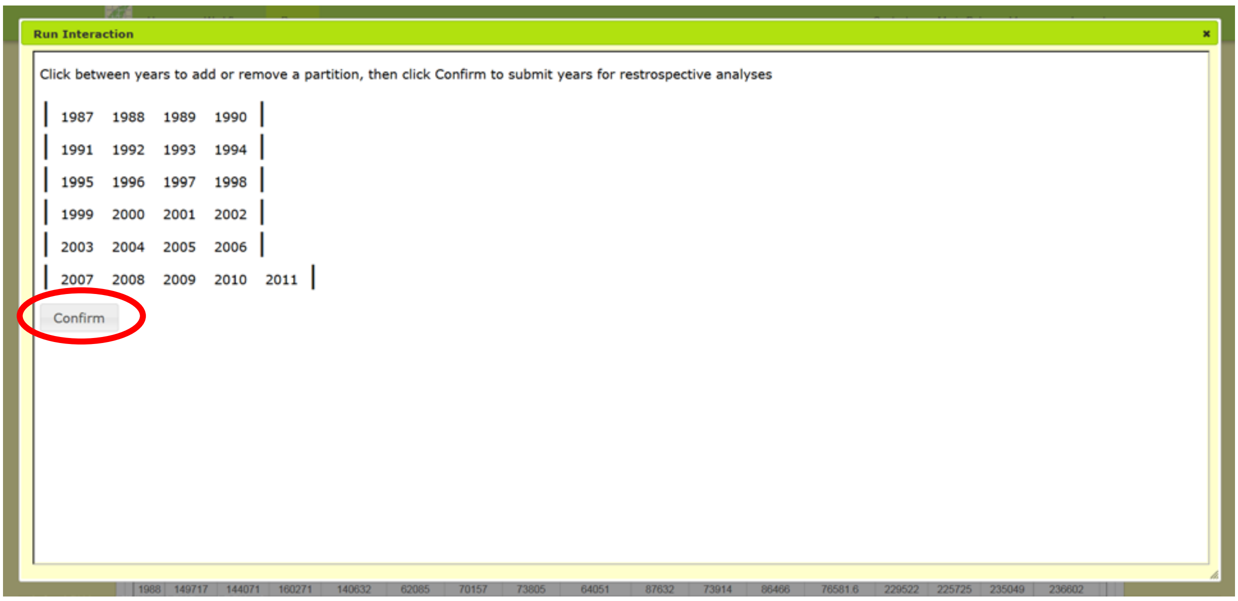
***Years for retrospective analysis*:** Set the sets for the study period manually. Click after the desired year.

In this example 6 time periods are used for the retrospective analysis (i.e., five 4-year periods and one 5-year period). In practice, the decision about an appropriate number of time periods should be based on two criteria: (i) the more time periods the better for the resolution of IID dynamics, and (ii) there needs to be a minimum number of years in each time period to reduce the influence of outlier demographic conditions the could produce population matrices that are not representative of long-term dynamics

Click every 4 year, (e.g. 1987 1988 1989 1990, see red arrow). Click between 1990 and 1991, repeat the process. The last period will be for 5 years. Finally, click in confirm (red oval).

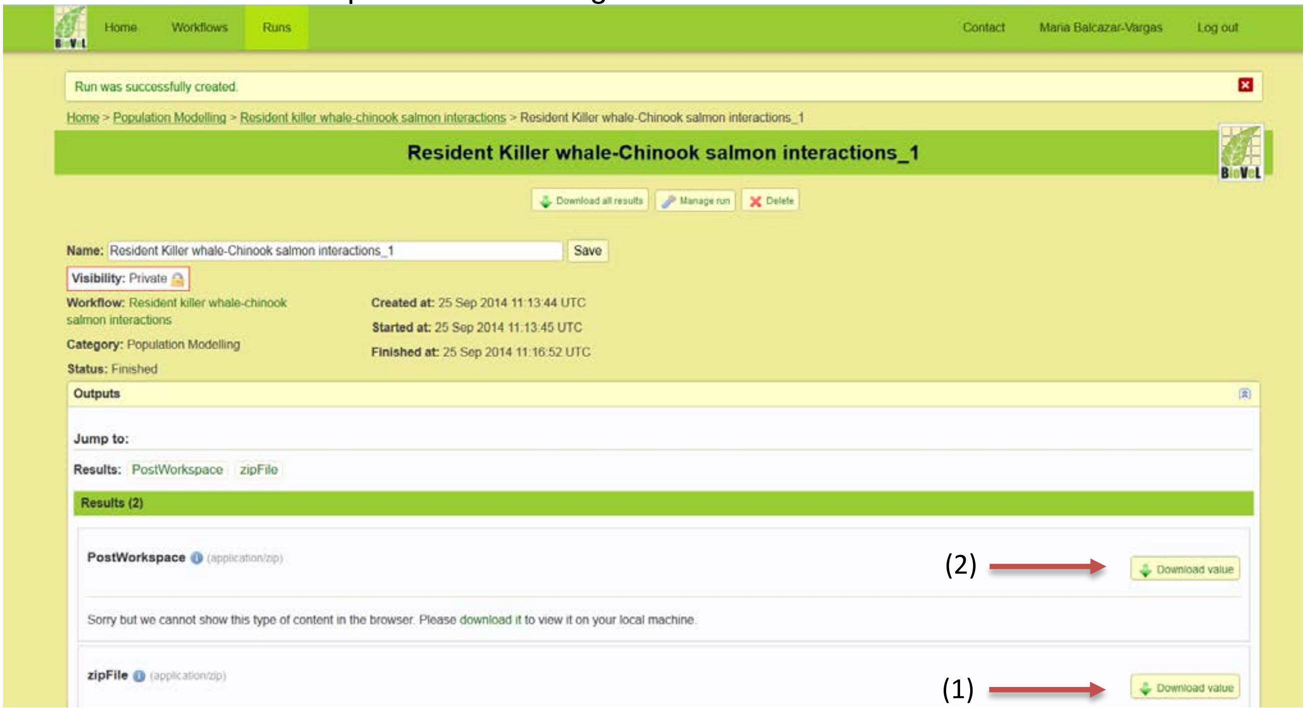

Run Interaction
Click between years to add or remove a partition, then click Confirm to submit years for restrospective analyses
1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008
2009 2010 2011
Confirm


Run Interaction
Click between years to add or remove a partition, then click Confirm to submit years for restrospective analyses
1987 1988 1989 1990
1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011
Confirm


Run Interaction
Click between years to add or remove a partition, then click Confirm to submit years for restrospective analyses
1987 1988 1989 1990
1991 1992 1993 1994
1995 1996 1997 1998
1999 2000 2001 2002
2003 2004 2005 2006
2007 2008 2009 2010 2011
Confirm

3.3 Outputs

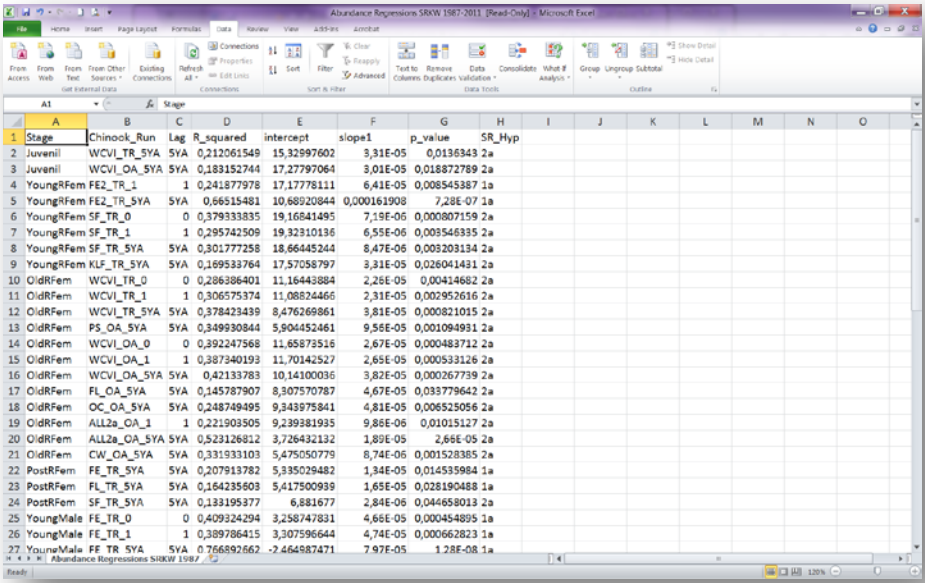
Once the analyses are finished, the user can download all the results by clicking Download value button (1). Numerical and graph results will be download as a zip file that can be save by the user. The numerical results are .csv files than can be opened with Excel and the plot files are .PDF files. A second result is the PostWorkspace, a zip file that is needed to run the second workflow: Exploration of fishing scenarios workflow.



3.3.1 Results

ZipFile

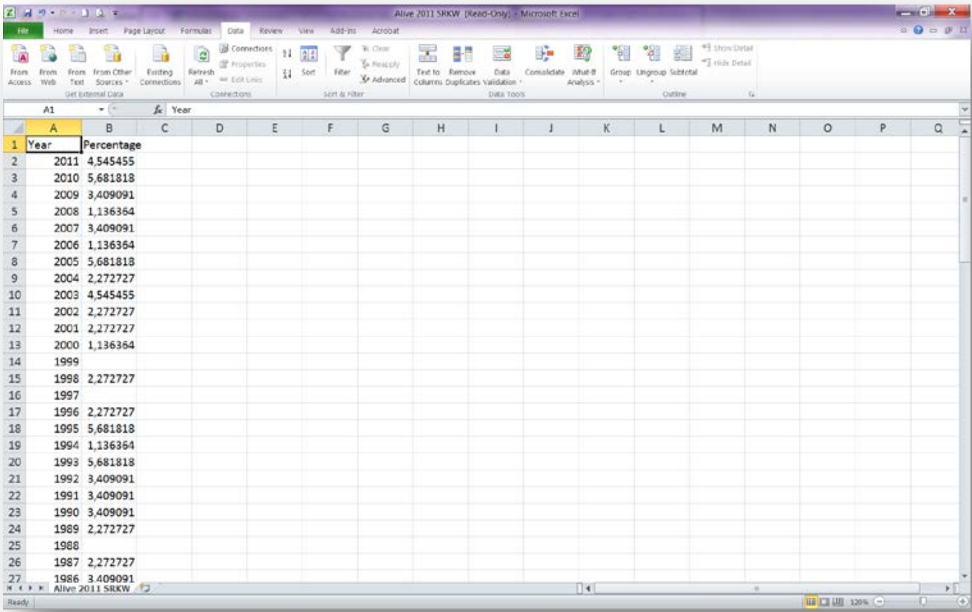
Abundance Regressions Population Start year-End year (csv): Statistics from beta regressions between Chinook abundance and killer whale vital rates.



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

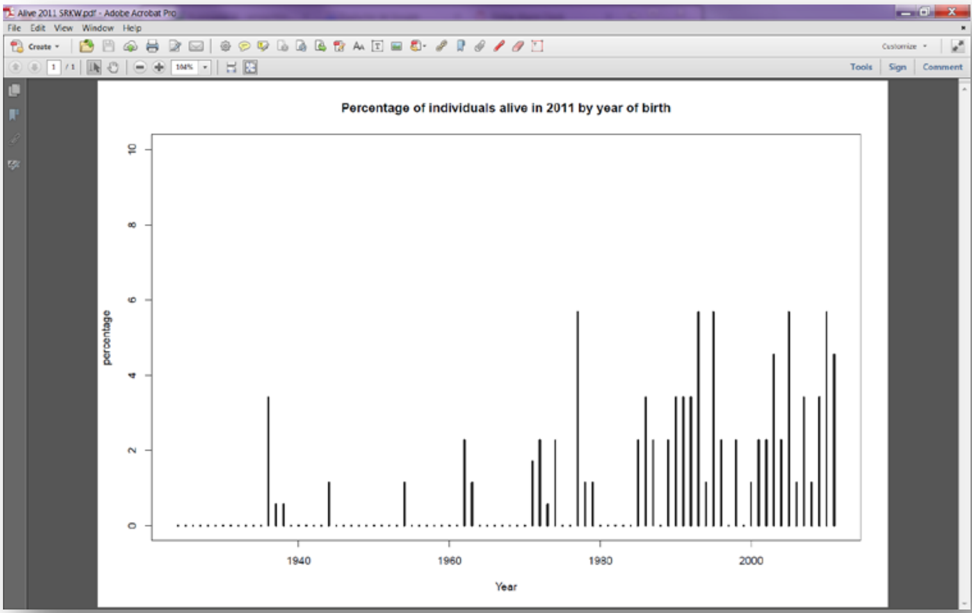


Year	Percentage
2011	4,545455
2010	5,681818
2009	3,409091
2008	1,136364
2007	3,409091
2006	1,136364
2005	5,681818
2004	2,272727
2003	4,545455
2002	2,272727
2001	2,272727
2000	1,136364
1999	
1998	2,272727
1997	
1996	2,272727
1995	5,681818
1994	1,136364
1993	5,681818
1992	3,409091
1991	3,409091
1990	3,409091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

Alive 2011 SRKW.csv

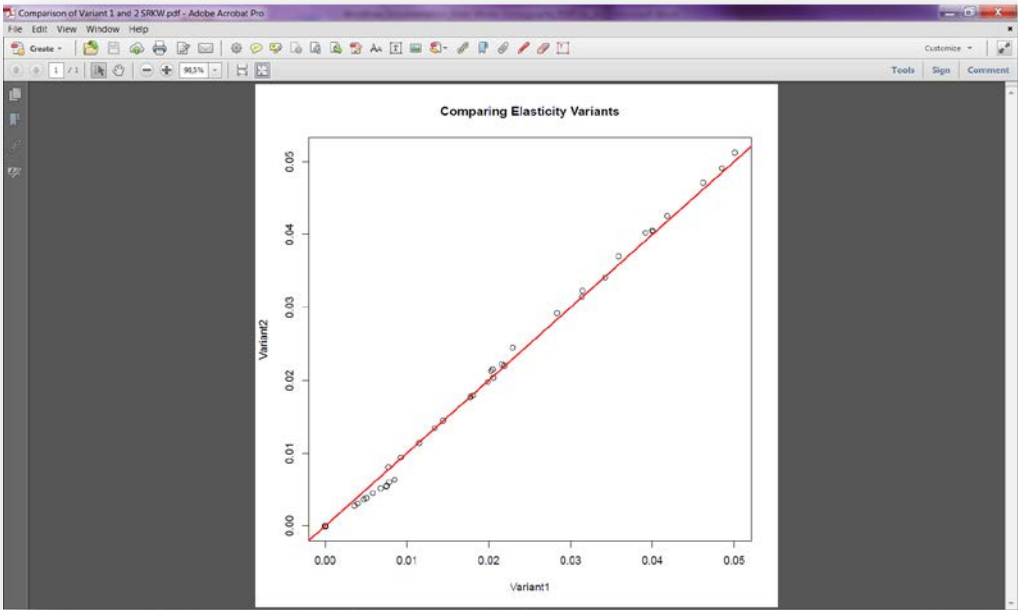
***Relative importance of Chinook salmon abundance on resident Killer whale population viability* pack**

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



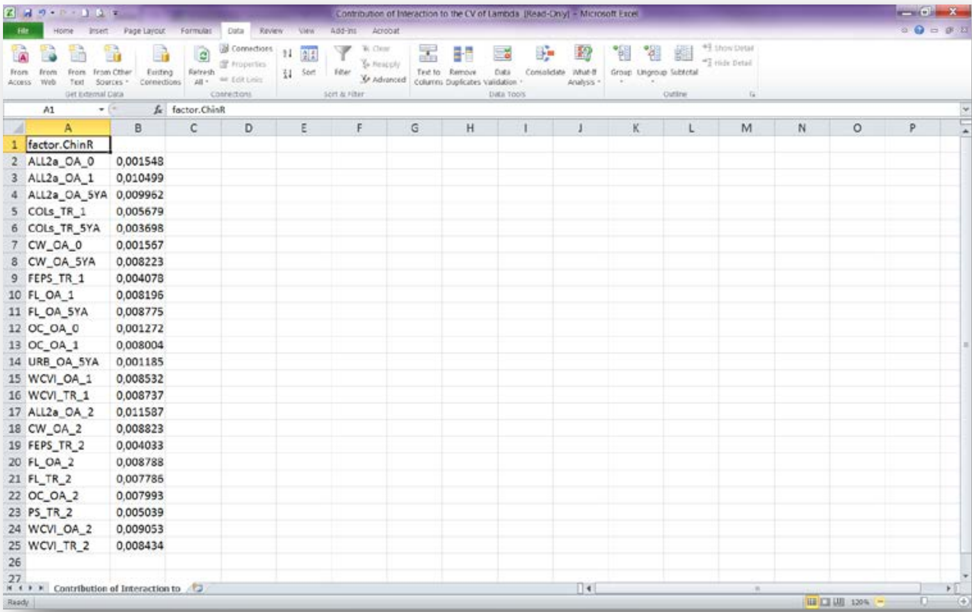
Alive 2011 SRKW.pdf

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

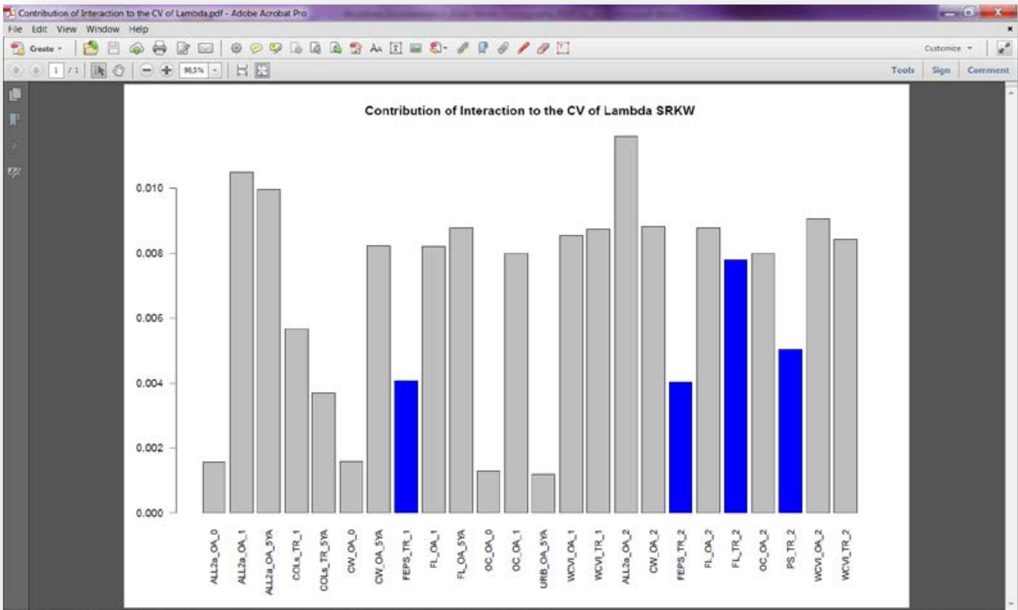
Contribution of Interaction to the CV of Lambda (csv): This file shows the proportion of the CV in population growth due to specific interactions between Chinook salmon stocks and abundance type and killer whale vital rates as explained by retrospective perturbation analysis.



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

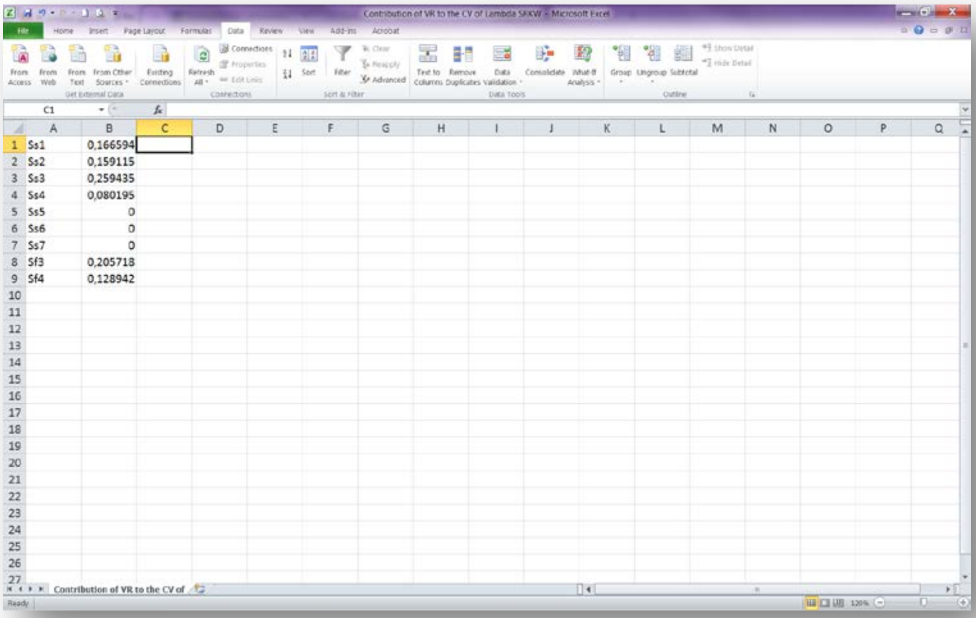
Contribution of Interaction to the CV of Lambda (csv)

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



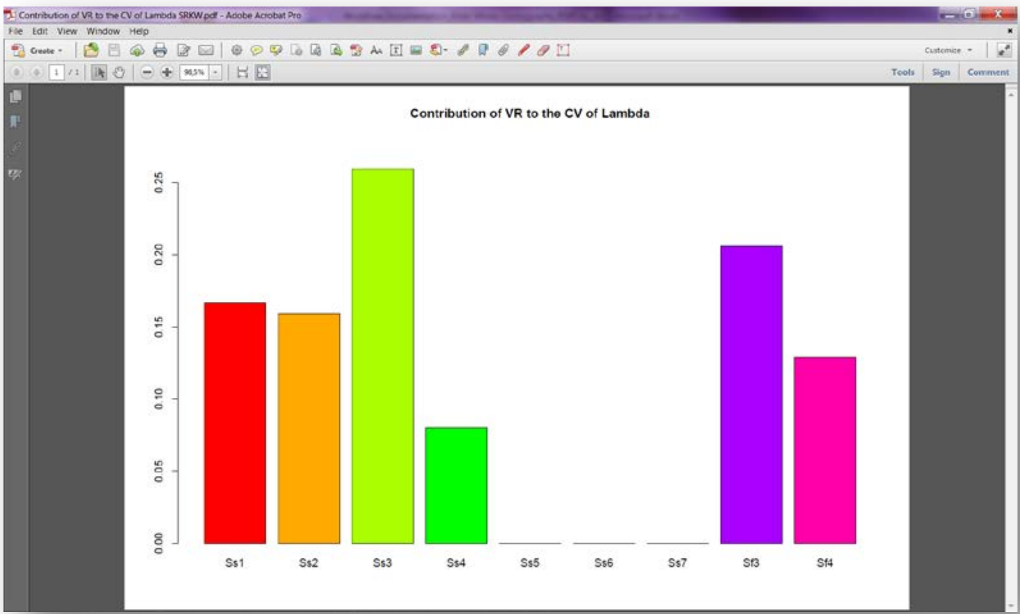
Contribution of Interaction to the CV of Lambda (pdf)

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



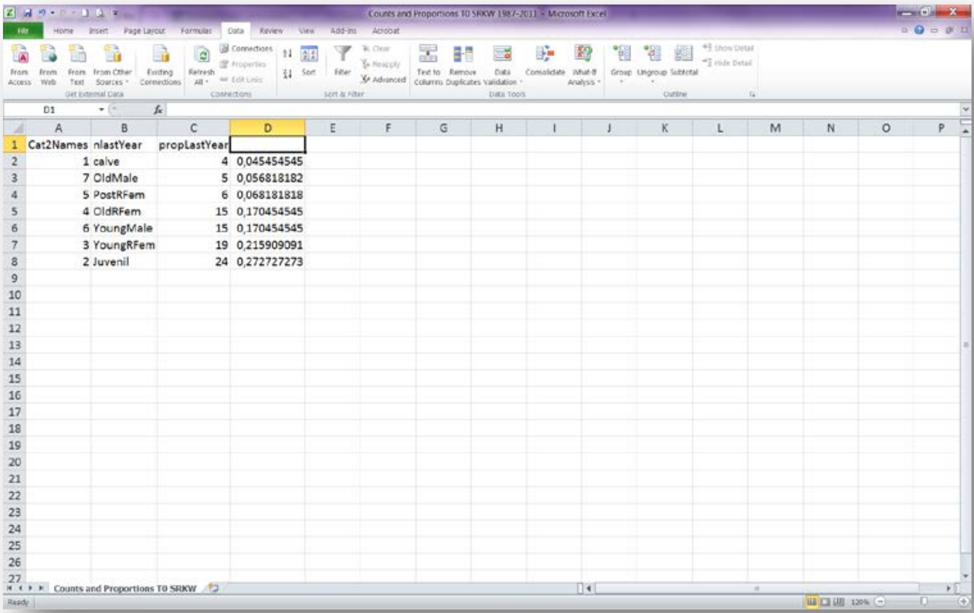
Contribution of VR to the CV of Lambda Population (cvs)

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)

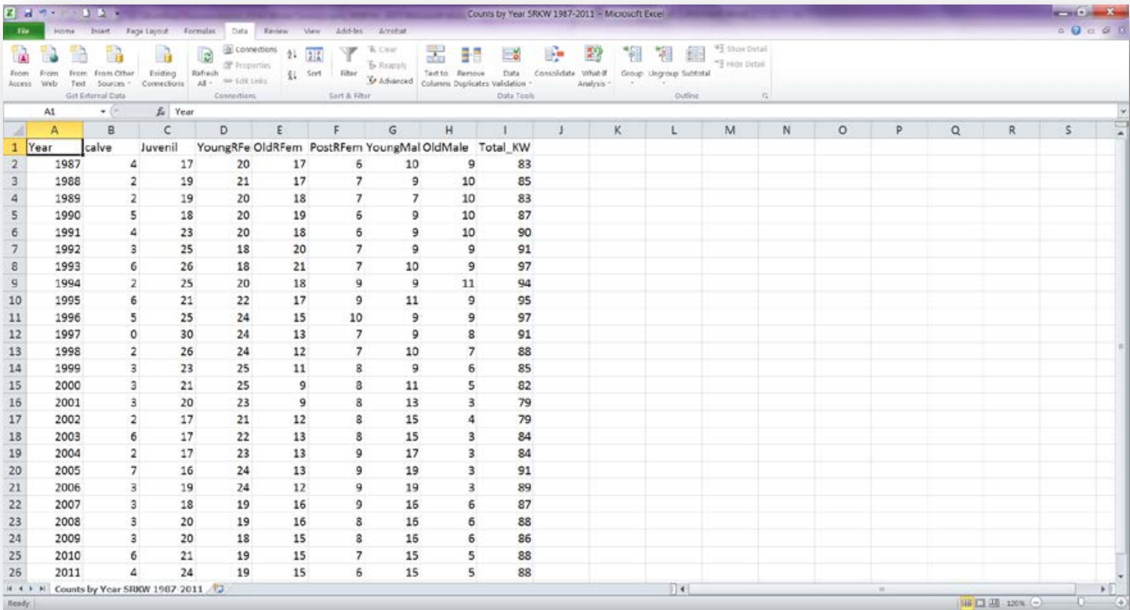
Counts and Proportions T0 Population Start year-End year (csv): Number of individuals and relative proportion by stage in the last year of the selected time period. These proportions are used to represent initial conditions for projections



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)

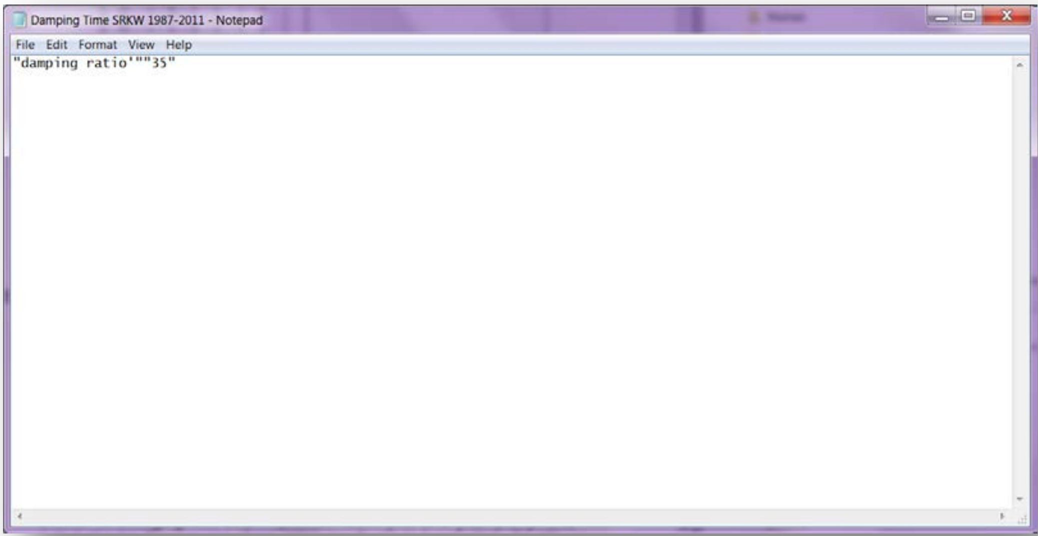
Counts by Year Population Start year-End year (csv): Number of individuals by life stage (calves, juveniles, young reproductive females, old reproductive females, post-reproductive females, young mature males, and old mature males) and year through the selected time period. Last column represents total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

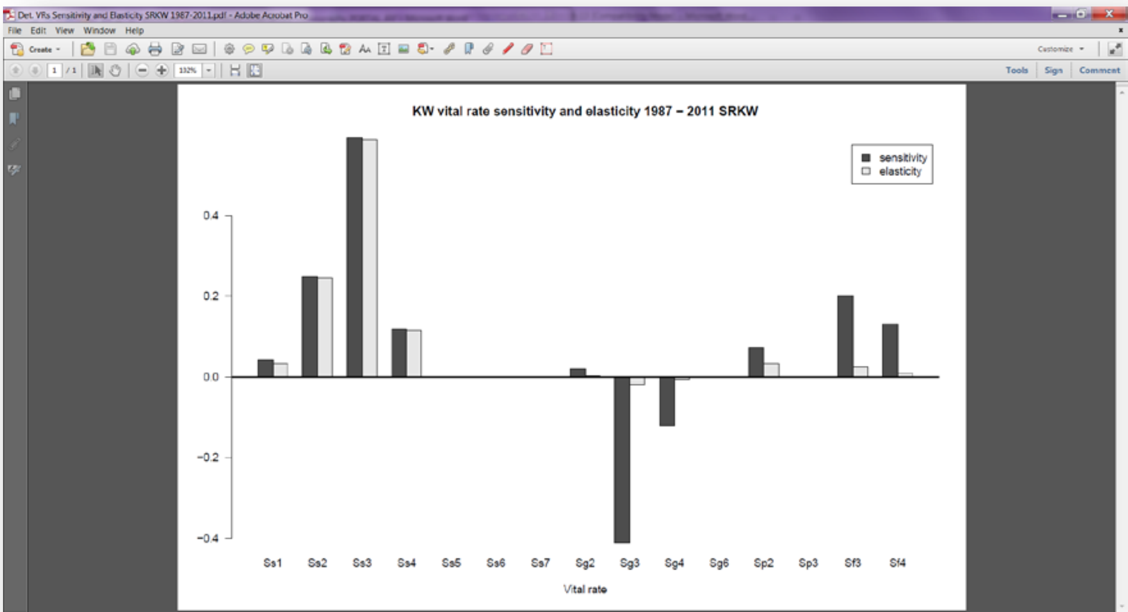
Counts by Year SRKW 1987-2011

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.



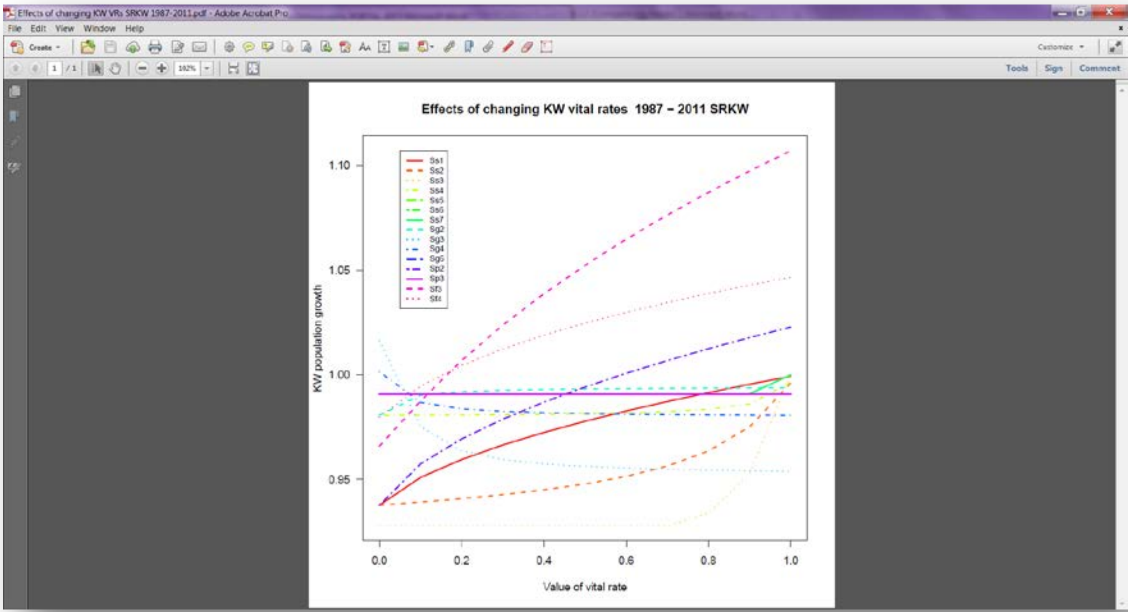
Damping Time SRKW 1987-2011

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)



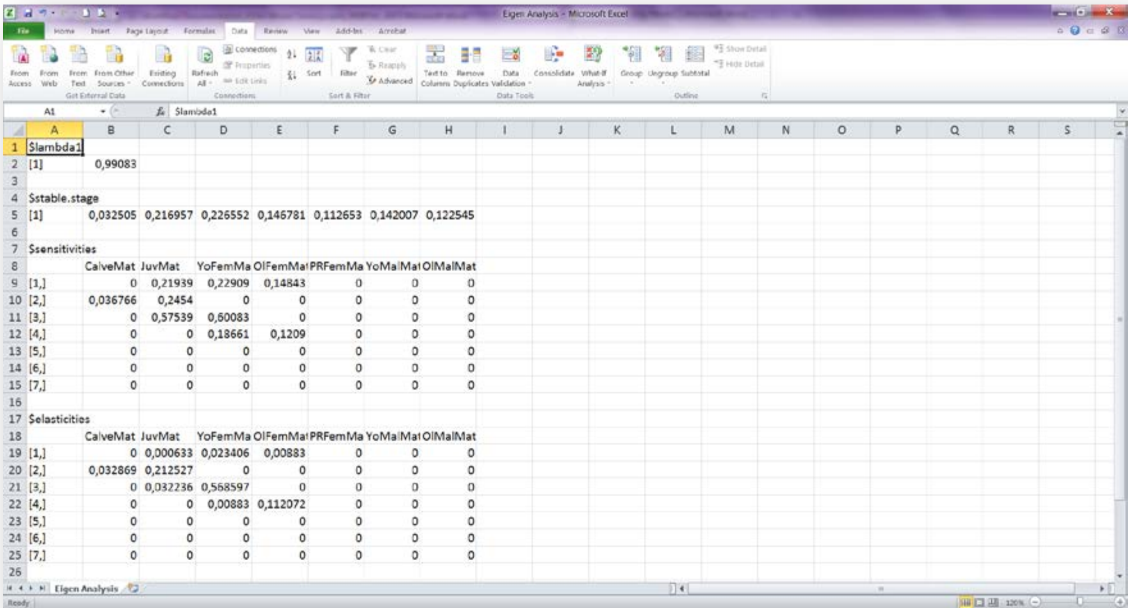
Det. VRs Sensitivity and Elasticity SRKW 1987-2011

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

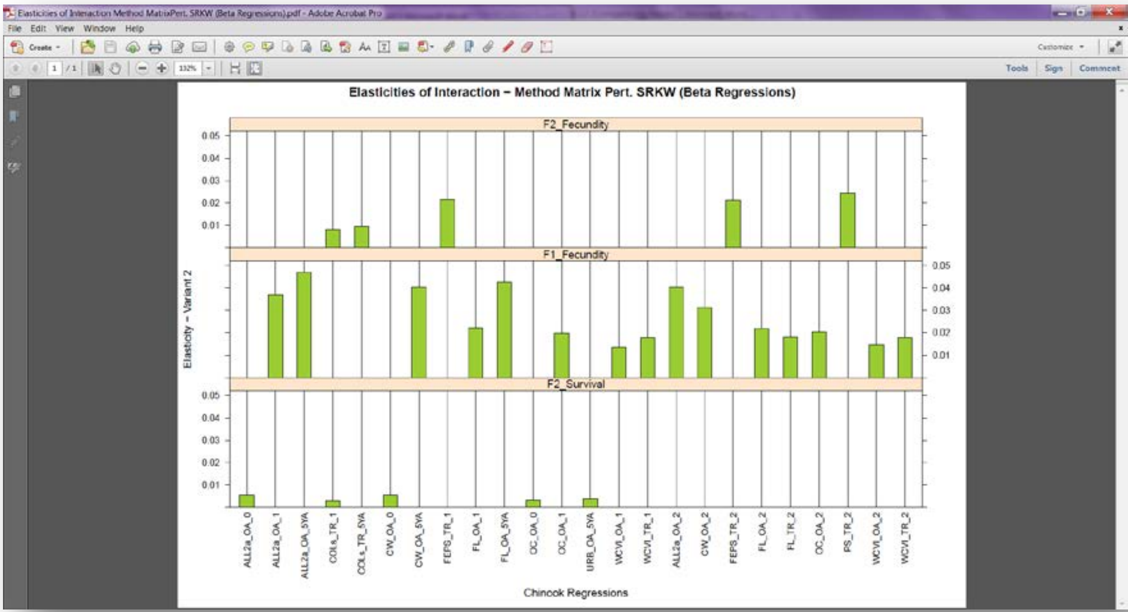
Eigen Analysis (txt): Dominant eigenvalue (asymptotic population growth rate), stable stage distribution, sensitivities, elasticities, reproductive value, and damping ratio based on mean matrix of selected population.



	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
26								

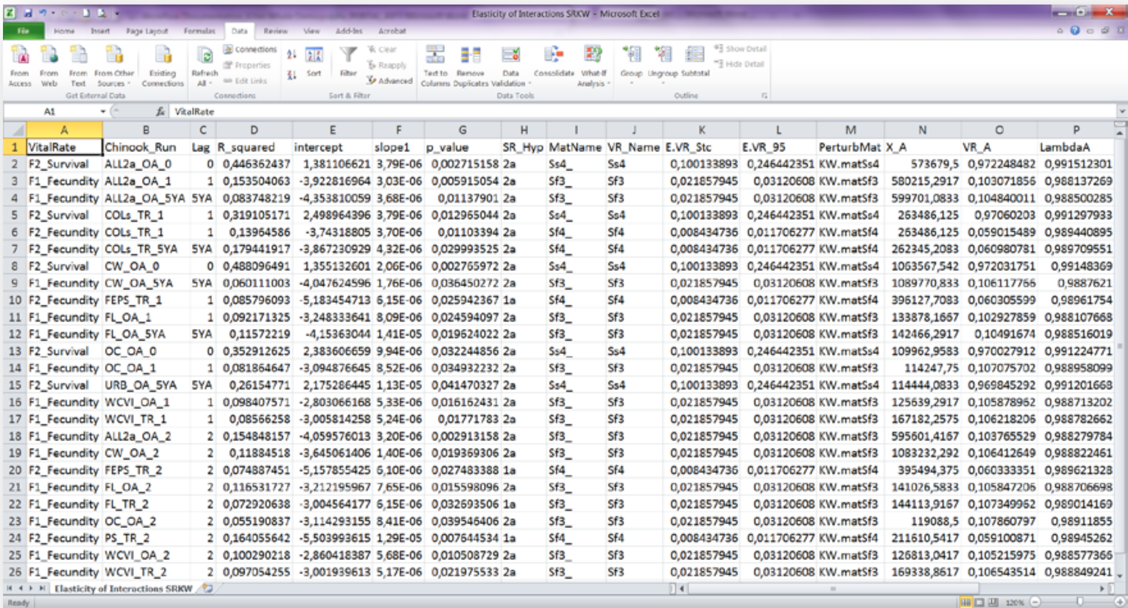
Eigen Analysis (open in Excel)

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.

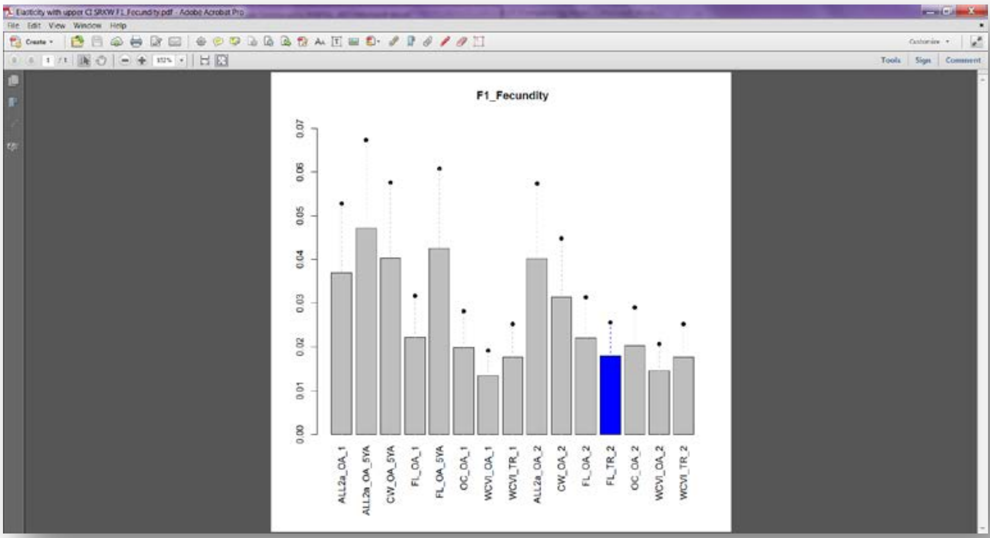


	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	VitalRate	Chinook_Run	Lag	R_squared	intercept	slope1	p_value	SR_Hyp	MatName	VR_Name	E.VR_Stc	E.VR_95	PerturbMat	X_A	VR_A	LambdaA
2	F2_Survival	ALL2a_OA_0	0	0,446362437	1,381106621	3,79E-06	0,002715158	2a	Ss4_	Ss4	0,100133893	0,246442351	KW.matSs4	573679,5	0,972248482	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

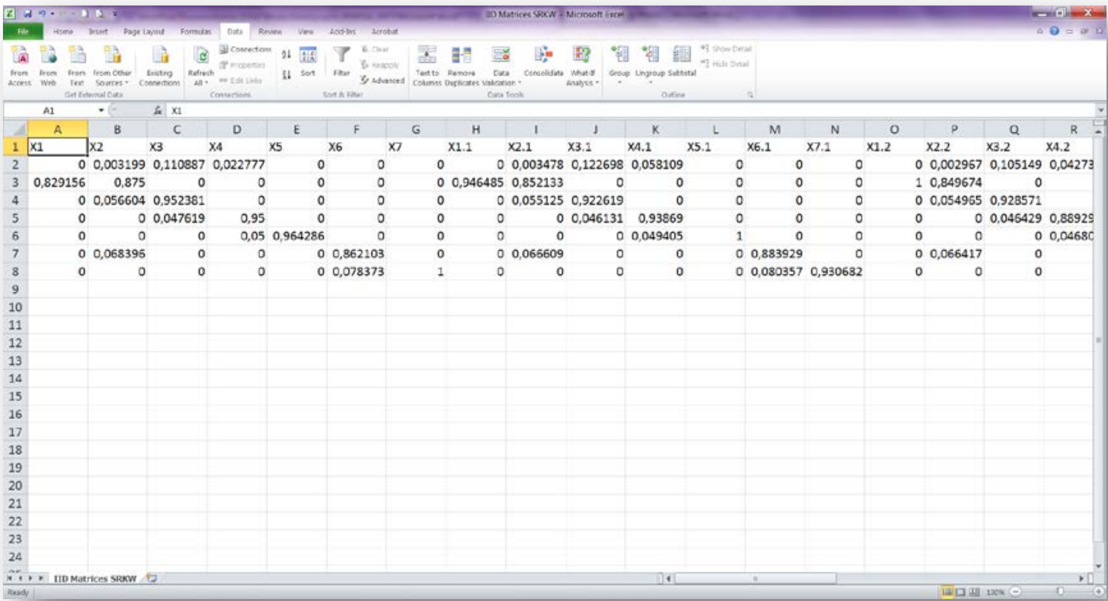
***Relative importance of Chinook salmon abundance on resident Killer whale population viability* pack**

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

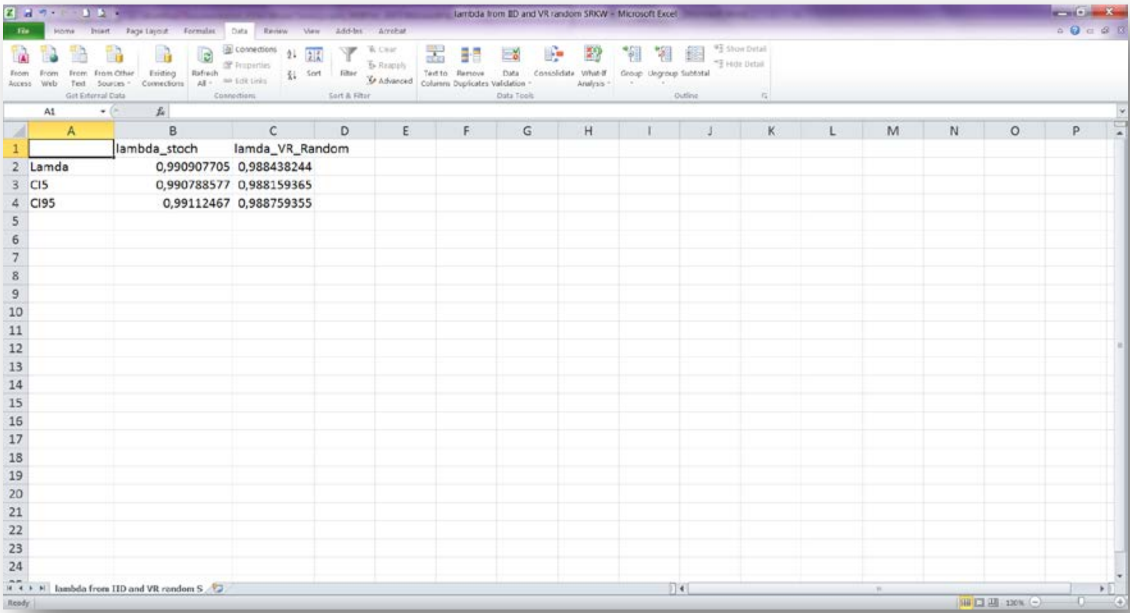
IID Matrices Population (csv): Projection matrices produced by discrete time periods within the study period (see Input Port “ENVIR”). Each of these matrices represents population dynamics for discrete temporal strata. Default is six time periods (see Input Ports “Study_period_year_x”). These matrices 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 SRK

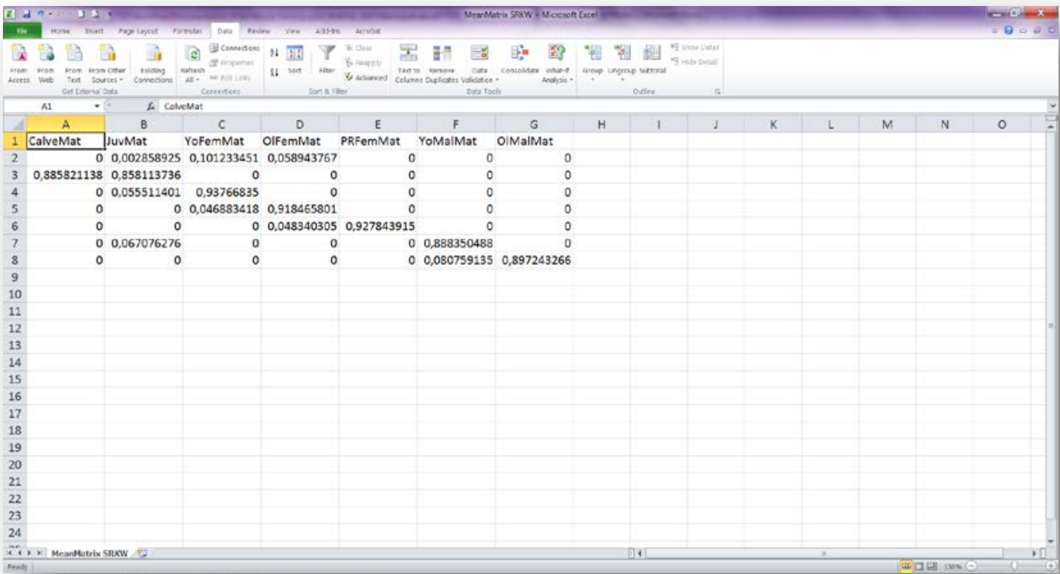
lambda from IID and VR random Population (csv): Stochastic population growth rate computed from IID matrices and from vital rates as random variables (see Input Port “ENVIR”)



	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

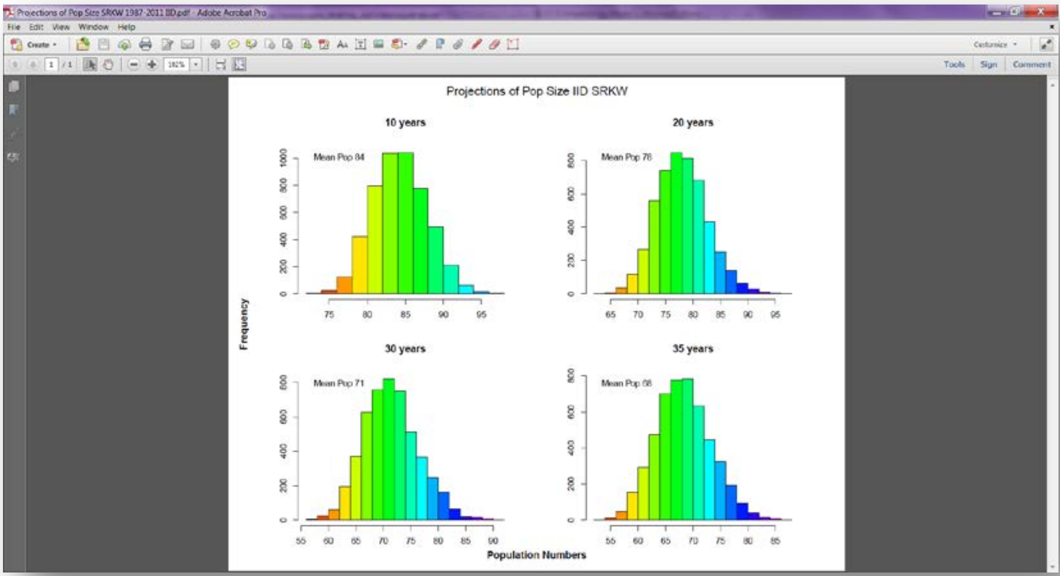
MeanMatrix Population (csv): Two-sex, stage structured matrix based on mean vital rate (survival and fecundity) values for the selected time period. A birth-flow matrix model is used with seven life stages and fixed transition probabilities based on stage duration (details in Vélez-Espino et al. 2014).



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

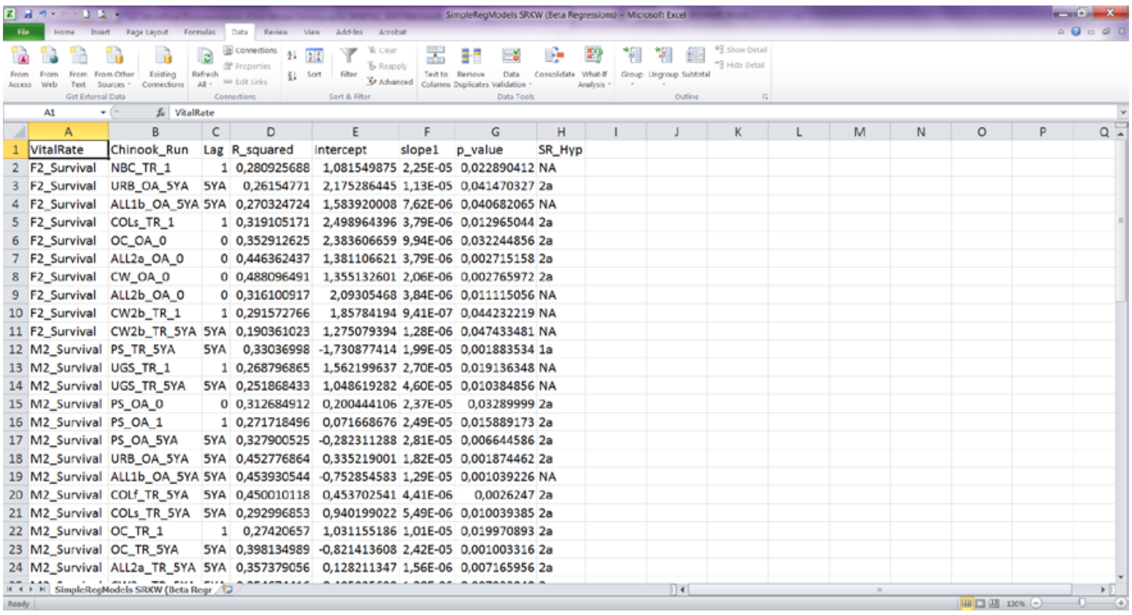
MeanMatrix SRKW

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

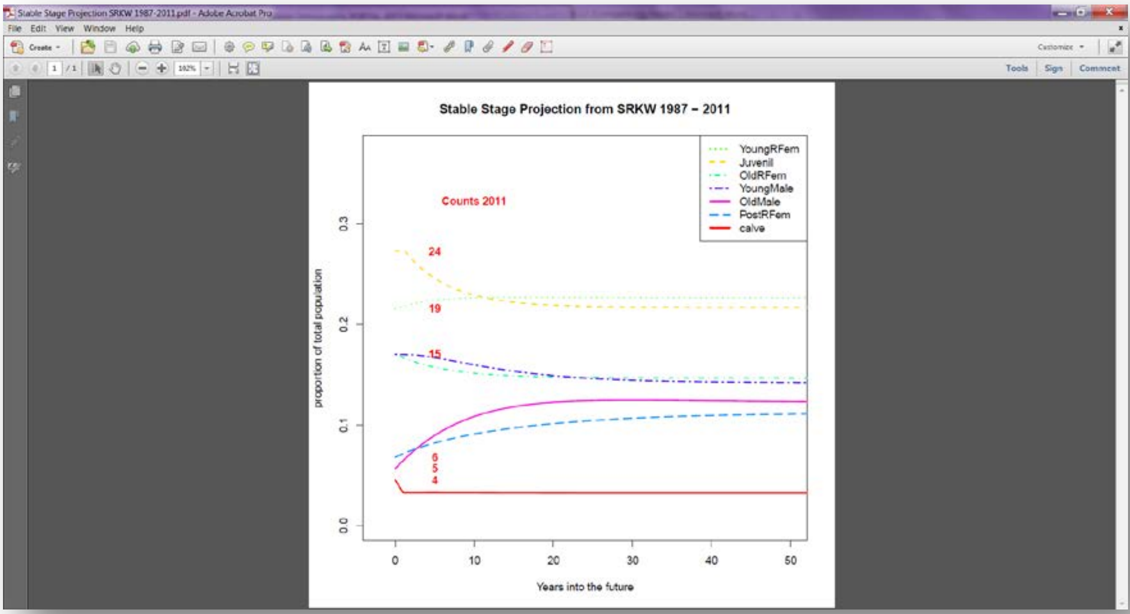
SimpleRegModels Population (Type of Regressions) (csv): Statistics for all significant regressions (beta or linear) between killer whale vital rates and Chinook salmon stocks. The list of regressions includes vital rates not contributing directly to population growth such as survival of males and post-reproductive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

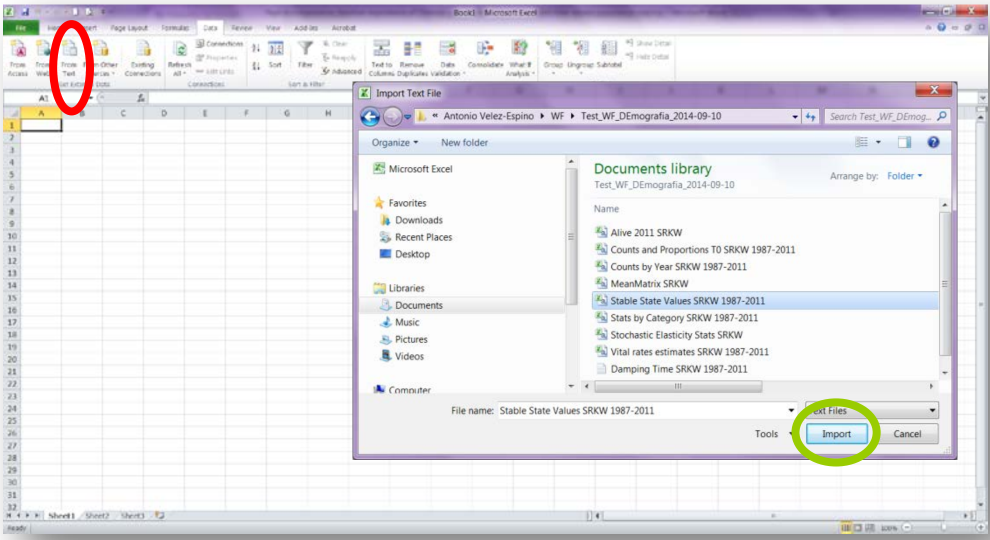


Stable Stage Projection SRKW 1987-2011

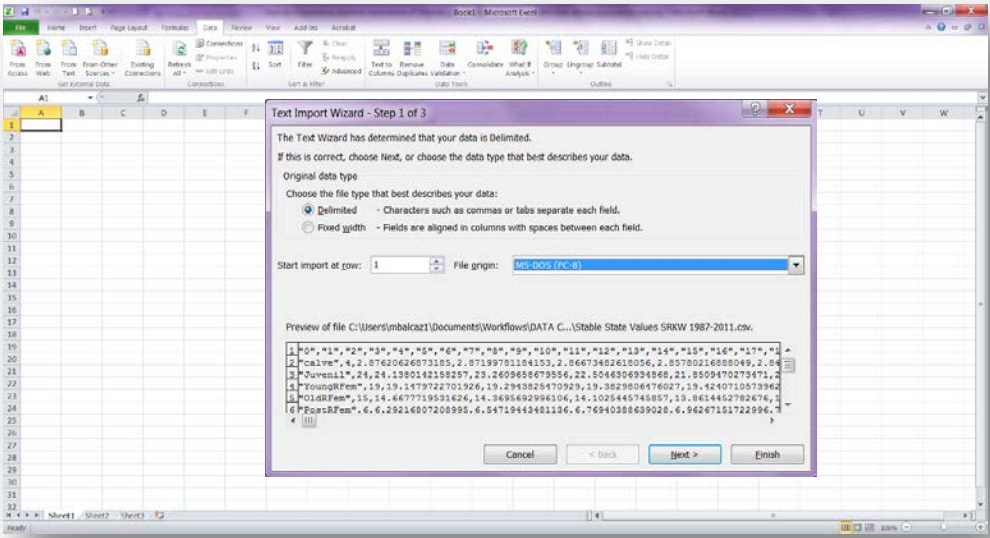
Stable State Values Population Start year – End year (csv): Long-term projections of population size by life stage based on transient dynamics.

Note: If the user used ≥ 1850 ***Sims***, you need to open the file as follows:

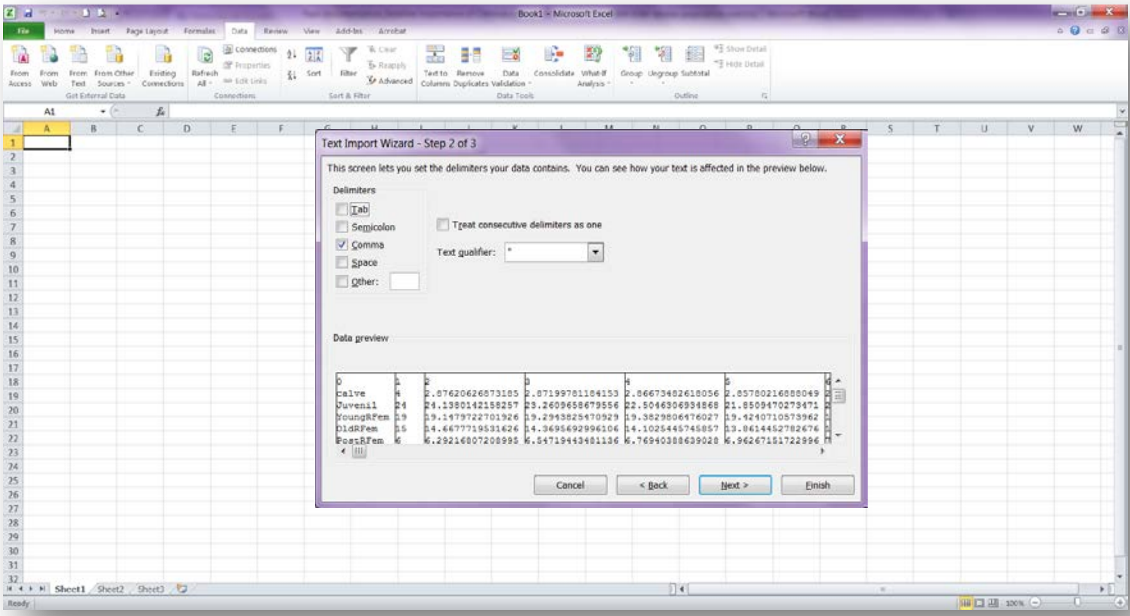
1. Open excel (versions 2007 onwards)
2. Go to Data tab
3. Click on From text (red oval)
4. Open the Folder where the file *Stable State Values SRKW 1987-2011.csv* is.
5. Import the file *Stable State Values SRKW 1987-2011.csv* (green oval).



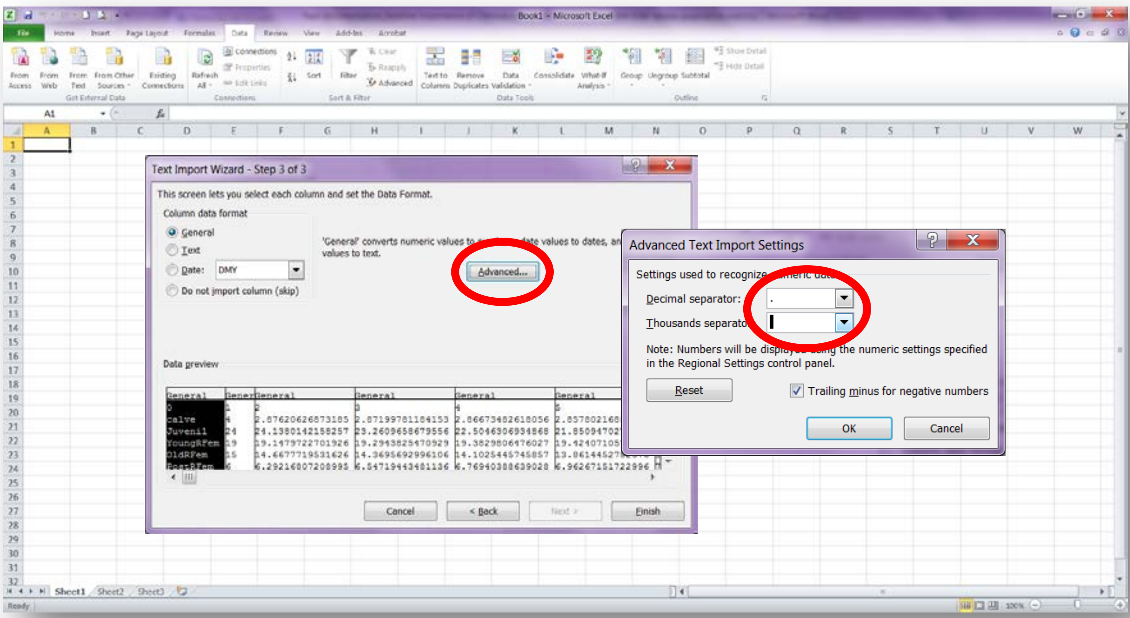
6. Follow three steps to open the file
    a. Text import wizard: step 1:
        i. Choose Delimited
        ii. File origin: MS DOS (PC-8)
        iii. Click next



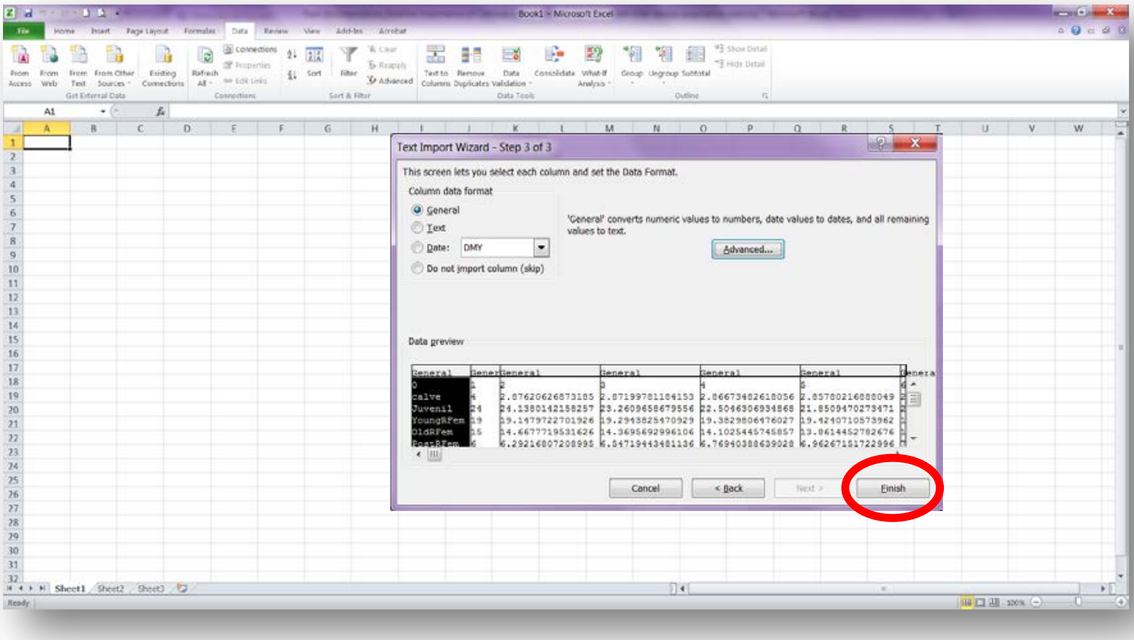
    b. Text import wizard: step 2:
        i. Choose Coma delimited
        ii. Click next



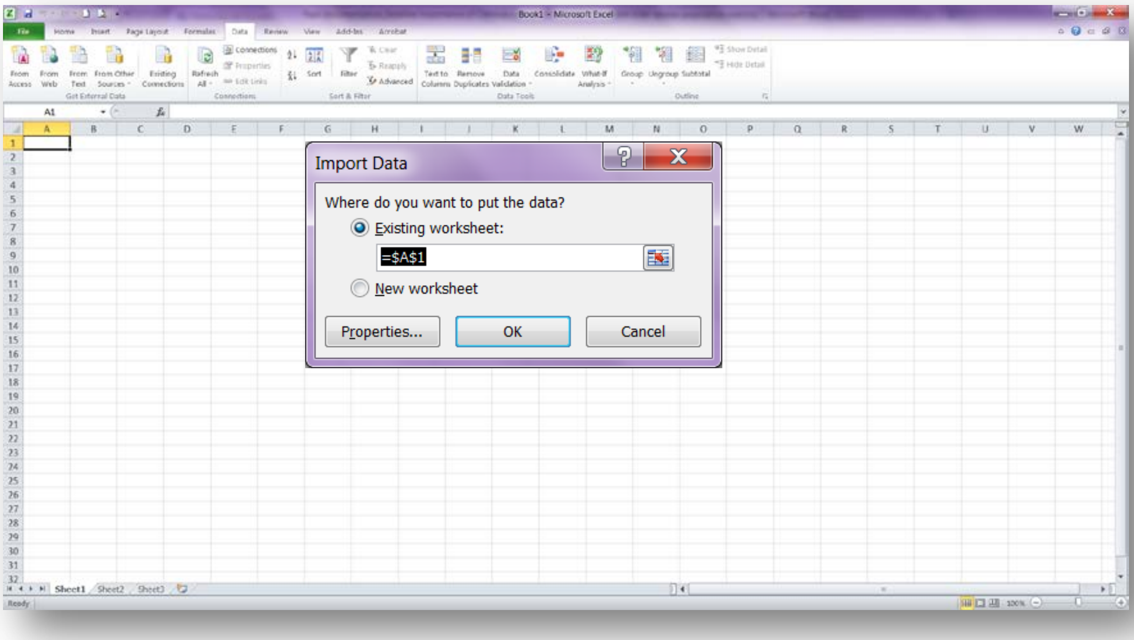
c. Text import wizard: step 3:
   i. Click in Advance (red oval) and the Advance Text Import Settings window appears.
   ii. Decimal separator: decimal numbers must be separated by a period, red oval).
   iii. Thousands separator: choose empty space (red oval).
   iv. Click ok

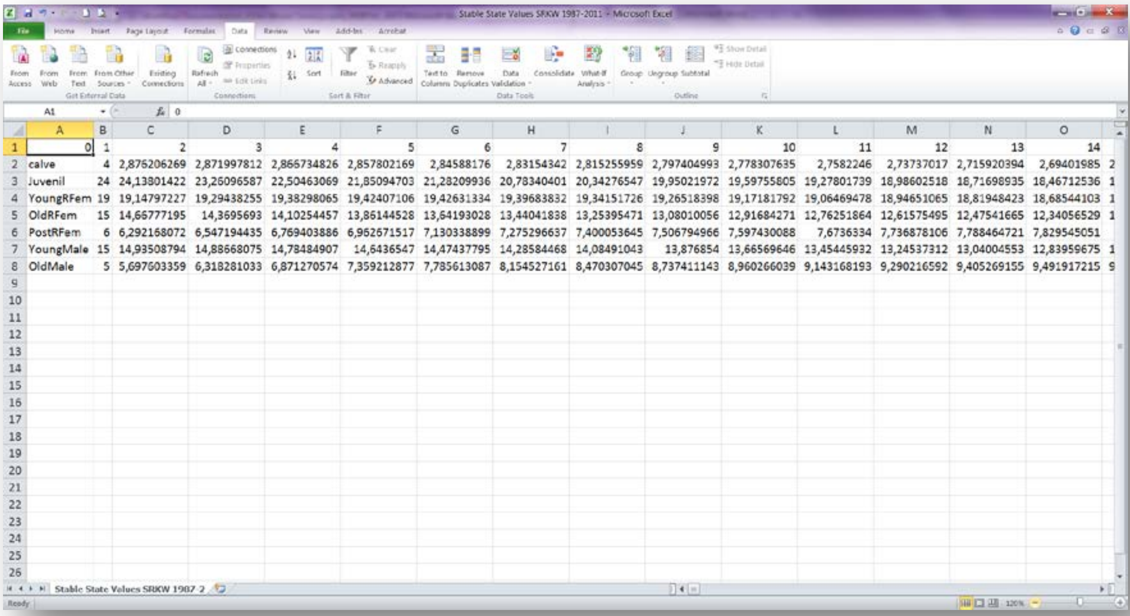


7. Click in Finish.



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

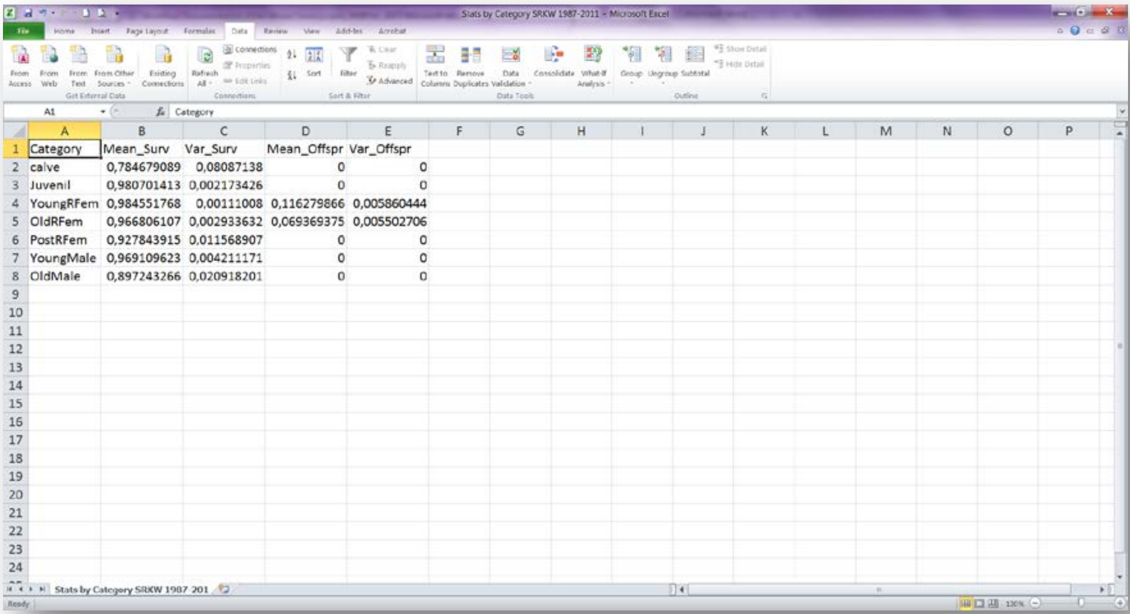




0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
calve	4	2,876206269	2,871997812	2,866734826	2,857802169	2,84588176	2,83154342	2,815255959	2,797404993	2,778307635	2,7582246	2,73737017	2,715920394	2,69401985
Juvenil	24	24,13801422	23,26096587	22,50463069	21,85094703	21,28209936	20,78340401	20,34276547	19,95021972	19,59755805	19,27801739	18,98602518	18,71698935	18,46712536
YoungRFem	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
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
PostRFem	6	6,292168072	6,547194435	6,769403886	6,962671517	7,130338899	7,275296637	7,400053645	7,506794966	7,597430088	7,6736334	7,736878106	7,788464721	7,829545051
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
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

Stable State Values SRKW 1987-2011

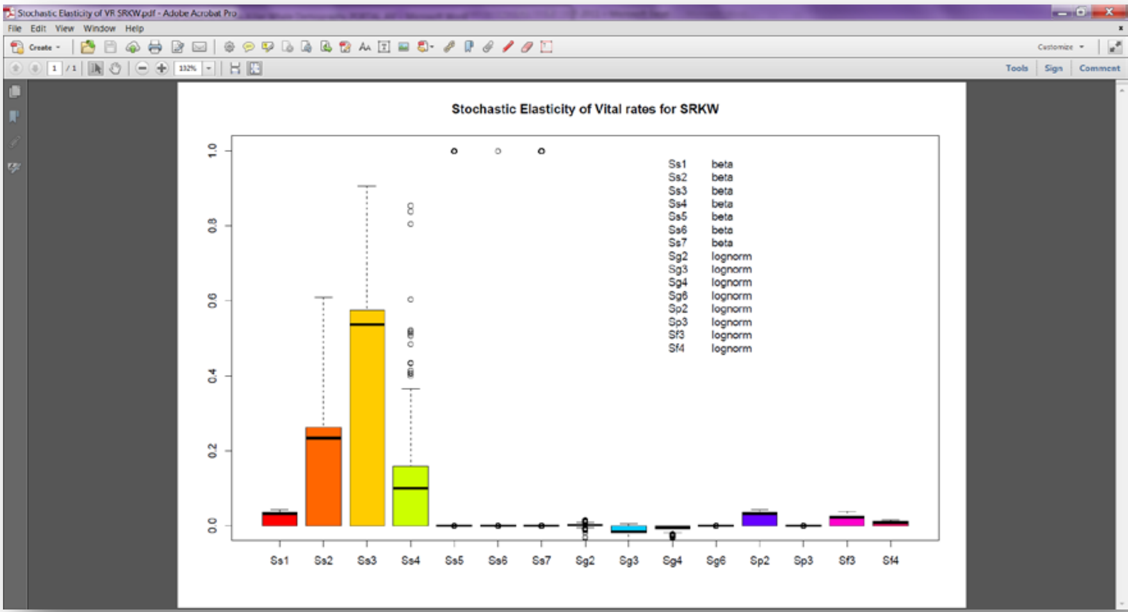
Stats by Category Population Start year – End year (csv): Mean and variance of vital rates (survival and fecundity) by life stage. Mean and variance generated from annual values during the selected time period are used to generate vital rate probability distributions (see "Stochastic_Vital_rates").



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

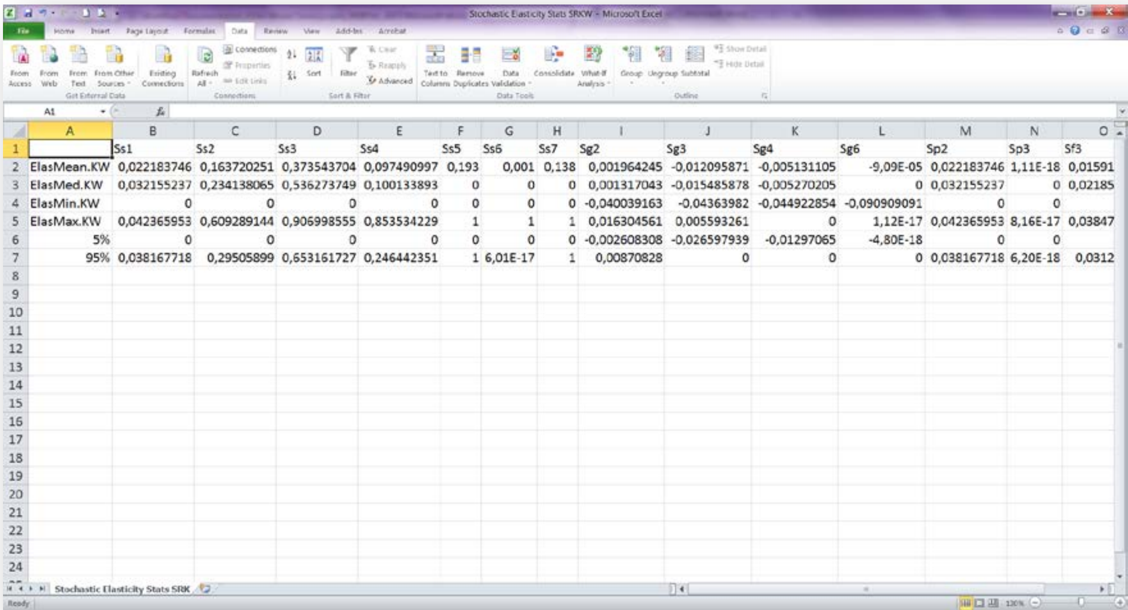
Stats by Category SRKW 1987-2011

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



Stochastic Elasticity of VR SRKW

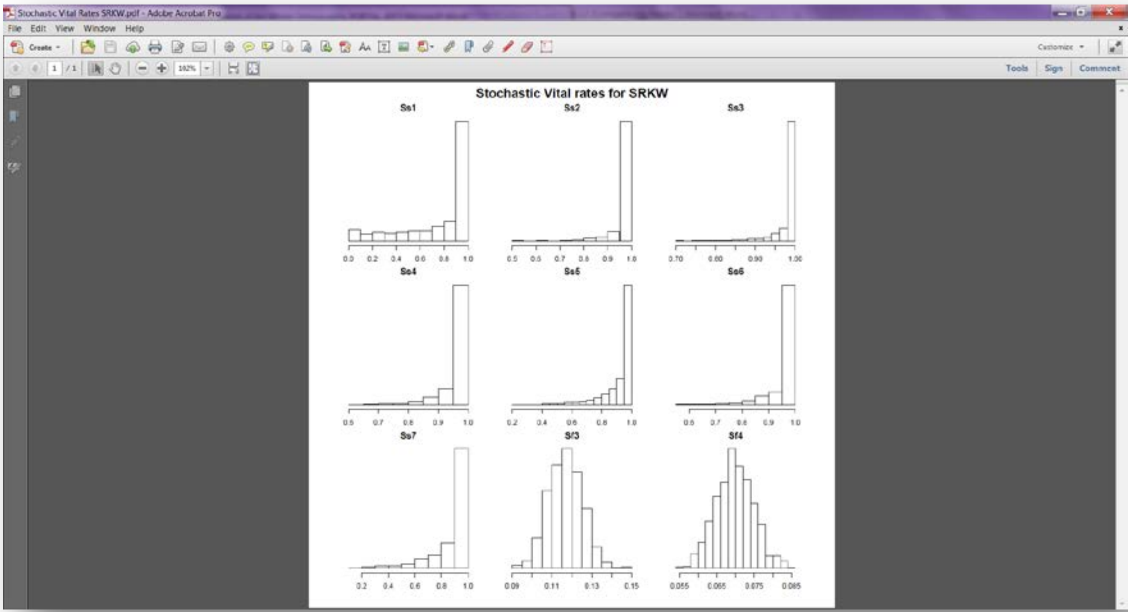
Stochastic Elasticity Stats Population (csv): Mean, median, minimum, maximum, and 95% confidence limits of stochastic elasticities of vital rates.



	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.



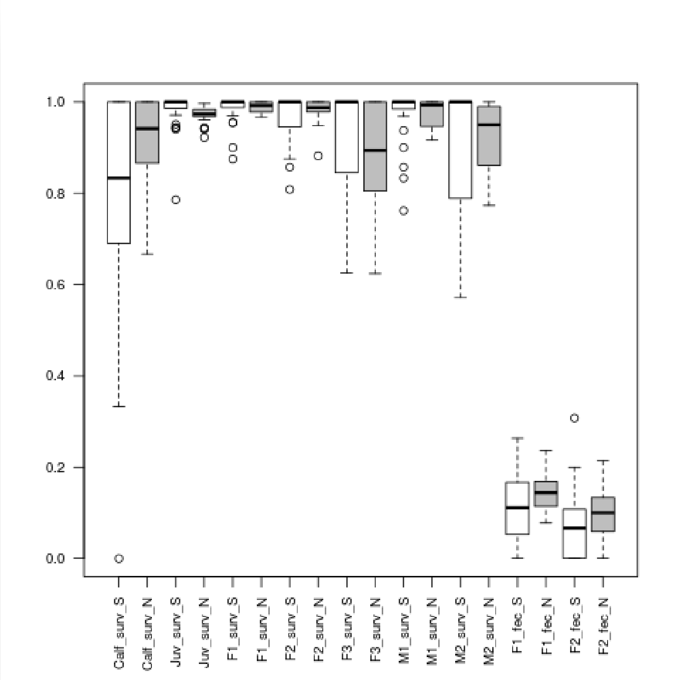
Stochastic Vital Rates SRKW

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

PostWorkspace

PostWorkspace (zip file): An R Workspace that transfers values from the Resident killer whale-chinook salmon interactions (main) workflow to the Exploration of fishing scenario (post-processing) workflow. This file must be provided as an input to the post-processing workflow in order for it to have access to values generated in the main workflow.

Exploration of fishing scenarios.

This workflow cannot be run without running first the Resident killer whale-chinook salmon interactions workflow. The Exploration of fishing scenarios workflow needs the PostWorkspace, a zip file generated by the first workflow. See details page 39, PostWorkspace (zip file).

2. Input files for tutorial

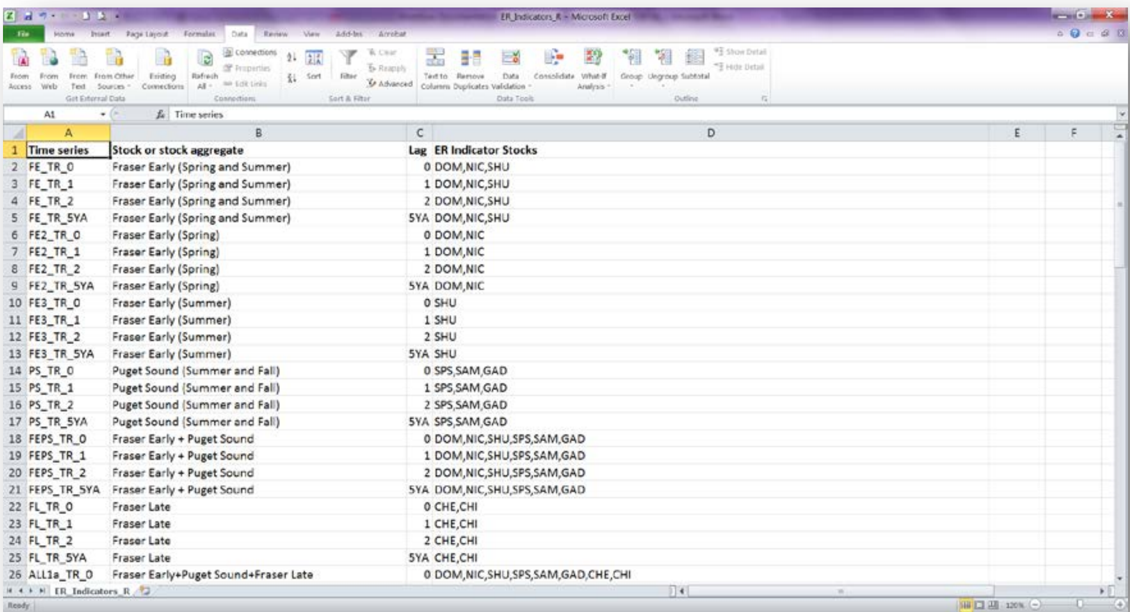
The workflow accepts input data in a .csv, coma delimited and a zip file. The examples input files for the tutorial are available and described below. In this tutorial, five input files are used.

2.1 Input data

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

- ER_Indicators_R
- Term_Run_R
- TRE_HR_R
- TRE_R
- PostWorkspace

ER_Indicators_R : This file shows the exploitation rate (ER) indicator stocks used to represent exploitation-rate time series with terminal-run time series of Chinook salmon aggregates.



Time series	Stock or stock aggregate	Lag	ER Indicator Stocks
FE_TR_0	Fraser Early (Spring and Summer)	0	DOM,NIC,SHU
FE_TR_1	Fraser Early (Spring and Summer)	1	DOM,NIC,SHU
FE_TR_2	Fraser Early (Spring and Summer)	2	DOM,NIC,SHU
FE_TR_5YA	Fraser Early (Spring and Summer)	5YA	DOM,NIC,SHU
FE2_TR_0	Fraser Early (Spring)	0	DOM,NIC
FE2_TR_1	Fraser Early (Spring)	1	DOM,NIC
FE2_TR_2	Fraser Early (Spring)	2	DOM,NIC
FE2_TR_5YA	Fraser Early (Spring)	5YA	DOM,NIC
FE3_TR_0	Fraser Early (Summer)	0	SHU
FE3_TR_1	Fraser Early (Summer)	1	SHU
FE3_TR_2	Fraser Early (Summer)	2	SHU
FE3_TR_5YA	Fraser Early (Summer)	5YA	SHU
PS_TR_0	Puget Sound (Summer and Fall)	0	SPS,SAM,GAD
PS_TR_1	Puget Sound (Summer and Fall)	1	SPS,SAM,GAD
PS_TR_2	Puget Sound (Summer and Fall)	2	SPS,SAM,GAD
PS_TR_5YA	Puget Sound (Summer and Fall)	5YA	SPS,SAM,GAD
FEPS_TR_0	Fraser Early + Puget Sound	0	DOM,NIC,SHU,SPS,SAM,GAD
FEPS_TR_1	Fraser Early + Puget Sound	1	DOM,NIC,SHU,SPS,SAM,GAD
FEPS_TR_2	Fraser Early + Puget Sound	2	DOM,NIC,SHU,SPS,SAM,GAD
FEPS_TR_5YA	Fraser Early + Puget Sound	5YA	DOM,NIC,SHU,SPS,SAM,GAD
FL_TR_0	Fraser Late	0	CHE,CHI
FL_TR_1	Fraser Late	1	CHE,CHI
FL_TR_2	Fraser Late	2	CHE,CHI
FL_TR_5YA	Fraser Late	5YA	CHE,CHI
ALL1a_TR_0	Fraser Early+Puget Sound+Fraser Late	0	DOM,NIC,SHU,SPS,SAM,GAD,CHE,CHI

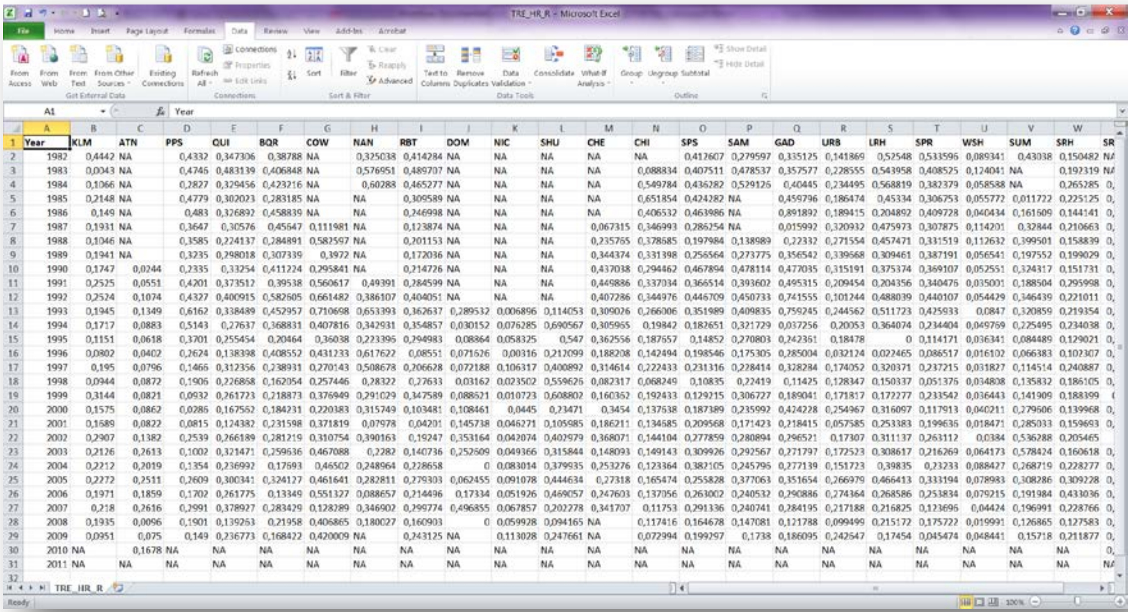
<u>Term_Run_R :</u> This file contains the time series of terminal run for each of the ER indicator stocks.

Year	KLM	ATN	PPS	QUI	BQR	COW	NAN	RBT	DOM	NIC	SHU	CHE	CHI	SPS	SAM	GAD	URB	LRH	SPR	WSH	SUM	SRH	SR
1982	3,6	NA	174	466,2	310	NA	348,1	1301,9	NA	NA	NA	NA	NA	1075,3	2149,1	488,2	1121,7	1318,4	2125,8	3068,7	13,5	674,3	NA
1983	15,8	NA	172	314	253,5	NA	479,3	948,4	NA	NA	NA	NA	1884,9	1796,8	3151,7	329,8	543,3	710,1	396,7	1793,3	NA	412,9	NA
1984	21,4	NA	181	479	140	NA	193	960,3	NA	NA	NA	NA	1098,3	1621,9	174,6	484,8	1077	497	481,9	3637,3	NA	510,4	
1985	120,1	NA	35	743,1	305,5	NA	NA	603,1	NA	NA	NA	NA	435,7	746,7	NA	187,6	2574,9	463,2	799,8	2408,9	67,7	514,7	
1986	164,3	NA	47	719,1	361,9	NA	NA	390,3	NA	NA	NA	NA	594,5	215,7	NA	2	3844,8	911	195,4	561,6	41,5	369,6	
1987	188,6	NA	65	583,9	357,6	130,6	NA	1077,1	NA	NA	NA	14,4	893,6	236,1	NA	88,2	2598,2	3479,3	59,1	460,2	53,8	509,7	
1988	119,3	NA	47	934,7	189,1	48,3	NA	1832,3	NA	NA	NA	102,8	1206,7	1051,7	425,4	350,6	1942,3	1360,3	313,4	1638	70,3	965,2	
1989	595,6	NA	30	996	286,3	181	NA	3090,9	NA	NA	NA	553,6	543,3	2791,6	988	943,9	786,1	142,5	1120,7	2458,3	72,1	858	
1990	473,3	NA	60	585,8	283,9	248	NA	3970,7	NA	NA	NA	1259,3	601,4	2588,6	1092,9	496,7	438,1	155,8	1096,6	2329,4	156,7	968,7	
1991	194,3	651,3	39	344,1	312,5	702,9	303,7	5831,6	NA	NA	NA	383,7	836,7	965,9	501,9	484,3	204,4	321,2	1638,1	2794	444,1	1494,4	
1992	477,7	786,2	33	310,1	186,5	572,5	688	4276,9	NA	NA	NA	560,3	1944,2	636,5	270,6	36,3	250,3	530,5	1455	2290,3	154,1	2024,9	
1993	168,5	1065,6	23	140,7	158,9	808,1	444	3274,2	38,4	88,1	125	574	1219,4	664,2	432,6	27	325,2	247	600,9	4600,4	132,2	1299,8	
1994	97,2	1459,4	8	175,2	137,5	500,5	229,7	1917,2	201,2	1606	166,4	237,5	423,7	1207,6	591,6	39,4	704,7	18	670,5	4662,5	22,1	2789,8	
1995	154,3	2147,8	17	133,8	146,8	839,5	961,6	842,2	422,7	1721,4	120,1	96,4	1599,4	2809,4	484,8	130,9	567,6	31,1	823,4	4255,9	132,5	3531,4	
1996	442,4	1973,7	28	173,4	141,8	565,2	282,7	615,4	339,1	69,4	467,3	681,3	1144,5	3679,5	958,8	206	745,5	57,3	766,1	3705,7	262,8	1768	
1997	491,3	1058,1	21	238,8	156,7	566,2	101,6	1516,6	253,6	181,7	191,3	371,4	1388,9	1923,2	995,2	221,3	788,1	139,9	462,7	2170,6	1007,1	2654,9	
1998	424,7	937,5	1	375,6	142,8	295,7	136,6	2120,5	565,1	990,1	288,5	1027,3	2882	1546,5	546,9	397,7	618,6	91,4	775,7	1506,7	1255	2266,8	
1999	466,9	1272,2	40	571,8	182,2	237,5	173	794,9	14,8	2941,7	140,8	924,7	2403,2	1821,5	161,9	595,8	1048,6	248	1223,9	1667,4	476,3	1681,5	
2000	258,7	945,7	54	581,7	162,6	533,2	116,4	206	58,8	2148,2	506,4	386	2170,7	1728,6	221,5	490,1	662,8	147,3	682,6	6089,8	1105,3	2235,4	
2001	432,2	630	192	1003,3	325	358,8	257,1	830,1	227,7	2069,2	931,8	576	3041,3	2722,6	1199,5	528,4	1604,6	719,2	5137,1	35071,4	3140,1	2911,9	
2002	647,9	613,3	82	612,4	209,6	438,1	455,2	1488,4	95,2	2025,8	832,2	176	3612,7	2338,9	1063,9	639,2	1710	970,4	2811	19189,2	3623,9	3524,8	
2003	443,3	339,1	92	291,1	162	131,8	533,9	2200,2	114,2	2047,2	1039,9	413,9	3613,5	1355,6	507,8	690,8	1844,5	944,8	4557,5	6337,2	2897,2	3630,4	
2004	712,3	373,5	72	518,3	279,4	122,9	587,4	3610,4	4,1	401,6	632	291,3	5616,7	1058,2	327,4	899,5	1957,5	796,8	4553,7	6332,1	2487,7	3413,1	
2005	241,3	470,2	231	538,1	308,3	125,8	361	2120,2	206,8	416,3	394,3	461,4	3161,2	1371,3	374,4	922,6	1637,8	284,6	1578,4	2741,4	6399,4	2871,5	
2006	218,1	1019,8	170,1	549,2	489,1	104,3	1189,4	2006,3	60,4	419	657,7	217	2484,8	2277,9	1027,9	741,7	1205,2	54,6	513,8	1823,3	2518,9	929	
2007	381,4	239,7	109,7	319,7	381,5	179	630,6	1366,8	8	125,4	315,2	199	1450,7	2189,8	1393,5	1169,3	405,1	110,4	853,5	1511,4	3564,6	1001,6	
2008	377,6	120,5	73	294	264,9	93,4	212,8	1225,1	76,2	670,9	1161,6	NA	2056,5	1768,6	1200,2	901,1	653,3	252,5	1757,9	2176,5	1248,6	533,9	
2009	497,3	423,1	193	266,4	381,4	146,2	NA	905,6	NA	254,7	1101,5	NA	2484,6	1909,4	1214,2	986,4	795,4	497,9	2321,8	1466,1	610,9	766,4	
2010	NA	509,8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
2011	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

<u>TRE_HR_R:</u> This file contains the time series of terminal run equivalent (TRE) ocean harvest rates of ER indicator stocks, where TRE is computed as:

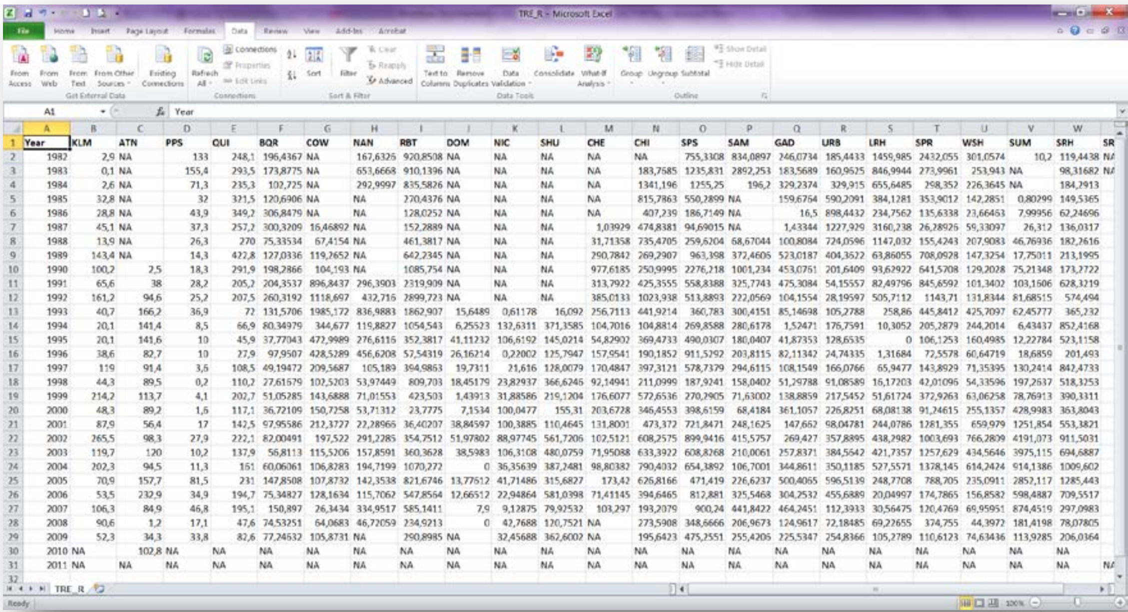
$$TRE_{indicator,y} = \sum_{\text{PreTerm Fishery}} \sum_{a=3}^{6} Catch_{a,y} * MR_{a,y}$$

Chinook salmon is an anadromous and semelparous species that spend 1-5 years in the ocean before returning to their natal streams to spawn. For the exploration of fishing scenarios where changes in terminal run size occur as a result of changes in ocean (i.e. pre-terminal) harvest rates, terminal run equivalents (*TRE*) were used to account for the fact that only a portion of the fish not caught in ocean fisheries in a given year is expected to become part of the terminal run according to their maturation rates (*MR*), which are time variant and stock specific. Age-2 Chinook were not included in this equation because RKW prey mostly on age-3 and older Chinook. *TRE*s were then used to compute both proportional increases in terminal run size in the absence of pre-terminal (i.e. ocean) fishing and the terminal run scalars resulting from a specified change in ocean harvest rates in exploitation rate indicator stocks. These scalars were then used to calculate changes in terminal run of a stock of interest (more details in Vélez-Espino et al. 2014).



Year	KLM	ATN	PPS	QUI	BQR	COW	NAN	RBT	DOM	NIC	SHU	CHE	CHI	SPS	SAM	GAD	URB	LRH	SPR	WSH	SUM	SRH	SR
1982	0,4442	NA	0,4332	0,347306	0,38788	NA	0,325038	0,414284	NA	NA	NA	NA	NA	0,412607	0,279597	0,335125	0,141869	0,52548	0,533596	0,089341	0,43038	0,150482	NA
1983	0,0043	NA	0,4746	0,483139	0,406848	NA	0,576951	0,489707	NA	NA	NA	NA	0,088834	0,407511	0,478537	0,357577	0,228555	0,543958	0,408525	0,124041	NA	0,192319	NA
1984	0,1066	NA	0,2827	0,329456	0,423216	NA	0,60288	0,465277	NA	NA	NA	NA	0,549784	0,436282	0,529126	0,40445	0,234495	0,568819	0,382379	0,058588	NA	0,265285	0,
1985	0,2148	NA	0,4779	0,302023	0,283185	NA	NA	0,309589	NA	NA	NA	NA	0,651854	0,424282	NA	0,459796	0,186474	0,45334	0,306753	0,055772	0,011722	0,225125	0,
1986	0,149	NA	0,483	0,326892	0,458839	NA	NA	0,246998	NA	NA	NA	NA	0,406532	0,463986	NA	0,891892	0,189415	0,204892	0,409728	0,040434	0,161609	0,144141	0,
1987	0,1931	NA	0,3647	0,30576	0,45647	0,111981	NA	0,123874	NA	NA	NA	0,067315	0,346993	0,286254	NA	0,015992	0,320932	0,475973	0,307875	0,114201	0,32844	0,210663	0,
1988	0,1046	NA	0,3585	0,224137	0,284891	0,582597	NA	0,201153	NA	NA	NA	0,235765	0,378685	0,197984	0,138989	0,22332	0,271554	0,457471	0,331519	0,112632	0,399501	0,158839	0,
1989	0,1941	NA	0,3235	0,298018	0,307339	0,3972	NA	0,172036	NA	NA	NA	0,344374	0,331398	0,256564	0,273775	0,356542	0,339568	0,309461	0,387191	0,056541	0,197552	0,199029	0,
1990	0,1747	0,0244	0,2335	0,33254	0,411224	0,295841	NA	0,214726	NA	NA	NA	0,437038	0,294462	0,467894	0,478114	0,477035	0,315191	0,375374	0,369107	0,052551	0,324317	0,151731	0,
1991	0,2525	0,0551	0,4201	0,373512	0,39538	0,560617	0,49391	0,284599	NA	NA	NA	0,449886	0,337034	0,366514	0,393602	0,495315	0,209454	0,204356	0,340476	0,035001	0,188504	0,295998	0,
1992	0,2524	0,1074	0,4327	0,400915	0,582605	0,661482	0,386107	0,404051	NA	NA	NA	0,407286	0,344976	0,446709	0,450733	0,741555	0,101244	0,488039	0,440107	0,054429	0,346439	0,221011	0,
1993	0,1945	0,1349	0,6162	0,338489	0,452957	0,710698	0,653393	0,362637	0,289532	0,006896	0,114053	0,309026	0,266006	0,351989	0,409835	0,759245	0,244562	0,511723	0,425933	0,0847	0,320859	0,219354	0,
1994	0,1717	0,0883	0,5143	0,27637	0,368831	0,407816	0,342931	0,354857	0,030152	0,076285	0,690567	0,305965	0,19842	0,182651	0,321729	0,037256	0,20053	0,364074	0,234404	0,049769	0,225495	0,234038	0,
1995	0,1151	0,0618	0,3701	0,255454	0,20464	0,36038	0,223396	0,294983	0,08864	0,058325	0,547	0,362556	0,187657	0,14852	0,270803	0,242361	0,18478	0	0,114171	0,036341	0,084489	0,129021	0,
1996	0,0802	0,0402	0,2624	0,138398	0,408552	0,431233	0,617622	0,08551	0,071626	0,00316	0,212099	0,188208	0,142494	0,198546	0,175305	0,285004	0,032124	0,022465	0,086517	0,016102	0,066383	0,102307	0,
1997	0,195	0,0796	0,1466	0,312356	0,238931	0,270143	0,508678	0,206628	0,072188	0,106317	0,400892	0,314614	0,222433	0,231316	0,228414	0,328284	0,174052	0,320371	0,237215	0,031827	0,114514	0,240887	0,
1998	0,0944	0,0872	0,1906	0,226858	0,162054	0,257446	0,28322	0,27633	0,03162	0,023502	0,559626	0,082317	0,068249	0,10835	0,22419	0,11425	0,128347	0,150337	0,051376	0,034808	0,135832	0,186105	0,
1999	0,3144	0,0821	0,0932	0,261723	0,218873	0,376949	0,291029	0,347589	0,088521	0,010723	0,608802	0,160362	0,192433	0,129215	0,306727	0,189041	0,171817	0,172277	0,233542	0,036443	0,141909	0,188399	(
2000	0,1575	0,0862	0,0286	0,167562	0,184231	0,220383	0,315749	0,103481	0,108461	0,0445	0,23471	0,3454	0,137638	0,187389	0,235992	0,424228	0,254967	0,316097	0,117913	0,040211	0,279606	0,139968	0,
2001	0,1689	0,0822	0,0815	0,124382	0,231598	0,371819	0,07978	0,04201	0,145738	0,046271	0,105985	0,186211	0,134685	0,209568	0,171423	0,218415	0,057585	0,253383	0,199636	0,018471	0,285033	0,159693	0,
2002	0,2907	0,1382	0,2539	0,266189	0,281219	0,310754	0,390163	0,19247	0,353164	0,042074	0,402979	0,368071	0,144104	0,277859	0,280894	0,296521	0,17307	0,311137	0,263112	0,0384	0,536288	0,205465	
2003	0,2126	0,2613	0,1002	0,321471	0,259636	0,467088	0,2282	0,140736	0,252609	0,049366	0,315844	0,148093	0,149143	0,309926	0,292567	0,271797	0,172523	0,308617	0,216269	0,064173	0,578424	0,160618	0,
2004	0,2212	0,2019	0,1354	0,236992	0,17693	0,46502	0,248964	0,228658	0	0,083014	0,379935	0,253276	0,123364	0,382105	0,245796	0,277139	0,151723	0,39835	0,23233	0,088427	0,268719	0,228277	0,
2005	0,2272	0,2511	0,2609	0,300341	0,324127	0,461641	0,282811	0,279303	0,062455	0,091078	0,444634	0,27318	0,165474	0,255828	0,377063	0,351654	0,266979	0,466413	0,333194	0,078983	0,308286	0,309228	0,
2006	0,1971	0,1859	0,1702	0,261775	0,13349	0,551327	0,088657	0,214496	0,17334	0,051926	0,469057	0,247603	0,137056	0,263002	0,240532	0,290886	0,274364	0,268586	0,253834	0,079215	0,191984	0,433036	0,
2007	0,218	0,2616	0,2991	0,378927	0,283429	0,128289	0,346902	0,299774	0,496855	0,067857	0,202278	0,341707	0,11753	0,291336	0,240741	0,284195	0,217188	0,216825	0,123696	0,04424	0,196991	0,228766	0,
2008	0,1935	0,0096	0,1901	0,139263	0,21958	0,406865	0,180027	0,160903	0	0,059928	0,094165	NA	0,117416	0,164678	0,147081	0,121788	0,099499	0,215172	0,175722	0,019991	0,126865	0,127583	0,
2009	0,0951	0,075	0,149	0,236773	0,168422	0,420009	NA	0,243125	NA	0,113028	0,247661	NA	0,072994	0,199297	0,1738	0,186095	0,242647	0,17454	0,045474	0,048441	0,15718	0,211877	0,
2010	NA	0,1678	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0,
2011	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

TRE_R: This file contains the time series of terminal run equivalents (TREs) of all ER indicator stocks.



Year	KLM	ATN	PPS	QUI	BQR	COW	NAN	RBT	DOM	NIC	SHU	CHE	CHI	SPS	SAM	GAD	URB	LRH	SPR	WSH	SUM	SRH	SR
1982	2,9	NA	133	248,1	196,4367	NA	167,6326	920,8508	NA	NA	NA	NA	NA	755,3308	834,0897	246,0734	185,4433	1459,985	2432,055	301,0574	10,2	119,4438	NA
1983	0,1	NA	155,4	293,5	173,8775	NA	653,6668	910,1396	NA	NA	NA	NA	183,7585	1235,831	2892,253	183,5689	160,9625	846,9944	273,9961	253,943	NA	98,31682	NA
1984	2,6	NA	71,3	235,3	102,725	NA	292,9997	835,5826	NA	NA	NA	NA	1341,196	1255,25	196,2	329,2374	329,915	655,6485	298,352	226,3645	NA	184,2913	
1985	32,8	NA	32	321,5	120,6906	NA	NA	270,4376	NA	NA	NA	NA	815,7863	550,2899	NA	159,6764	590,2091	384,1281	353,9012	142,2851	0,80299	149,5365	
1986	28,8	NA	43,9	349,2	306,8479	NA	NA	128,0252	NA	NA	NA	NA	407,239	186,7149	NA	16,5	898,4432	234,7562	135,6338	23,66463	7,99956	62,24696	
1987	45,1	NA	37,3	257,2	300,3209	16,46892	NA	152,2889	NA	NA	NA	1,03929	474,8381	94,69015	NA	1,43344	1227,929	3160,238	26,28926	59,33097	26,312	136,0317	
1988	13,9	NA	26,3	270	75,33534	67,4154	NA	461,3817	NA	NA	NA	31,71358	735,4705	259,6204	68,67044	100,8084	724,0596	1147,032	155,4243	207,9083	46,76936	182,2616	
1989	143,4	NA	14,3	422,8	127,0336	119,2652	NA	642,2345	NA	NA	NA	290,7842	269,2907	963,398	372,4606	523,0187	404,3622	63,86055	708,0928	147,3254	17,75011	213,1995	
1990	100,2	2,5	18,3	291,9	198,2866	104,193	NA	1085,754	NA	NA	NA	977,6185	250,9995	2276,218	1001,234	453,0761	201,6409	93,62922	641,5708	129,2028	75,21348	173,2722	
1991	65,6	38	28,2	205,2	204,3537	896,8437	296,3903	2319,909	NA	NA	NA	313,7922	425,3555	558,8388	325,7743	475,3084	54,15557	82,49796	845,6592	101,3402	103,1606	628,3219	
1992	161,2	94,6	25,2	207,5	260,3192	1118,697	432,716	2899,723	NA	NA	NA	385,0133	1023,938	513,8893	222,0569	104,1554	28,19597	505,7112	1143,71	131,8344	81,68515	574,494	
1993	40,7	166,2	36,9	72	131,5706	1985,172	836,9883	1862,907	15,6489	0,61178	16,092	256,7113	441,9214	360,783	300,4151	85,14698	105,2788	258,86	445,8412	425,7097	62,45777	365,232	
1994	20,1	141,4	8,5	66,9	80,34979	344,677	119,8827	1054,543	6,25523	132,6311	371,3585	104,7016	104,8814	269,8588	280,6178	1,52471	176,7591	10,3052	205,2879	244,2014	6,43437	852,4168	
1995	20,1	141,6	10	45,9	37,77043	472,9989	276,6116	352,3817	41,11232	106,6192	145,0214	54,82902	369,4733	490,0307	180,0407	41,87353	128,6535	0	106,1253	160,4985	12,22784	523,1158	
1996	38,6	82,7	10	27,9	97,9507	428,5289	456,6208	57,54319	26,16214	0,22002	125,7947	157,9541	190,1852	911,5292	203,8115	82,11342	24,74335	1,31684	72,5578	60,64719	18,6859	201,493	
1997	119	91,4	3,6	108,5	49,19472	209,5687	105,189	394,9863	19,7311	21,616	128,0079	170,4847	397,3121	578,7379	294,6115	108,1549	166,0766	65,9477	143,8929	71,35395	130,2414	842,4733	
1998	44,3	89,5	0,2	110,2	27,61679	102,5203	53,97449	809,703	18,45179	23,82937	366,6246	92,14941	211,0999	187,9241	158,0402	51,29788	91,08589	16,17203	42,01096	54,33596	197,2637	518,3253	
1999	214,2	113,7	4,1	202,7	51,05285	143,6888	71,01553	423,503	1,43913	31,88586	219,1204	176,6077	572,6536	270,2905	71,63002	138,8859	217,5452	51,61724	372,9263	63,06258	78,76913	390,3311	
2000	48,3	89,2	1,6	117,1	36,72109	150,7258	53,71312	23,7775	7,1534	100,0477	155,31	203,6728	346,4553	398,6159	68,4184	361,1057	226,8251	68,08138	91,24615	255,1357	428,9983	363,8043	
2001	87,9	56,4	17	142,5	97,95586	212,3727	22,28966	36,40207	38,84597	100,3885	110,4645	131,8001	473,372	721,8471	248,1625	147,662	98,04781	244,0786	1281,355	659,979	1251,854	553,3821	
2002	265,5	98,3	27,9	222,1	82,00491	197,522	291,2285	354,7512	51,97802	88,97745	561,7206	102,5121	608,2575	899,9416	415,5757	269,427	357,8895	438,2982	1003,693	766,2809	4191,073	911,5031	
2003	119,7	120	10,2	137,9	56,8113	115,5206	157,8591	360,3628	38,5983	106,3108	480,0759	71,95088	633,3922	608,8268	210,0061	257,8371	384,5642	421,7357	1257,629	434,5646	3975,115	694,6887	
2004	202,3	94,5	11,3	161	60,06061	106,8283	194,7199	1070,272	0	36,35639	387,2481	98,80382	790,4032	654,3892	106,7001	344,8611	350,1185	527,5571	1378,145	614,2424	914,1386	1009,602	
2005	70,9	157,7	81,5	231	147,8508	107,8732	142,3538	821,6746	13,77612	41,71486	315,6827	173,42	626,8166	471,419	226,6237	500,4065	596,5139	248,7708	788,705	235,0911	2852,117	1285,443	
2006	53,5	232,9	34,9	194,7	75,34827	128,1634	115,7062	547,8564	12,66512	22,94864	581,0398	71,41145	394,6465	812,881	325,5468	304,2532	455,6889	20,04997	174,7865	156,8582	598,4887	709,5517	
2007	106,3	84,9	46,8	195,1	150,897	26,3434	334,9517	585,1411	7,9	9,12875	79,92532	103,297	193,2079	900,24	441,8422	464,2451	112,3933	30,56475	120,4769	69,95951	874,4519	297,0983	
2008	90,6	1,2	17,1	47,6	74,53251	64,0683	46,72059	234,9213	0	42,7688	120,7521	NA	273,5908	348,6666	206,9673	124,9617	72,18485	69,22655	374,755	44,3972	181,4198	78,07805	
2009	52,3	34,3	33,8	82,6	77,24632	105,8731	NA	290,8985	NA	32,45688	362,6002	NA	195,6423	475,2551	255,4206	225,5347	254,8366	105,2789	110,6123	74,63436	113,9285	206,0364	
2010	NA	102,8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
2011	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

***Relative importance of Chinook salmon abundance on resident Killer whale population viability* pack**

Hypotheses addressed in this investigation regarding RKW-Chinook salmon interactions.

1. **Hypothesis 1a (based on current evidence):** there is a strong link between SRKW population growth and the terminal run size[1] of Fraser Early, Fraser Late, and Puget Sound Chinook stocks[2].
2. **Hypothesis 1b (based on current evidence)**: there is a strong link between NRKW population growth and the terminal run size[1] of Northern BC, Central BC, WCVI, Upper Georgia Strait, and Lower Georgia Strait Chinook salmon stocks as well as the ocean (pre-terminal) abundance of Fraser Early, Puget Sound, and Upper Columbia Chinook stocks[2].
3. **Hypothesis 2a (assuming Chinook salmon remains an important diet component year-round and outside identified critical habitats)**: there is a strong link between SRKW population growth and the terminal run size of large stocks such as Sacramento Fall, Klamath Fall, Columbia Upriver Brights, Columbia Spring/Summer/Fall, Oregon Coastal, WCVI, or coastwide (excluding Northern BC, Central BC, and Southeast Alaska[3]), as well as the ocean (pre-terminal) abundance of ocean-type[4] stocks with large contributions to ocean fisheries such as WCVI, Columbia Upriver Brights, Fraser Late, Oregon Coastal, Puget Sound, or coastwide (excluding Southeast Alaska[5]).
4. **Hypothesis 2b (assuming Chinook salmon remains an important diet component year-round and outside identified critical habitats)**: there is a strong link between NRKW population growth and the terminal run size of Fraser Early and Puget Sound[6], and large stocks such as Columbia Upriver Brights, Columbia Spring/Summer/Fall, Fraser Late, Oregon Coastal, or coastwide (excluding Sacramento Fall, Klamath Fall[7] but including Southeast Alaska[8]), as well as the ocean (pre-terminal) abundance of ocean-type[3] stocks with large contributions to ocean fisheries such as WCVI, Fraser Late, Oregon Coastal, or coastwide (excluding Southeast Alaska[5]).

1 The terminal run includes terminal catch, which occurs after fish are available for killer whales, and therefore represents the Chinook available for RKW in their summer ranges.
2 Based on diet composition studies.
3 Out of the known preferred geographic range of SRKW.
4 Ocean-type Chinook stocks spend most of their ocean life in coastal waters and are therefore within known RKW geographic range.
5 South East Alaska Chinook salmon stocks exhibit a stream-type life history and perform extensive offshore oceanic migrations, and it is unlikely they are available for RKW. These stocks contribute on average less than 1% to the Chinook salmon available for PST ocean (pre-terminal) fisheries
6 Although Fraser Early is not among the larger stocks, NRKW encounters with both Puget Sound and Fraser Early terminal runs could be greater than determined by current observations.
7 Out of the known preferred geographic range of NRKW.
8 Within the known geographic range of NRKW.

<u>PostWorkspace:</u> An R Workspace that transfers values from the Resident killer whale-chinook salmon interactions (main) workflow to the Exploration of fishing scenario (post-processing) workflow. The zip file must be provided as an input to the post-processing workflow in order for it to have access to values generated in the main workflow. Therefore, take in account the input values used to run the main workflow.

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. *In Press*. 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 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).

Associations between RKW vital rates (fecundity and survival) and Chinook abundance were evaluated in light of the four hypotheses in Box 1 using beta regressions (see text above). Beta regressions were used because they incorporate features such as heteroscedasticity or skewness which are commonly observed in data taking values in the standard unit interval, such as rates or proportions. Abundance lags of 0-year and 1-year were used to examine relationships with survival rates whereas 0-year, 1-year, and 2-year abundance lags were used to examine relationships with fecundity. The rationale for the use of lag-1 models for survival is that the effects of nutritional stress could be capitalized on mortalities the next year after food shortage occurred. A recent study revealed that mortality indices were most highly correlated to changes in Chinook abundance after a lag of one year. Following the same rationale, lag-2 models were used for fecundity to account for malnutrition or starvation effects on pregnancy as well. Pregnancy lasts about a year in RKW. In addition, and in order to account for cumulative effects of Chinook abundance on RKW vital rates, a 5-year running average (Chinook abundance from *t*-4 to *t*) was also used for regression analyses. A total of 128 combinations of stock or stock aggregates, abundance type, and time lag were considered in the analysis of RKW-Chinook interactions. Since some of these stock-abundance type-time lag combinations were explored in relation to both NRKW and SRKW (see Hypotheses), a total of 196 RKW-Chinook linkages were analysed: 28 for hypothesis 1a, 60 for 2a, 40 for 1b, and 68 for 2b. Each one of these linkages encompasses relationships with the fecundity and survival of stages directly contributing to population growth, thus producing a total of 980 RKW-Chinook interactions

The relevance of interactions between Chinook abundance and killer whale population viability were based not only on statistical significance but also on their influence on expected population growth rates as quantified by perturbation analyses. The execution of demographic perturbation analyses involved prospective evaluations quantifying the relative effects on SRKW and NRKW population growth of interactions between RKW vital rates and Chinook salmon abundance within the hypothesis-driven framework. Prospective evaluations, based on elasticity analysis, were used to quantify the changes in λ that would result from any specified change in the vital rates. This information can be used to identify potential management targets because elasticities measure the relative influence of vital rates on λ.

Elasticities (ε) are partial derivatives of λ that can be computed in reference to small changes to matrix **M** elements (a_{kl}; equation 2) or lower-level parameters such as vital rates (v_i),which usually contribute to more than one matrix element, by applying the chain rule of differentiation (equation 3). Similarly, mean elasticities of interactions between individual vital rates and Chinook salmon abundance can be computed by extending the chain rule of differentiation to factors influencing the vital rates. Equation 4 transfers the effect of a change in Chinook abundance on a given vital rate (as determined by significant and filtered beta regressions) to effects on population growth (λ).

$$\varepsilon\left(a_{kl}\right)=\partial\log\lambda/\partial\log a_{kl} \qquad (2)$$

$$\varepsilon\left(v_i\right)=\frac{v_i}{\lambda}\frac{\partial\lambda}{\partial v_i}=\frac{v_i}{\lambda}\sum\frac{\partial\lambda}{\partial a_{kl}}\frac{\partial a_{kl}}{\partial v_i} \qquad (3)$$

$$\varepsilon\left(x_{Chinook\to v_i}\right)=\sum_i\frac{\partial\log\lambda}{\partial\log a_{kl}}\frac{\partial\log a_{kl}}{\partial v_i}\frac{\partial v_i}{\partial x_{Chinook\to v_i}} \qquad (4)$$

The term $x_{Chinook\to v_i}$ denotes Chinook abundance from specific stocks or stock aggregates interacting with vital rate v_i, and $\varepsilon\left(x_{Chinook\to v_i}\right)$ denotes the proportional change in λ resulting from a small change in $x_{Chinook\to v_i}$ through its interaction with v_i. The effects of $x_{Chinook\to v_i}$ on more than one vital rate are additive.

These analytical solutions are robust for perturbations up to 30% and occasionally up to 50%. However, nonlinearities often exhibited between vital rates and λ, reduce the accuracy of projections using elasticities for larger perturbations. Hence, we also conducted prospective perturbation analysis by directly perturbing the projection matrices Direct perturbations involve an iterative process, altering the magnitude of the vital rate in question while keeping all other matrix elements unchanged. 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:

$$\varepsilon\left(x_{Chinook\to v_i}\right)_{DP,\text{variant1}}=\frac{\Delta\lambda}{\Delta x_{Chinook}}=\frac{\left(\left(\lambda_{after}/\lambda_{before}\right)-1\right)}{\left(\left(x_{Chinook,after}/x_{Chinook,before}\right)-1\right)} \qquad (5)$$

$$\varepsilon\left(x_{Chinook\to v_i}\right)_{DP,\text{variant 2}}=\varepsilon\left(v_i\right)\frac{\Delta v_i}{\Delta x_{Chinook}}=\varepsilon\left(v_i\right)\frac{\left(\left(v_{i,after}/v_{i,before}\right)-1\right)}{\left(\left(x_{Chinook,after}/x_{Chinook,before}\right)-1\right)} \qquad (6)$$

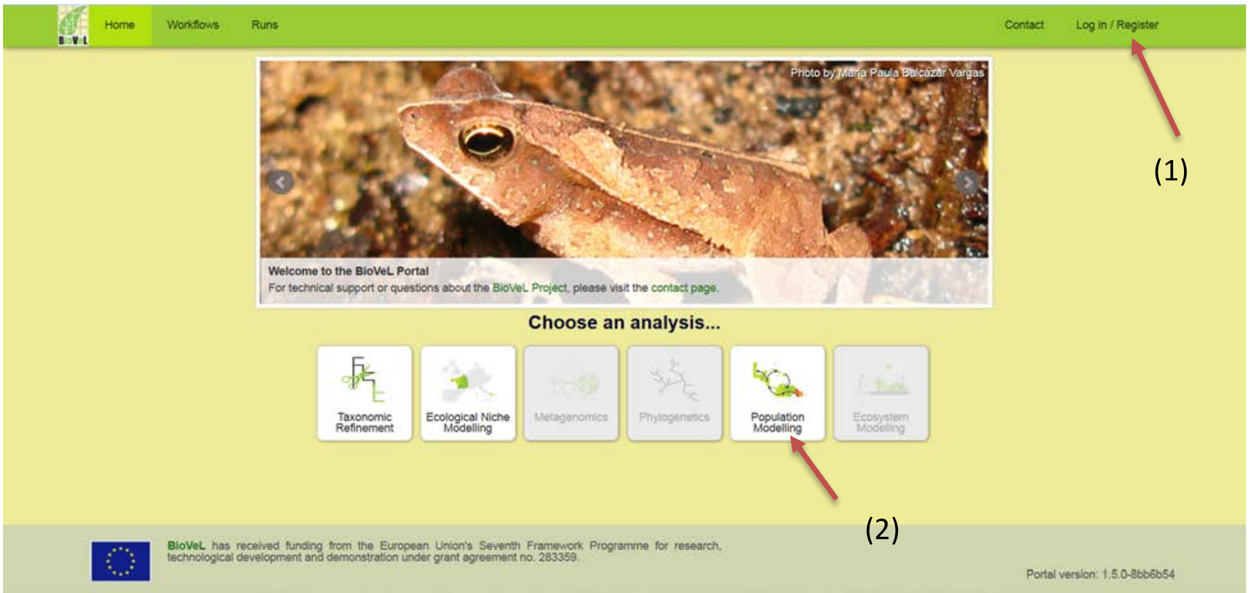
The term $x_{Chinook,before}$ is the Chinook abundance from a particular stock corresponding to the mean value of the interacting vital rate, $x_{Chinook,after}$ represents the simulated value of Chinook abundance that is used to explore the effect of changes in Chinook abundance (e.g. through changes 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. Across all significant beta regressions, the two variants generated similar elasticities of the interactions for SRKW and a slight divergence at higher elasticity values for NRKW. Variant 2 was used for subsequent analysis because it is better suited to incorporate uncertainty in vital rate elasticities as described below.

Stochastic elasticities were generated through simulations with vital rates represented as random variables. Vital rate annual values from 1987 to 2011 were used to generate their mean and variances for each of the killer whale populations. Simulations generated 5000 random matrices with vital rates drawn from defined probability distributions following Vélez-Espino *et al*. (2014). The beta distribution was used to simulate variation in stage-specific survival (σ_i). This distribution is appropriate for binary events (such as survival) and produces random variables confined to the interval 0 to 1. The lognormal distribution was used to simulate fecundity values (μ_i). This distribution produces only positive random variables bounded by zero and infinity. Population growth rates and vital rate elasticities were calculated for each of the 5000 matrices, and a parametric bootstrap was used to estimate mean stochastic elasticities and their 95% confidence intervals.

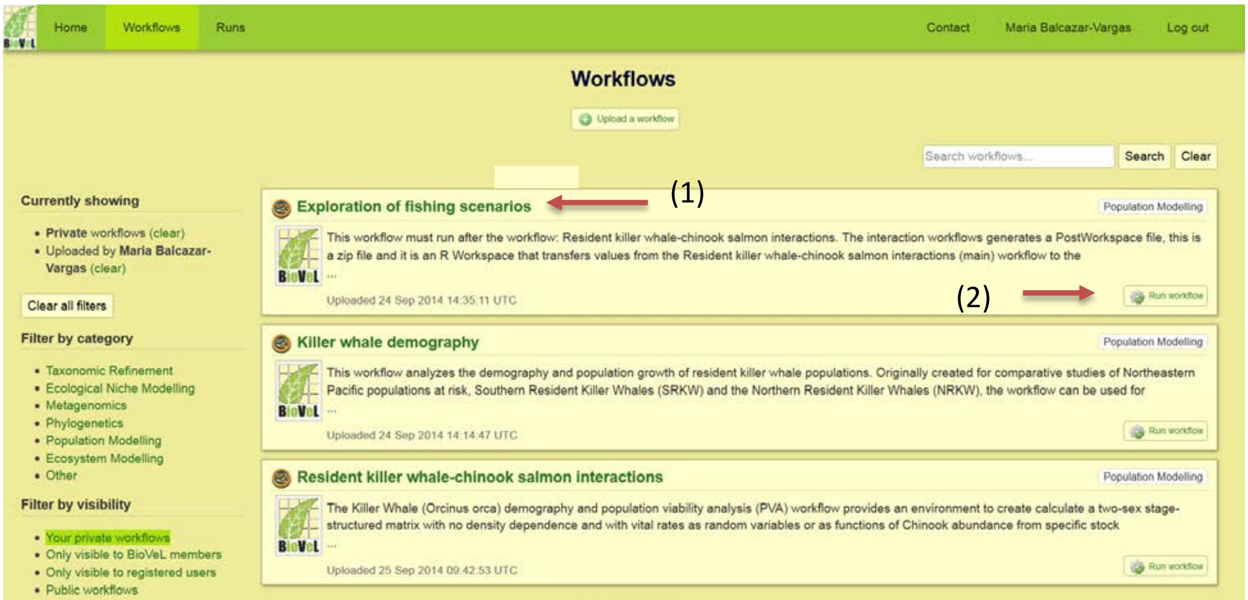
Relative importance of Chinook salmon abundance on resident Killer whale population viability **pack**

In your browser (preferably Firefox or Chrome) navigate to the BioVeL Portal 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.

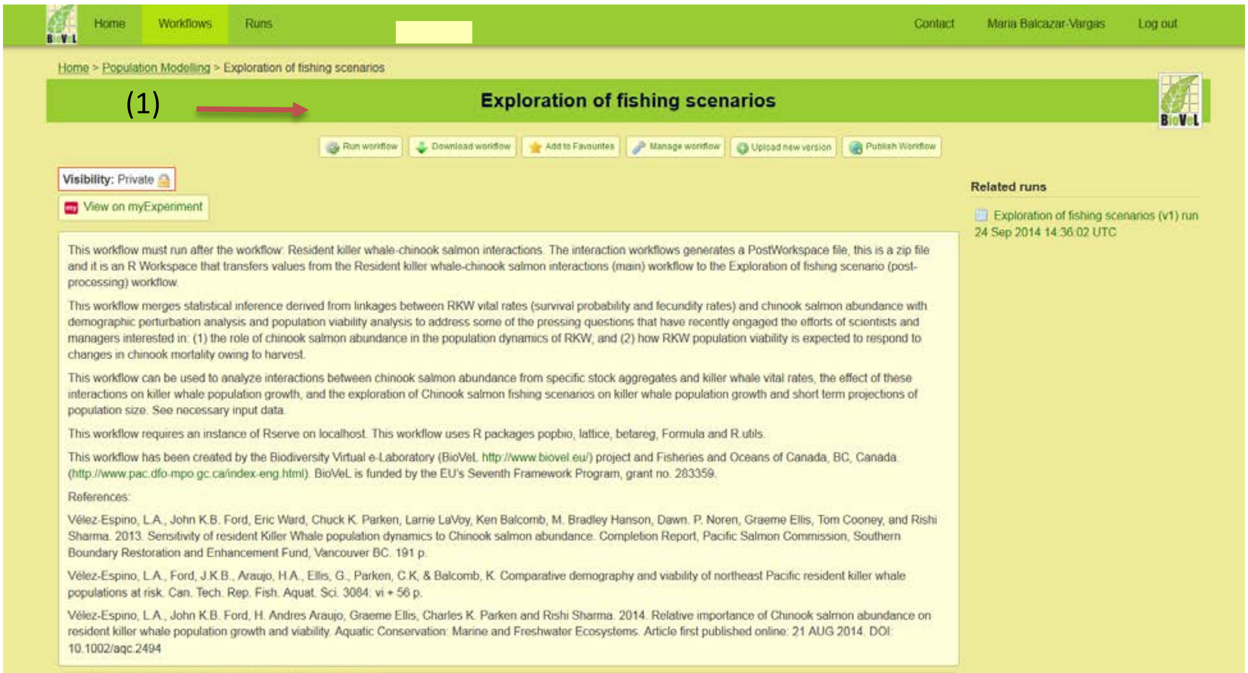
Choose the Population Modelling analysis and click, this will show you a list of relevant analysis:



On the resulting page choose the workflow: Exploration of fishing scenarios (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).

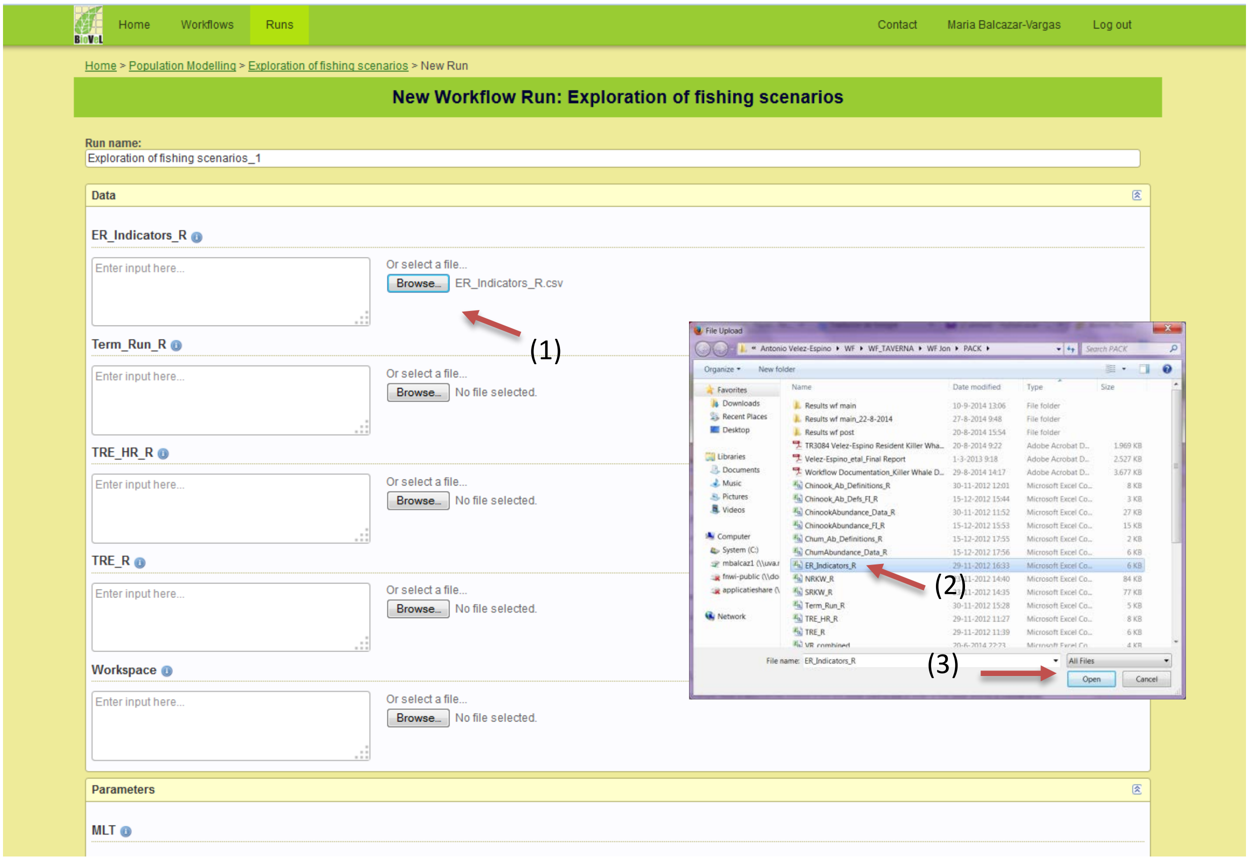


On the next page you can edit the name of the workflow run to make it easier for you to identify it later (e.g. *Exploration of fishing scenarios*_1).

3.1 Input Ports

3.1.1 Data

ER_Indicators_R: This file shows the exploitation rate (ER) indicator stocks used to represent exploitation-rate time series with terminal-run time series of Chinook salmon aggregates. To open the file. Click in Browse (1), a window dialog appears and the user selects the file ER_Indicators_R.csv, (2) and then clicks the Open button (3). Repeat this action for all the input DATA.



Term_Run_R: This file contains the time series of terminal run for each of the ER indicator stocks. To open the file. Click in choose file, a window dialog appears and the user selects the file e.g. Term_Run_R.csv and then clicks the Open button.

TRE_HR_R: This file contains the time series of terminal run equivalent (TRE) ocean harvest rates of ER indicator stocks. To open the file. Click in choose file, a window dialog appears and the user selects the file e.g. TRE_HR_R.csv and then clicks the Open button.

TRE_R: This file contains the time series of terminal run equivalents (TREs) of all ER indicator stocks. To open the file. Click in choose file, a window dialog appears and the user selects the file e.g. TRE_R.csv and then clicks the Open button.

***Workspace*:** The PostWorkspace is a zip file and it is an R Workspace that transfers values from the Resident killer whale-chinook salmon interactions (main) workflow to the Exploration of fishing scenario (post-processing) workflow. To open the file. Click in choose file, a window dialog appears and the user selects the file e.g. Workspace and then clicks the Open button.

3.1.2 Parameters

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

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

e.g.: 2011

MLT: This is a user-defined inverse multiplier for the harvest rate (HR) that affects the stock aggregates directly. MLT is inversely proportional to HRs but directly proportional to killer whale vital rates. MLT = 0.0 is used to maximize HRs. MLT values between 1.0 and 2.0 are used to represent increments in ocean abundance proportional to percent reductions in HRs.

e.g.: 1.64

***Mult*:** This is a user-defined multiplier of ocean harvest rates impacting terminal runs. Mult = 0.0 indicates the closure of ocean fisheries; Mult = 1.0 indicates no change in base values; Mult = 1.5 indicates a 50% increase in ocean HRs.

e.g.: 1.5.

***nreps*:** Number of replications for projections of population size.

e.g.: 10000

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

e.g.: SRKW

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

e.g.: 1987

***StockAggr*:** The stock aggregate, with abundance represented as terminal run (TR), is user defined from the list of significant stocks from the regression and elasticity analyses. The user needs to see "Elasticities of Interaction Method Matrix Pert._Population_(Beta Regressions).pdf" or "Elasticity of Interactions_Population.csv" to select relevant stock aggregates for further analysis.

e.g.: FEPS_TR_1

***StockAggrOA*:** The stock aggregate, with abundance represented as ocean abundance (OA), is user defined from the list of significant stocks from the regression and elasticity analyses. The user needs to see "Elasticities of Interaction Method Matrix Pert._Population_(Beta Regressions).pdf" or "Elasticity of Interactions_Population.csv" to select relevant stock aggregates for further analysis.

e.g.: CW_OA_2

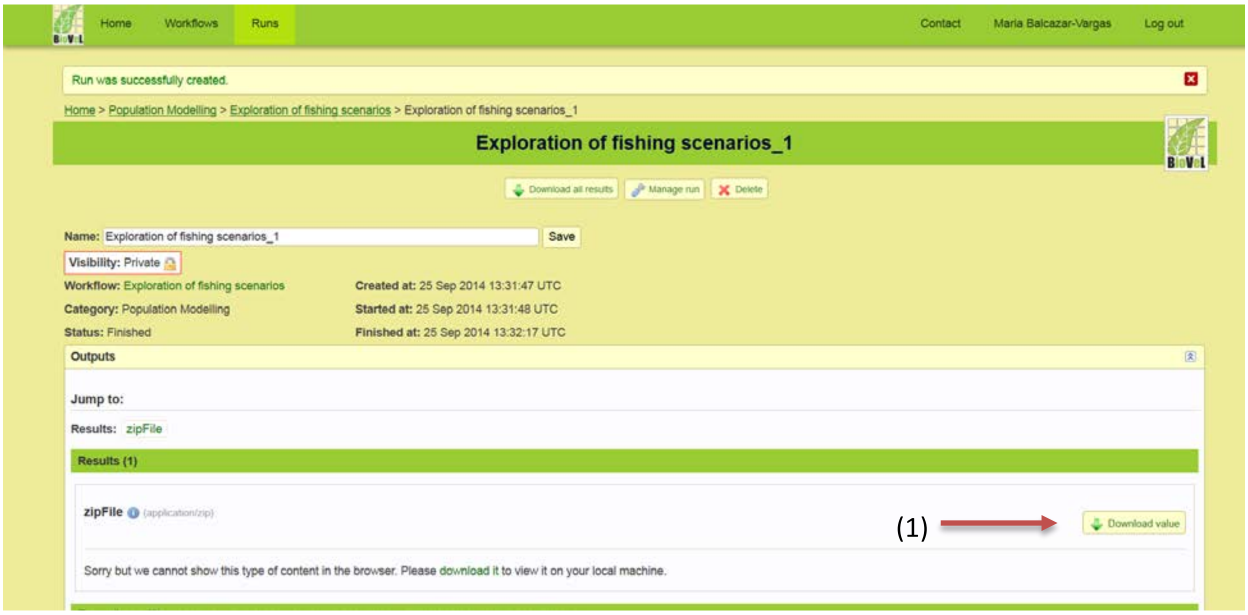
UseFImpacts: Instead of ocean abundance, the user can select time series of fishery impacts to run the analyses. In this case, the interaction would be between killer whale vital rates and fishing impacts rather than Chinook salmon ocean abundance. Choose "FALSE" to conduct analyses at the ocean abundance level.

e.g.: FALSE

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 ***NREPS*** to carry out the analyses.

3.3 Outputs

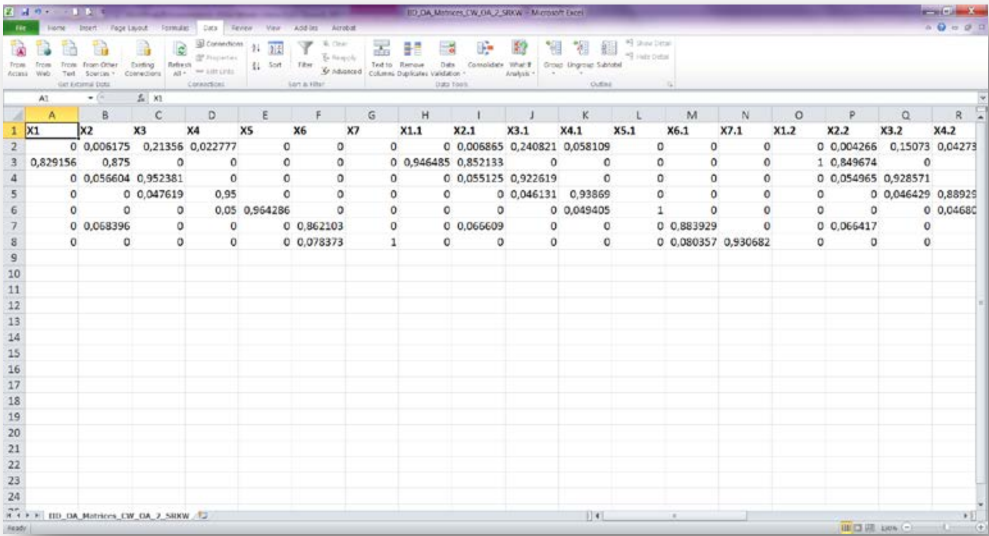
Once the analyses are finished, the user can download all the results by clicking Download value button (1). Numerical and graph results will be download as a zip file that can be save by the user. The numerical results are .csv files than can be opened with Excel and the plot files are .PDF files. A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



3.3.1 Results

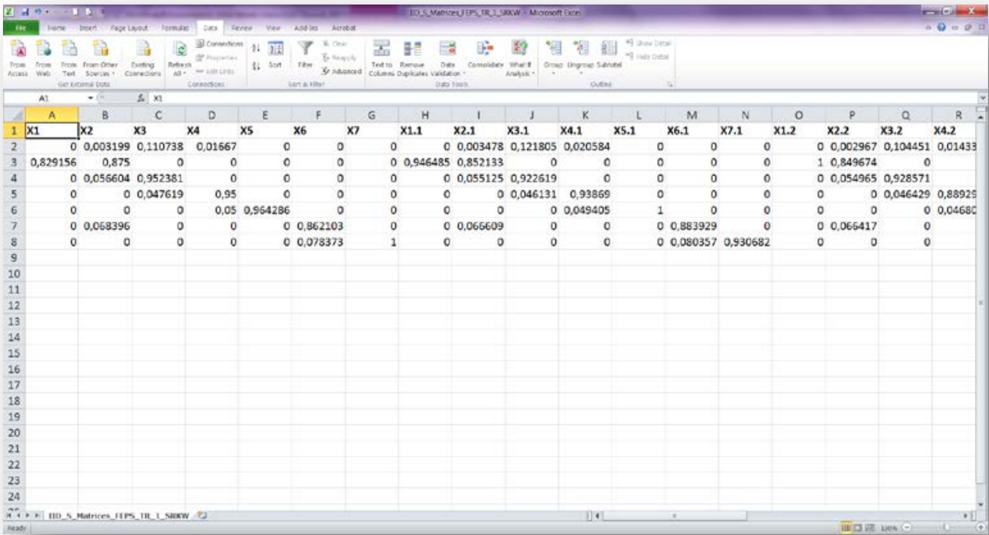
Zip File

IID_Abundance type (OA or TR)_Stock aggregate_Abundance type_time series lag_Population/csv: This output file shows the matrices produced by the retrospective analysis. There will be as many matrices in this file as time periods specified by the user. Following, there are two examples for two different stock aggregates: the first one is for the interaction between coastwide Chinook ocean abundance, two years lagged, and SRKW vital rates; the second is for Fraser Early-Puget Sound Chinook ocean abundance, one year lagged, and SRKW vital rates



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
0	0,006175	0,21356	0,022777	0	0	0	0	0,006865	0,240821	0,058109	0	0	0	0	0,004266	0,15073	0,04273
0,829156	0,875	0	0	0	0	0	0,946485	0,852133	0	0	0	0	0	1	0,849674	0	
0	0,056604	0,952381	0	0	0	0	0	0,055125	0,922619	0	0	0	0	0	0,054965	0,928571	
0	0	0,047619	0,95	0	0	0	0	0	0,046131	0,93869	0	0	0	0	0	0,046429	0,88929
0	0	0	0,05	0,964286	0	0	0	0	0	0,049405	1	0	0	0	0	0	0,0468
0	0,068396	0	0	0	0,862103	0	0	0,066609	0	0	0	0,883929	0	0	0,066417	0	
0	0	0	0	0	0,078373	1	0	0	0	0	0	0,080357	0,930682	0	0	0	

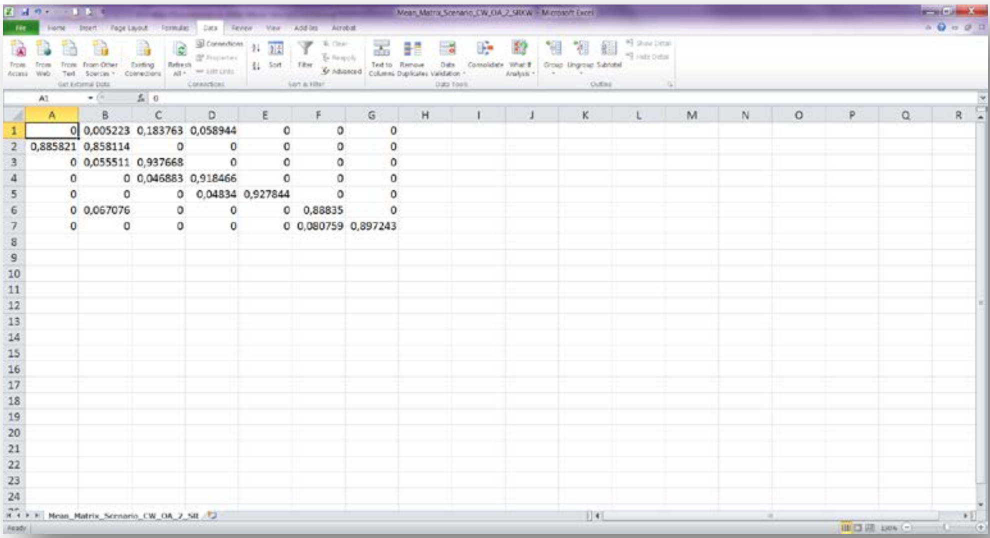
IID_OA_Matrices_CW_OA_2_SRKW.csv



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
0	0,003199	0,110738	0,01667	0	0	0	0	0,003478	0,121805	0,020584	0	0	0	0	0,002967	0,104451	0,01433
0,829156	0,875	0	0	0	0	0	0,946485	0,852133	0	0	0	0	0	1	0,849674	0	
0	0,056604	0,952381	0	0	0	0	0	0,055125	0,922619	0	0	0	0	0	0,054965	0,928571	
0	0	0,047619	0,95	0	0	0	0	0	0,046131	0,93869	0	0	0	0	0	0,046429	0,88929
0	0	0	0,05	0,964286	0	0	0	0	0	0,049405	1	0	0	0	0	0	0,0468
0	0,068396	0	0	0	0,862103	0	0	0,066609	0	0	0	0,883929	0	0	0,066417	0	
0	0	0	0	0	0,078373	1	0	0	0	0	0	0,080357	0,930682	0	0	0	

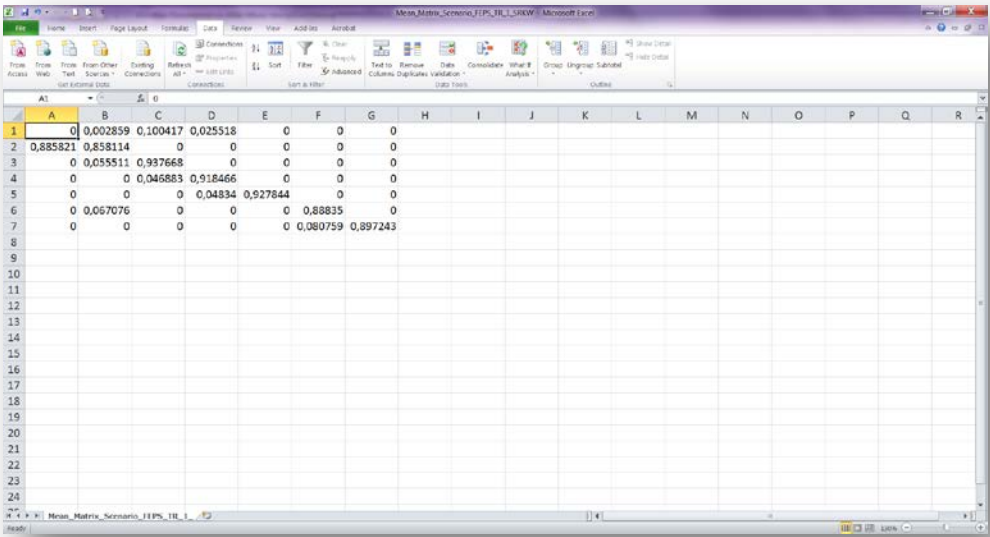
IID_S_Matrices_FEPS_TR_1_SRKW.csv

Mean_Matrix_Scenario_Stock Aggregate_Abundance type_time series lag_Population.csv: This output shows the mean killer whale matrix generated after the implementation of a fishing scenario (i.e., changes in ocean abundance or terminal run or fishing impacts), Following, there are two examples for two different stock aggregates: the first one is for the interaction between coastwide Chinook ocean abundance, two years lagged, and SRKW vital rates; the second is for Fraser Early-Puget Sound Chinook ocean abundance, one year lagged, and SRKW vital rates



	A	B	C	D	E	F	G
1	0	0,005223	0,183763	0,058944	0	0	0
2	0,885821	0,858114	0	0	0	0	0
3	0	0,055511	0,937668	0	0	0	0
4	0	0	0,046883	0,918466	0	0	0
5	0	0	0	0,04834	0,927844	0	0
6	0	0,067076	0	0	0	0,88835	0
7	0	0	0	0	0	0,080759	0,897243

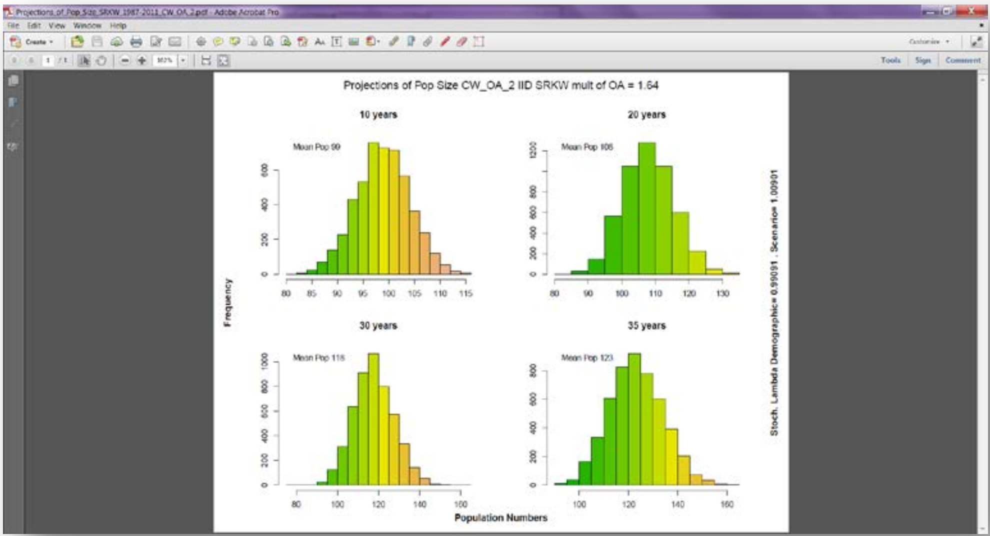
Mean_Matrix_Scenario_CW_OA_2_SRKW.cvs



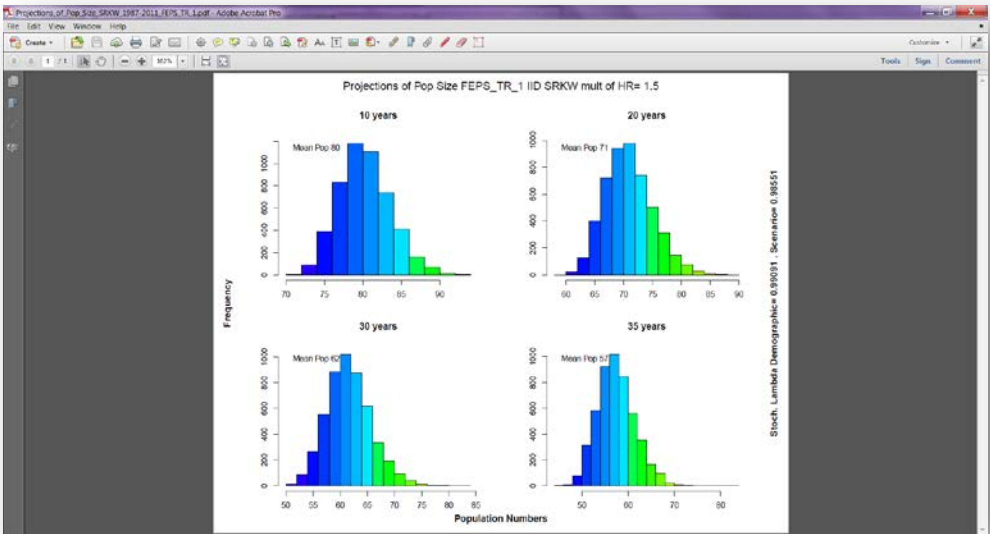
	A	B	C	D	E	F	G
1	0	0,002859	0,100417	0,025518	0	0	0
2	0,885821	0,858114	0	0	0	0	0
3	0	0,055511	0,937668	0	0	0	0
4	0	0	0,046883	0,918466	0	0	0
5	0	0	0	0,04834	0,927844	0	0
6	0	0,067076	0	0	0	0,88835	0
7	0	0	0	0	0	0,080759	0,897243

Mean_Matrix_Scenario_FEPS_TR_1_SRKW.csv

Projections_of_Pop_Size_Population_Start_year–End_year_Stock_Aggregate_Abundance type_time series lag_Population. (pdf): This figure shows histograms of population size projections at four time horizons with the farthest one being the damping time. In addition, this figure shows the values of the population growth rate before and after the implementation of a particular fishing scenario. The attributes of the fishing scenario are shown at the top of the figure. Following, there are two examples for two different stock aggregates: the first one is for the interaction between coastwide Chinook ocean abundance, two years lagged, and SRKW vital rates; the second is for Fraser Early-Puget Sound Chinook ocean abundance, one year lagged, and SRKW vital rates

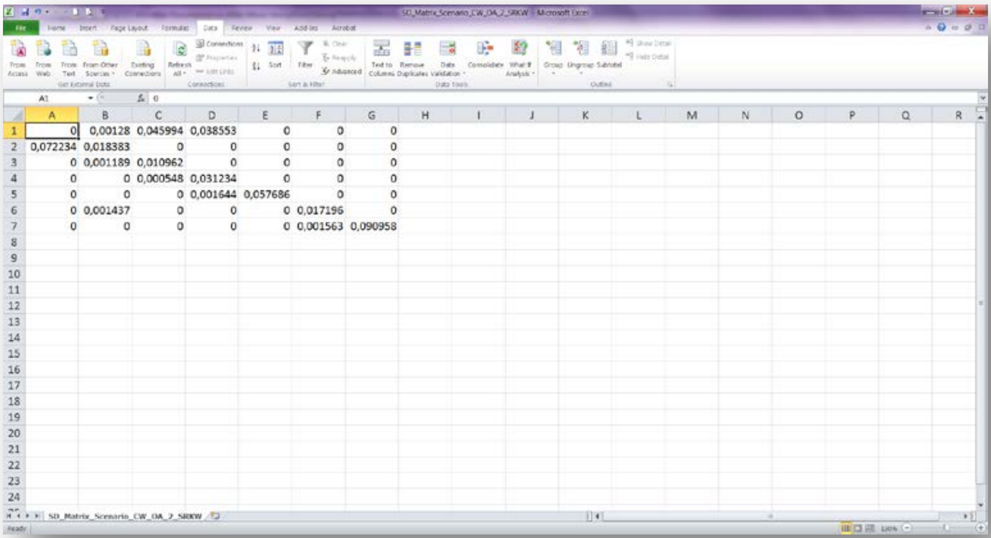


Projections_of_Pop_Size_SRKW_1987-2011_CW_OA_2.pdf



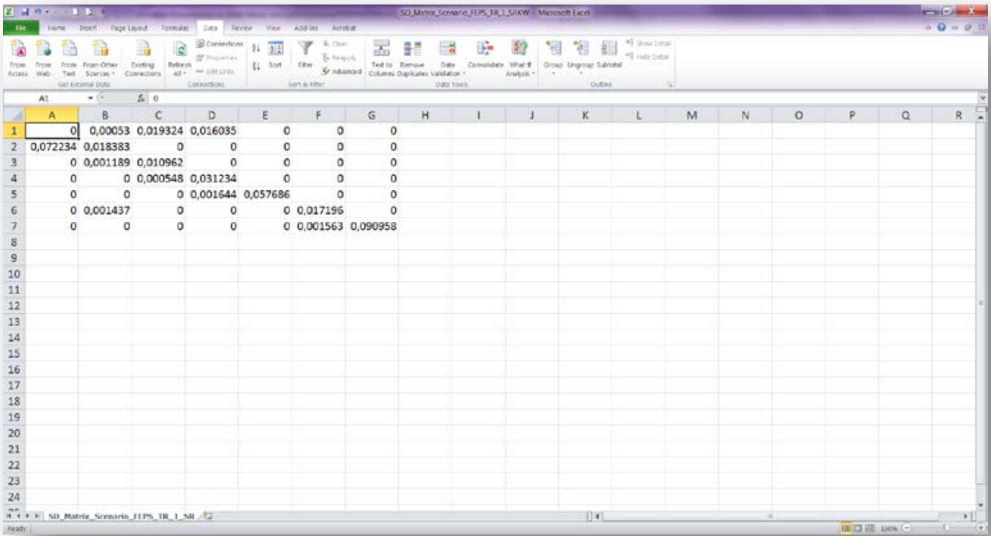
Projections_of_Pop_Size_SRKW_1987-2011_FEPS_TR_1 (pdf)

SD_Matrix_Scenario_Stock Aggregate_Abundance type_time series lag_Population.csv: This output shows the standard-deviation killer whale matrix generated after the implementation of a fishing scenario (i.e., changes in ocean abundance or terminal run or fishing impacts), Following, there are two examples for two different stock aggregates: the first one is for the interaction between coastwide Chinook ocean abundance, two years lagged, and SRKW vital rates; the second is for Fraser Early-Puget Sound Chinook ocean abundance, one year lagged, and SRKW vital rates



	A	B	C	D	E	F	G
1	0	0,00128	0,045994	0,038553	0	0	0
2	0,072234	0,018383	0	0	0	0	0
3	0	0,001189	0,010962	0	0	0	0
4	0	0	0,000548	0,031234	0	0	0
5	0	0	0	0,001644	0,057686	0	0
6	0	0,001437	0	0	0	0,017196	0
7	0	0	0	0	0	0,001563	0,090958

SD_Matrix_Scenario_CW_OA_2_SRKW.csv



	A	B	C	D	E	F	G
1	0	0,00053	0,019324	0,016035	0	0	0
2	0,072234	0,018383	0	0	0	0	0
3	0	0,001189	0,010962	0	0	0	0
4	0	0	0,000548	0,031234	0	0	0
5	0	0	0	0,001644	0,057686	0	0
6	0	0,001437	0	0	0	0,017196	0
7	0	0	0	0	0	0,001563	0,090958

SD_Matrix_Scenario_FEPS_TR_1_SRKW.csv

4. References

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

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