Benchmark Analysis for Lake Sockeye Conservation Units (CUs) in the Skeena

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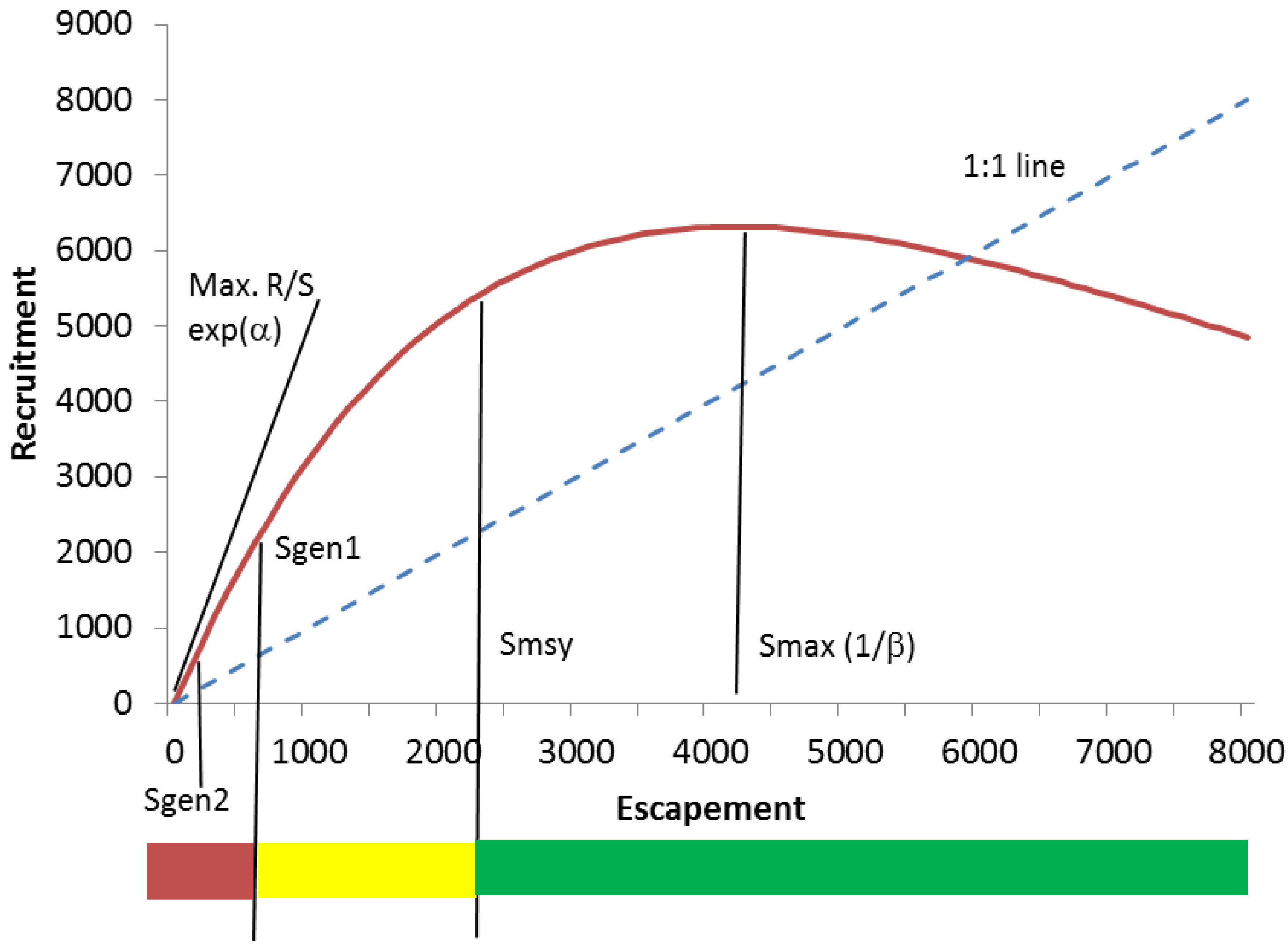
Benchmarks Defined from Stock-Recruitment Relationship



The Data

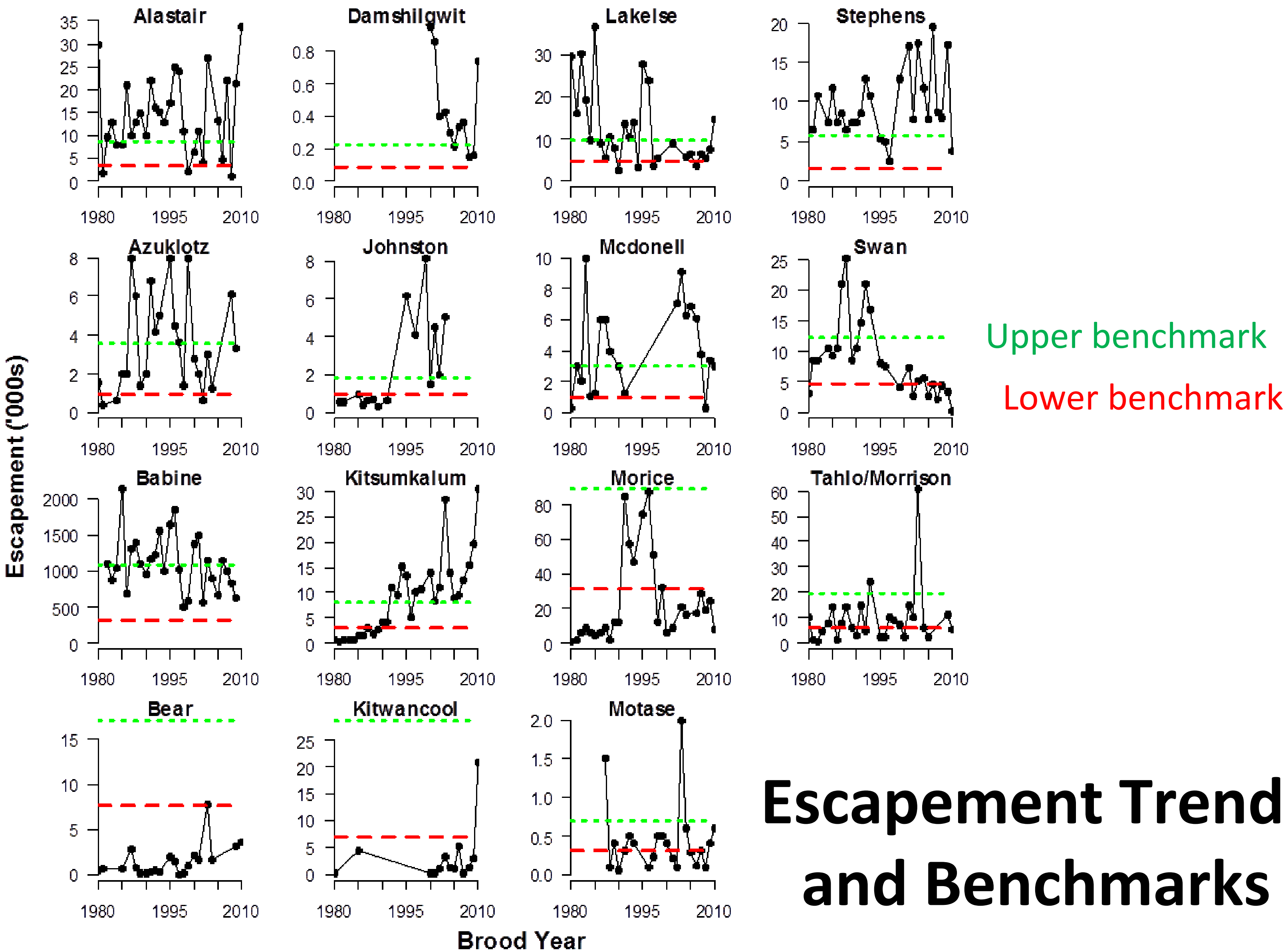
CU Name	N - SR	N - Age	PR-based Smax
Alastair	21	151 (2)	23,437
Aldrich			
Asitika			
Atna			
Azuklotz	13		5,933
Babine	23	17,489 (32)	1,808,245
Bear	6	46 (1)	40,532
Bulkley			
Damshilgwit	3	67 (1)	423
Dennis			
Ecstall/Lower			
Footsore			
Johanson			
Johnston	4		4,125
Kitsumkalum	19		20,531
Kitwancool	3	299 (4)	36,984
Kluatantan			
Kluayaz			
Lakelse	14	194 (1)	35,916
Maxan			
Mcdonell	6		4,072
Morice	15	98 (1)	191,362
Motase	10		1,764
Nilkitkwa			
Sicintine			
Slamgeesh			
Spawning			
Stephens	12		7,069
Sustut			
Swan	10	100 (1)	21,432
Tahlo/Morrison	18		44,587

31 CUs

16 with escapement data

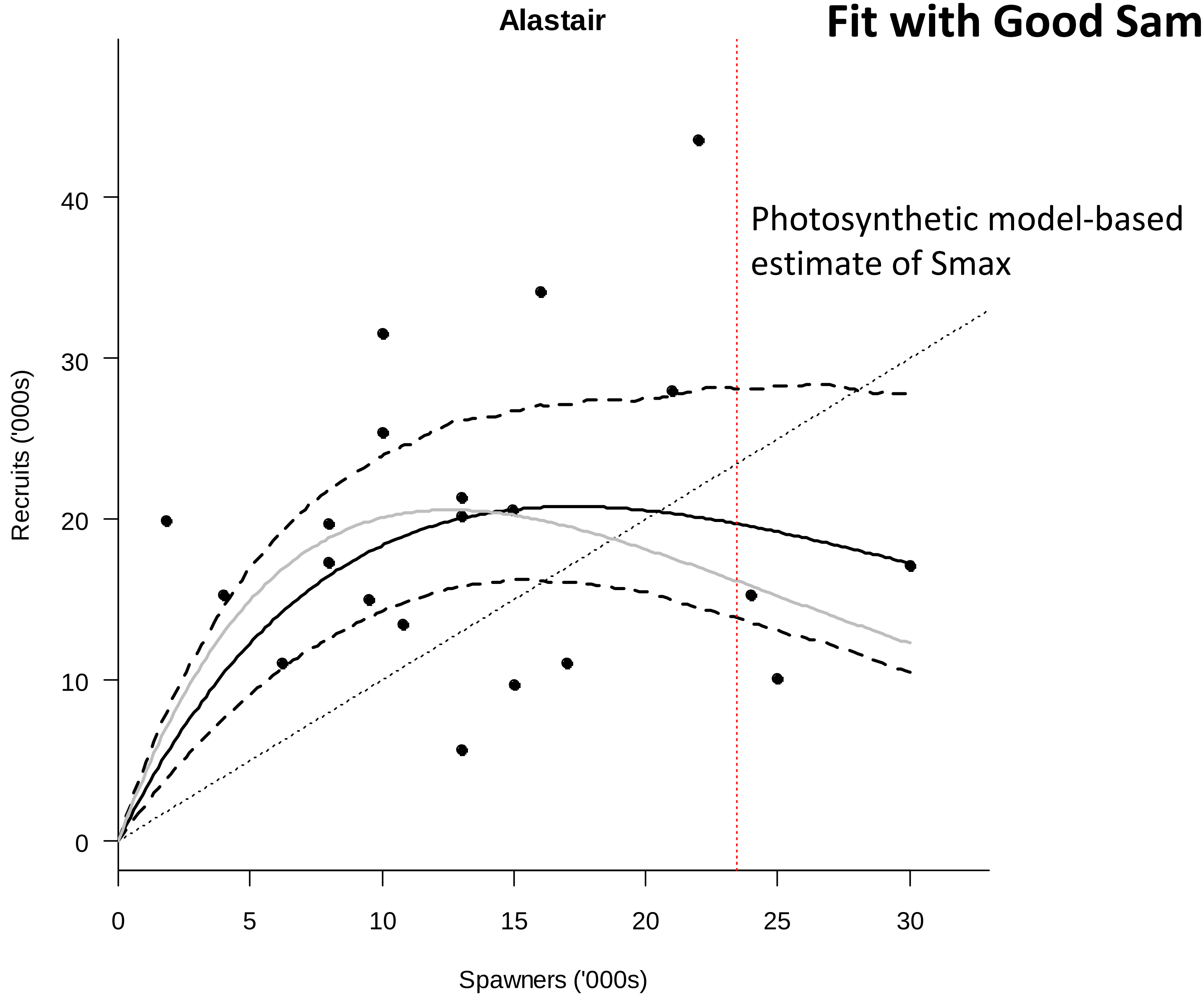
15 have escapement & recruitment data

8 have age data

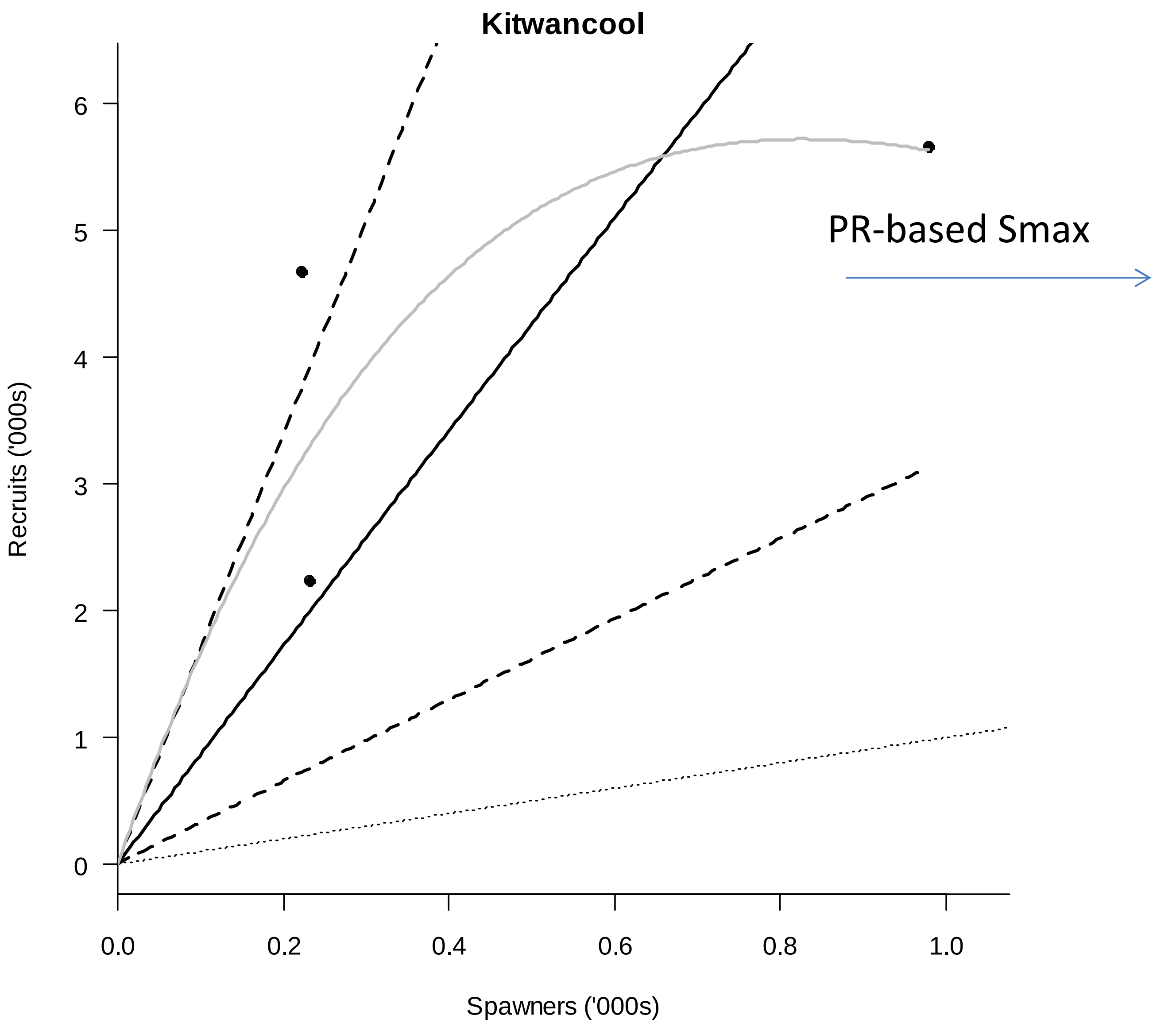


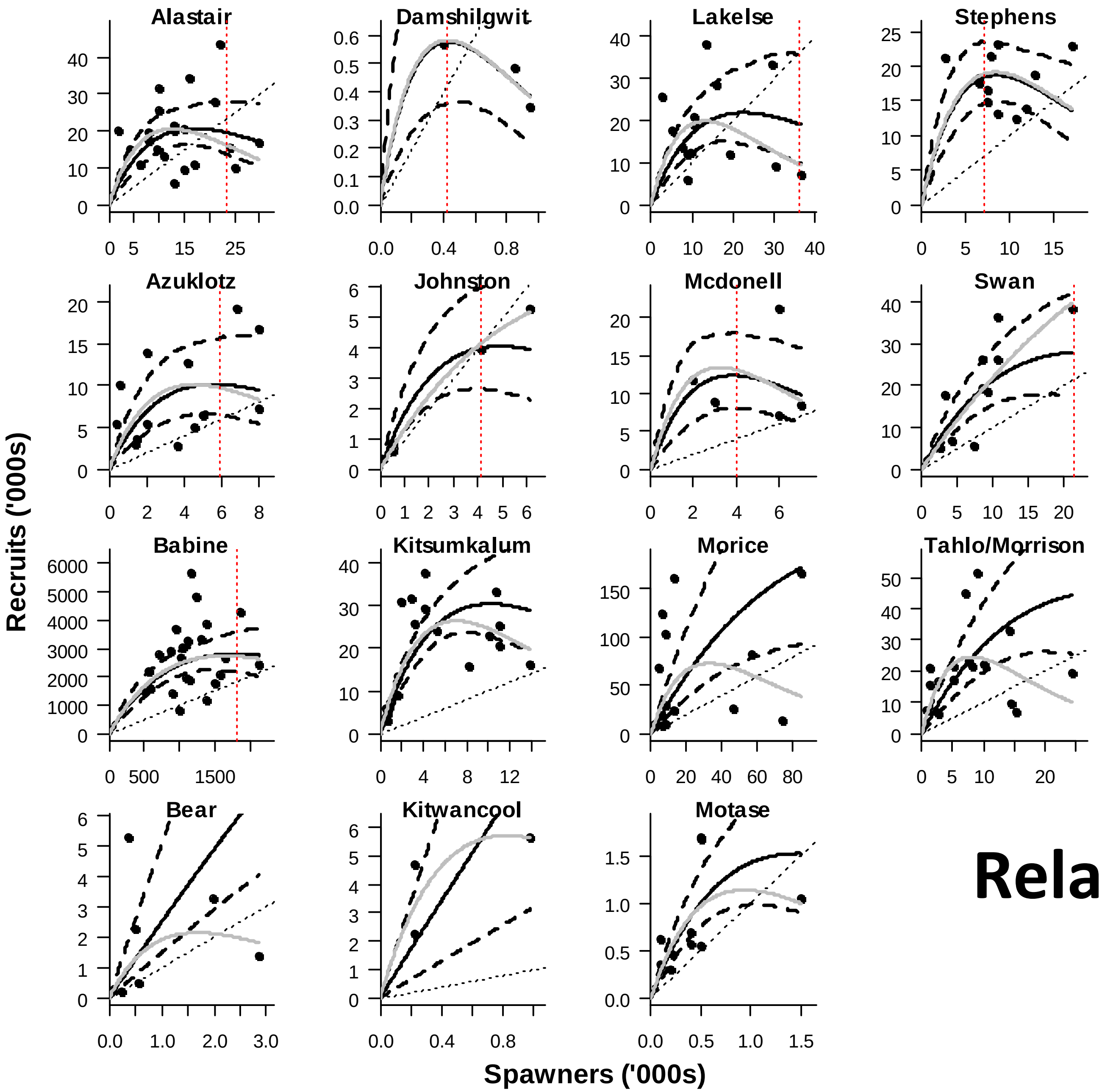
Escapement Trends and Benchmarks

Example of Stock-Recruitment Fit with Good Sample Size

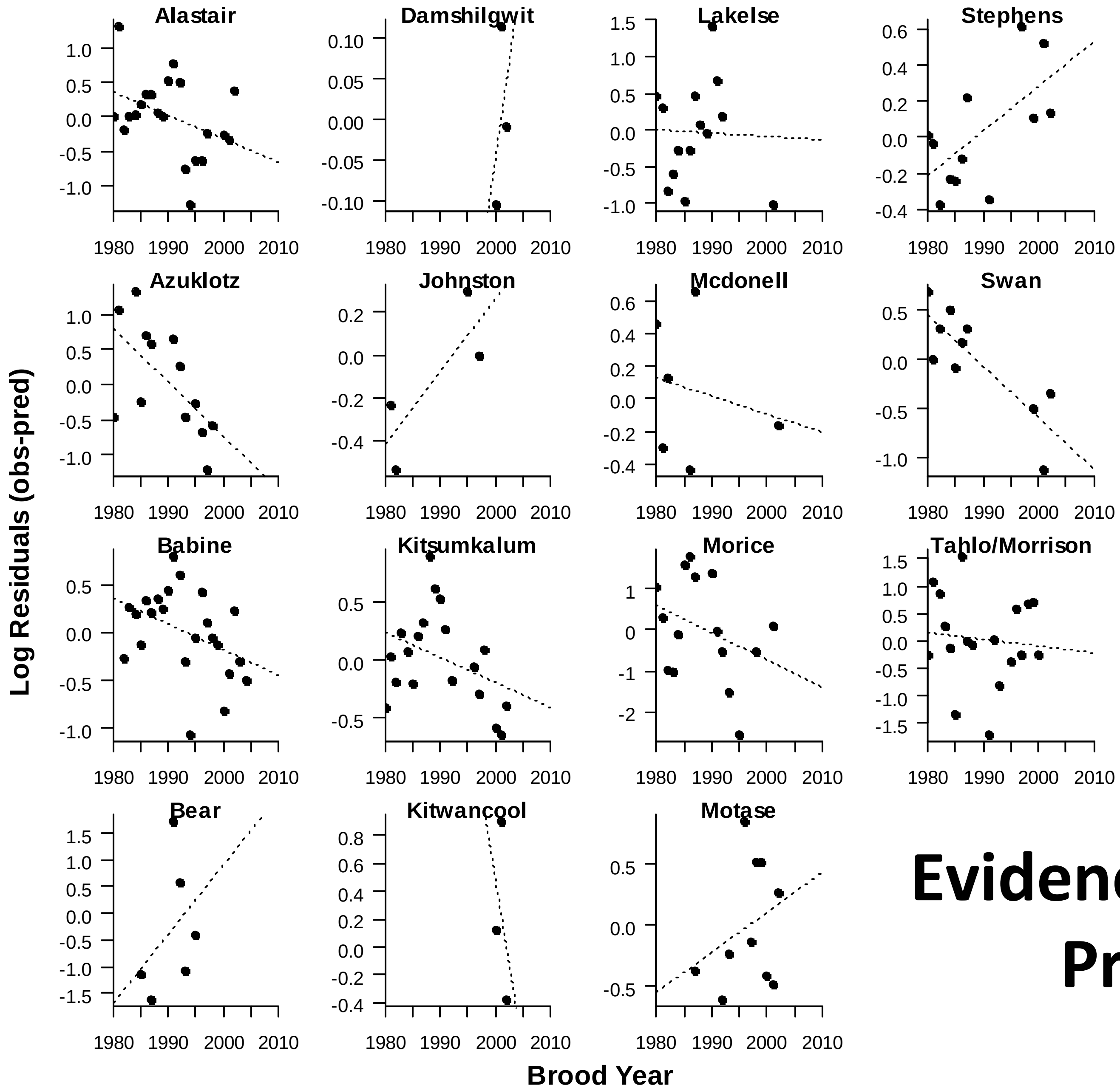


Example of Stock-Recruitment Fit with Very Limited Sample Size



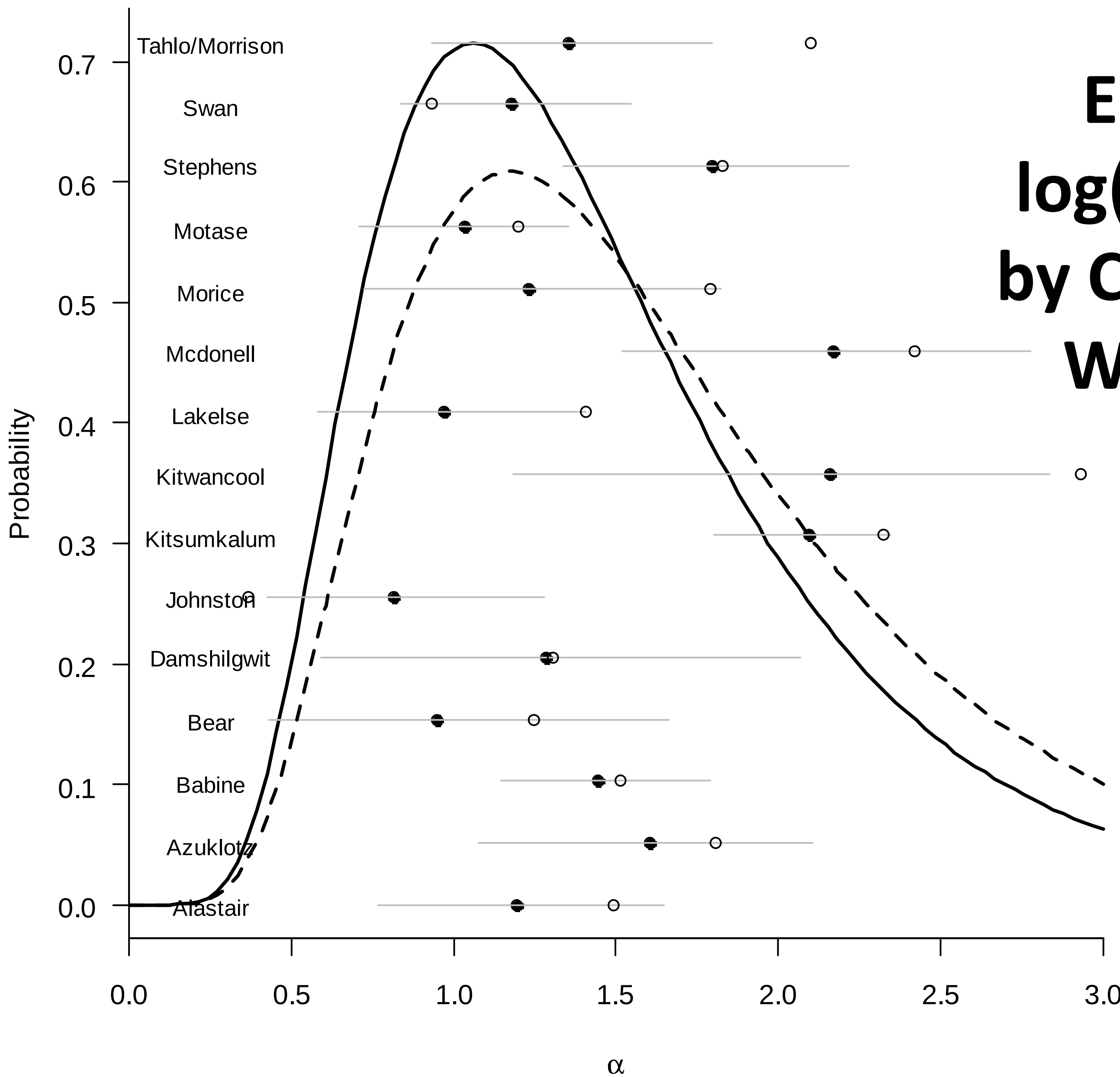


Relationships for all CUs

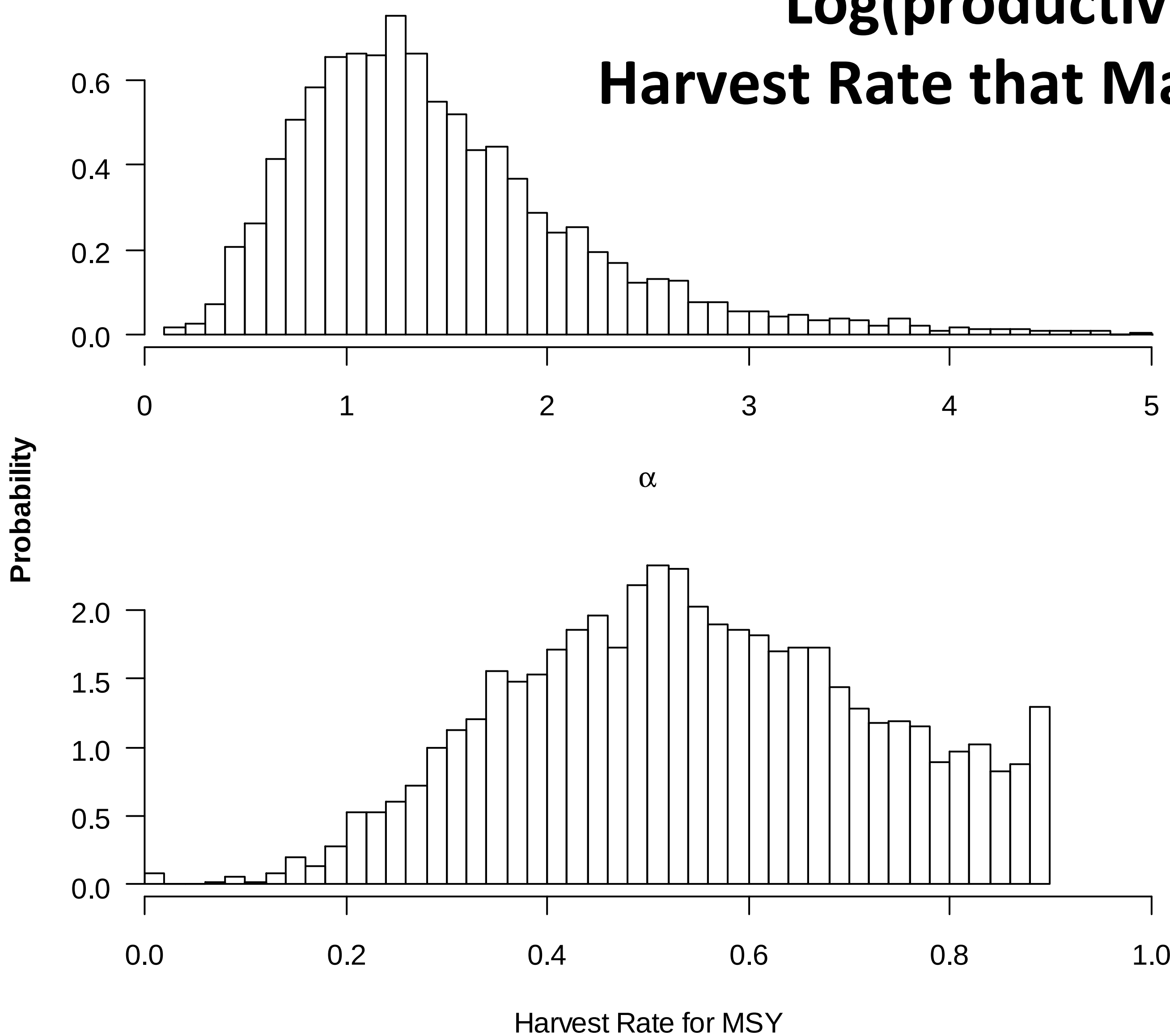


Evidence for Changing Productivity

Estimates of log(productivity) by CU and for CUs Without Data



CUs Without Data: Estimates of Log(productivity) and Harvest Rate that Maximizes Catch

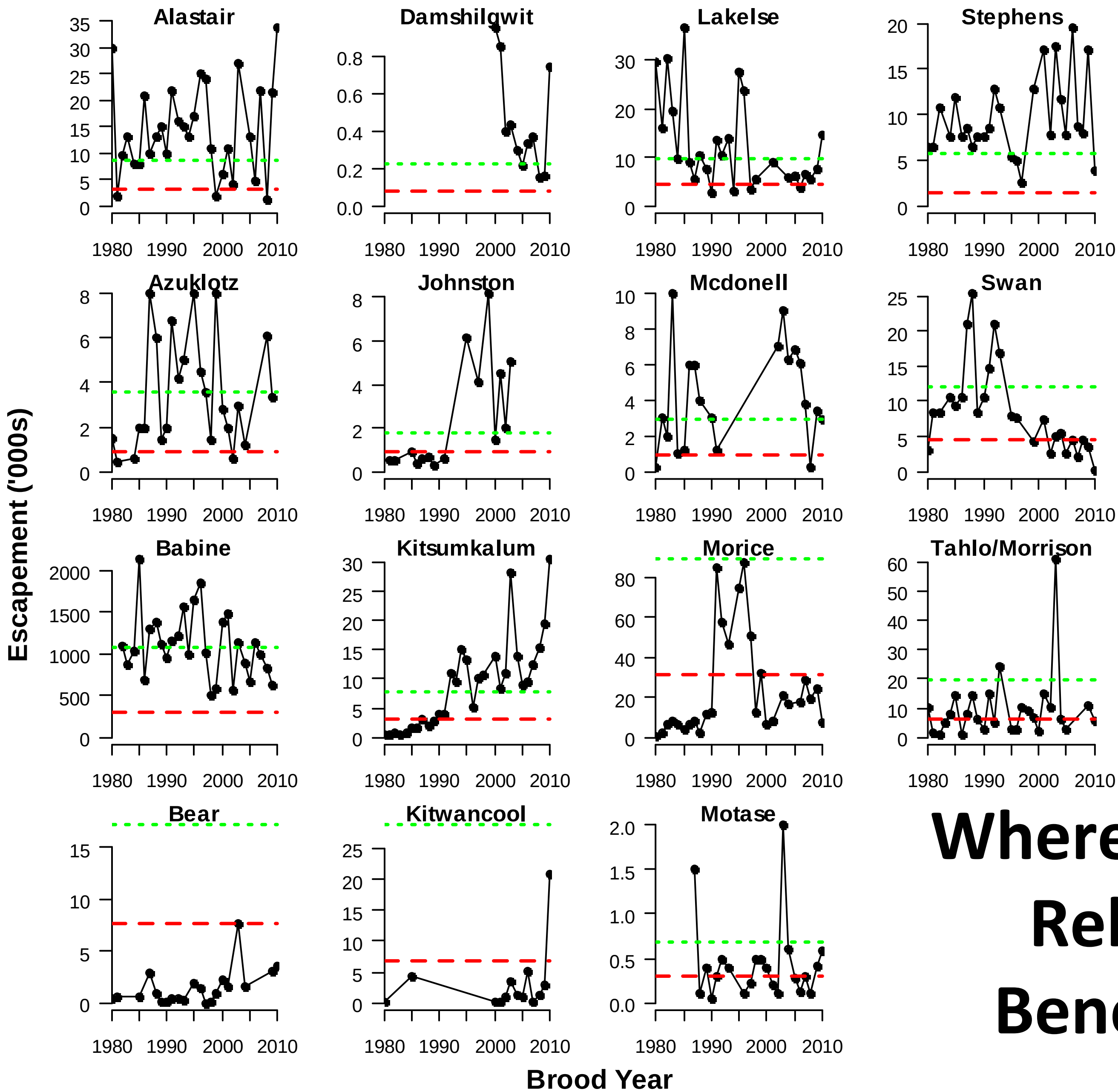


Benchmarks

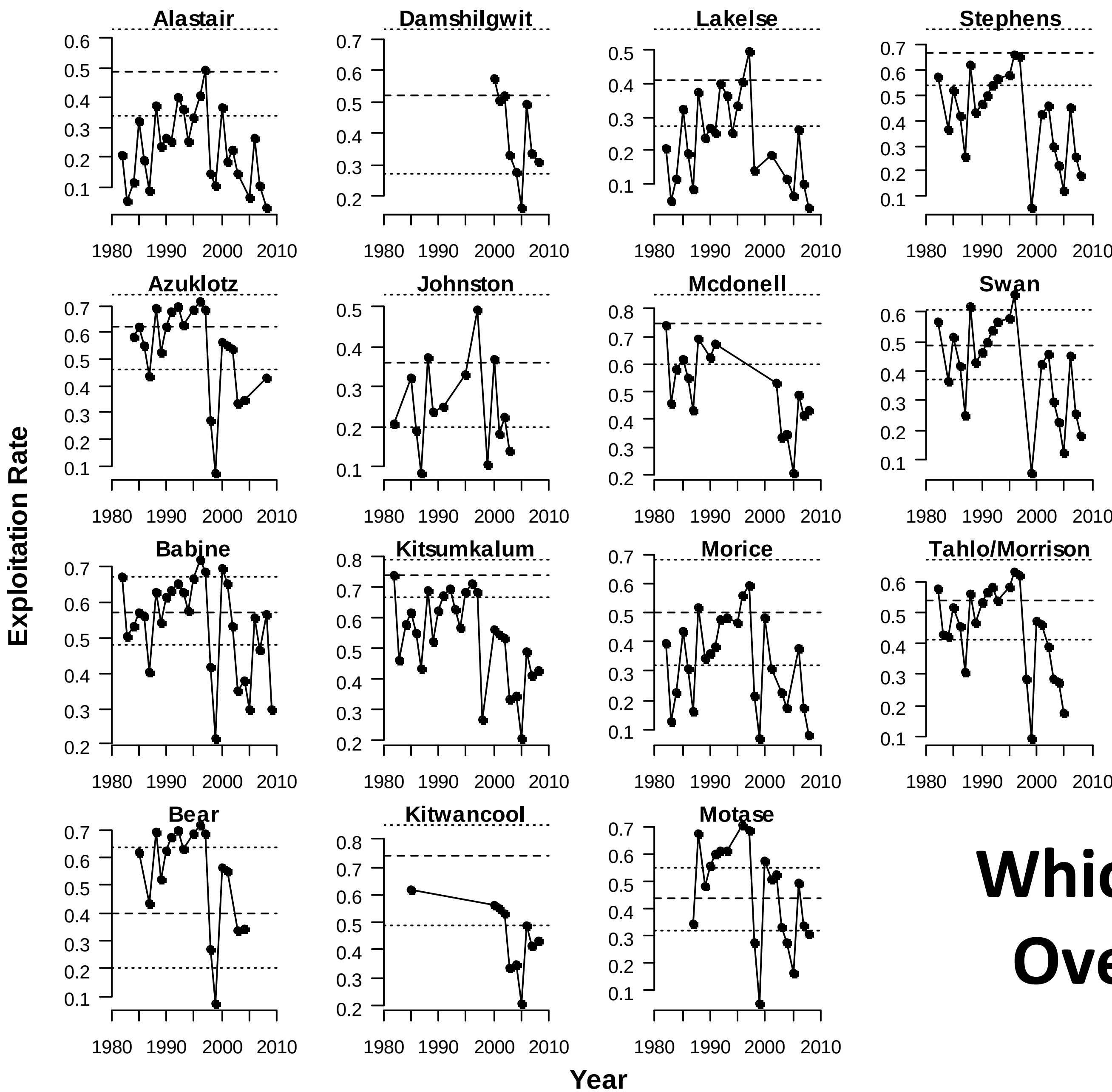
CU	Benchmark	Mean	LCL	UCL		CU	Benchmark	Mean	LCL	UCL
Alastair	Sgen2	1,144	328	2,675		Damshilgwit	Sgen2	30	5	74
	Sgen1	3,251	1,682	5,499			Sgen1	83	34	130
	Smsy	8,655	6,760	11,766			Smsy	225	153	297
	Smax	18,059	11,564	28,585			Smax	453	302	684
	Prod	3.38	2.20	5.20			Prod	3.89	1.80	7.90
	Uopt	0.49	0.34	0.63			Uopt	0.52	0.27	0.73
Azuklotz	Sgen2	214	50	570		Johnston	Sgen2	482	182	822
	Sgen1	905	391	1,690			Sgen1	953	562	1,418
	Smsy	3,586	2,500	5,270			Smsy	1,796	1,066	2,740
	Smax	5,917	3,651	9,445			Smax	5,138	3,202	7,689
	Prod	5.14	2.90	8.20			Prod	2.32	1.50	3.60
	Uopt	0.62	0.46	0.74			Uopt	0.36	0.20	0.53
Babine	Sgen2	80,879	27,850	176,678		Kitsumkalum	Sgen2	781	62	9,971
	Sgen1	307,985	159,214	550,652			Sgen1	3,183	607	36,311
	Smsy	1,072,553	792,052	1,553,761			Smsy	7,941	5,546	12,621
	Smax	1,901,936	1,213,821	3,043,237			Smax	10,840	7,168	18,610
	Prod	4.30	3.10	6.00			Prod	8.19	6.10	10.40
	Uopt	0.57	0.48	0.67			Uopt	0.74	0.67	0.79
Bear	Sgen2	3,435	906	6,990		Kitwancool	Sgen2	3,609	109	46,315
	Sgen1	7,676	3,861	13,409			Sgen1	6,834	1,563	12,269
	Smsy	17,103	6,674	33,180			Smsy	28,730	13,824	49,406
	Smax	42,509	23,341	71,998			Smax	38,734	19,990	64,854
	Prod	2.72	1.50	5.30			Prod	9.30	3.30	17.00
	Uopt	0.40	0.20	0.64			Uopt	0.74	0.49	0.85

Benchmarks

CU	Benchmark	Mean	LCL	UCL		CU	Benchmark	Mean	LCL	UCL
Lakelse	Sgen2	2,024	644	4,389		Stephens	Sgen2	320	65	707
	Sgen1	4,589	2,471	8,275			Sgen1	1,526	576	2,488
	Smsy	9,820	6,518	15,673			Smsy	5,777	4,627	7,512
	Smax	24,480	14,462	44,569			Smax	8,772	6,191	12,955
	Prod	2.70	1.80	4.10			Prod	6.18	3.80	9.20
	Uopt	0.41	0.27	0.56			Uopt	0.67	0.54	0.76
Mcdonell	Sgen2	407	10	4,159		Swan	Sgen2	1,577	573	3,207
	Sgen1	925	155	13,866			Sgen1	4,572	2,487	7,647
	Smsy	2,976	2,205	4,259			Smsy	12,179	7,584	18,608
	Smax	4,032	2,667	6,147			Smax	25,270	15,271	41,180
	Prod	9.17	4.60	16.10			Prod	3.30	2.30	4.70
	Uopt	0.75	0.6	0.85			Uopt	0.49	0.37	0.61
Morice	Sgen2	10,374	3,047	22,907		Tahlo/Morrison	Sgen2	1,796	473	4,465
	Sgen1	30,953	15,335	55,946			Sgen1	6,138	2,502	11,541
	Smsy	88,943	41,143	160,944			Smsy	19,552	10,060	34,336
	Smax	177,773	92,995	305,824			Smax	36,454	17,146	63,496
	Prod	3.55	2.10	6.20			Prod	3.95	2.50	6.00
	Uopt	0.50	0.32	0.68			Uopt	0.54	0.41	0.67
Motase	Sgen2	120	49	240						
	Sgen1	300	163	520						
	Smsy	690	420	1,190						
	Smax	1,594	933	2,743						
	Prod	2.85	2.00	3.90						
	Uopt	0.44	0.32	0.55						

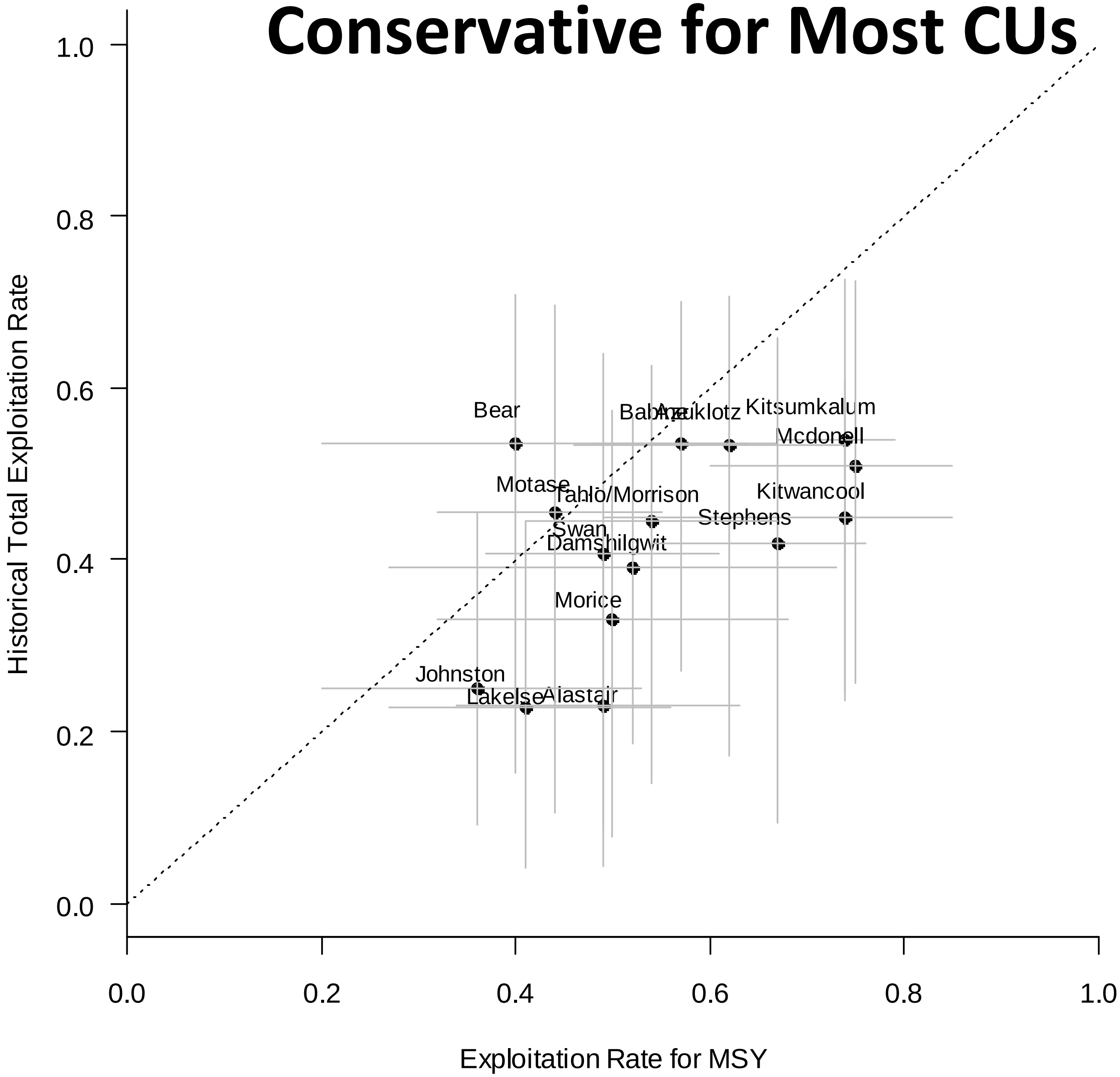


Where Are CUs in Relation to Benchmarks?

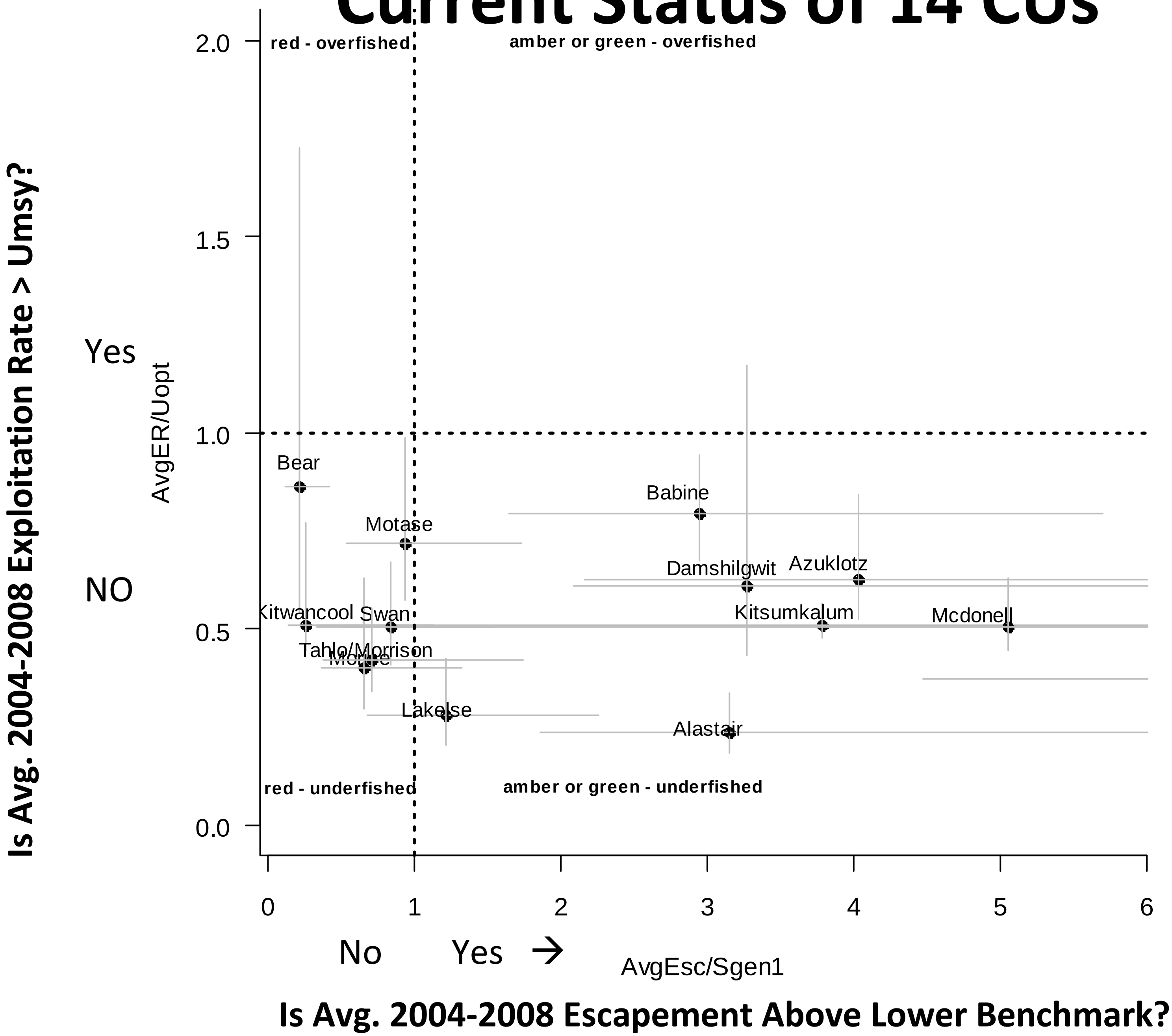


Which CUs are Overfished?

Historical Harvest Rates Have been Conservative for Most CUs



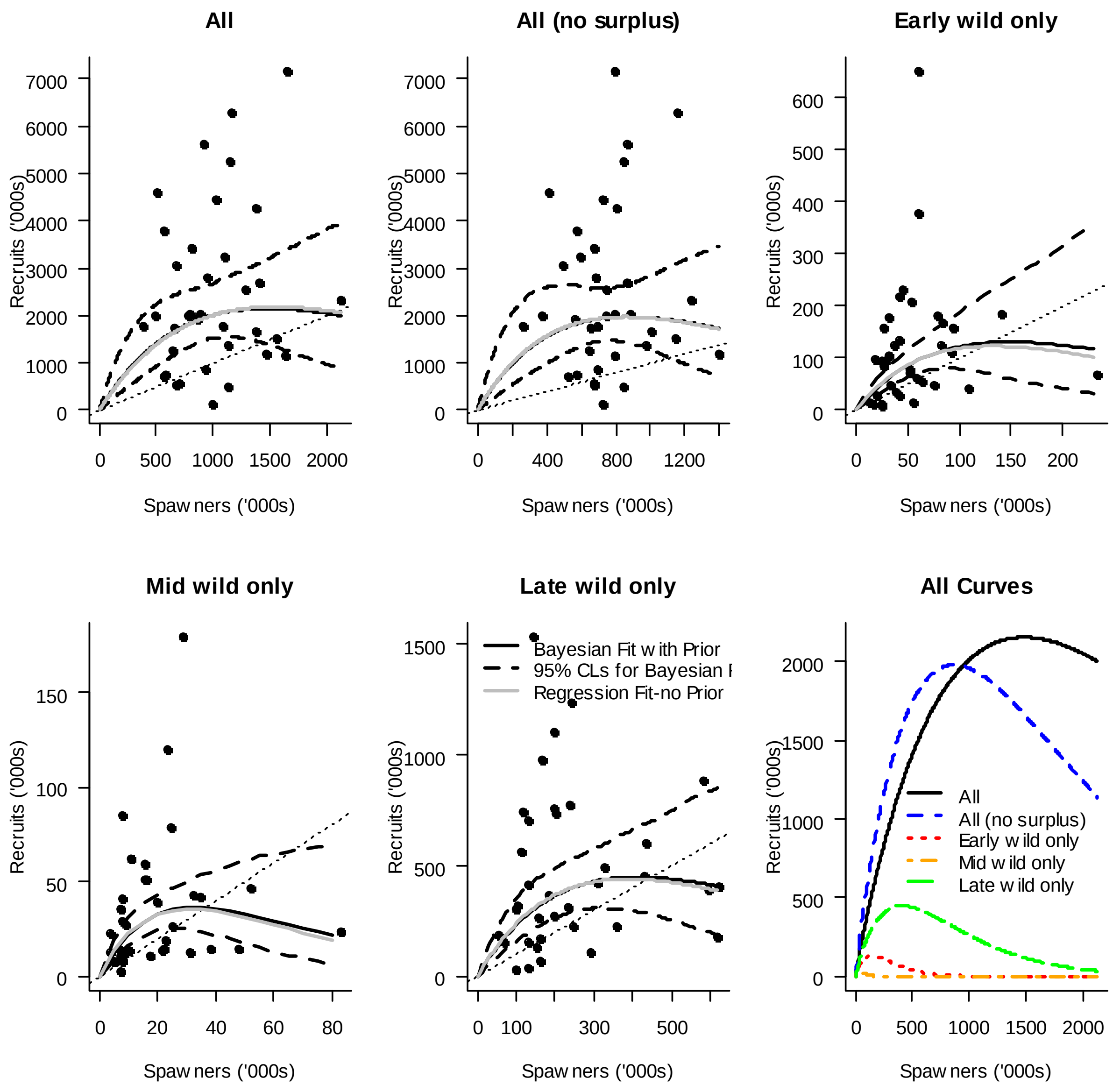
Current Status of 14 CUs



Effect of Using Average Age Composition on Estimates of Benchmarks

	Average Age Composition			Year-Specific Age Composition		
Babine						
	Mean	**LCL**	**UCL**	**Mean**	**LCL**	**UCL**
Sgen	240,879	141,036	392,949	375,605	131,093	1,151,051
Smsy	898,155	708,519	1,199,148	1,001,734	604,099	2,241,124
Smax	1,539,444	1,083,354	2,270,786	2,090,271	974,564	6,003,034
Prod	4.51	3.50	5.90	3.69	2.30	5.70
Uopt	0.59	0.51	0.67	0.52	0.36	0.66
Nass						
	Mean	**LCL**	**UCL**	**Mean**	**LCL**	**UCL**
Sgen	67,558	13,185	989,525	66,706	12,906	982,925
Smsy	229,575	162,762	355,000	221,080	156,573	352,835
Smax	316,629	198,528	552,986	306,962	194,396	559,613
Prod	8.51	5.00	13.40	8.44	4.90	13.70
Uopt	0.74	0.62	0.83	0.74	0.62	0.83

Babine Stock-Recruit Analysis



Babine Stock-Recruit Analysis

Recruit-Spawner Dataset	Avg. Escapement	Prod (e^{α})	Smsy	Smax	Uopt
All Babine recruits vs. all spawners+surplus	1,097,392	3.8	845,356	1,550,925	0.55
All Babine recruits vs. all spawners (no surplus)	810,328	6.3	584,259	856,478	0.68
Early wild recruits vs. early wild spawners	57,838	2.5	53,602	132,179	0.41
Mid wild recruits vs. mid wild spawners	24,934	3.1	14,848	31,236	0.48
Late wild recruits vs. late wild spawners	242,062	3.1	184,135	388,193	0.47

Summary

1. 43%, or 6 of 14 CUs where status could be assessed (stock-recruit data and recent escapement data) were in ‘red’ zone.

2. Very little evidence of overfishing for any CUs. Current low abundance for some likely caused by recent downturn in productivity.

3. Wide variation in productivity among CUs, which leads to big trade-offs between yield and conservation in order to protect weak CUs.

Summary

4. Wild stocks in Babine system have lower productivity than enhanced stock or aggregate, and will therefore be overfished if Babine stock is fished at Uopt for aggregate.

5. Evidence for declining productivity over time for 2 of 15 stocks and increasing productivity for one of 15. Declining non-significant slope for 8 of 15.

6. Uncertain whether historical stock-recruit data will represent future conditions. No defensible way of deciding which historical data to use or to forecast future productivity.

Future Work

1. Simulation analysis to estimate bias due to measurement error, non-representative sampling (time series), fixed age structure. Uncertain how bad bias is with use of semi-informative priors on carrying capacity and hierarchical model.

2. Minor changes likely due to tweaks to ‘data’ (in-river harvest, revised exploitation rates, additional years of data, corrections to escapements, changes in uncertainty in carry capacity priors).

3. Repeat analysis for other species with map-based estimates of carrying capacity.

4. Management strategy evaluation (Walters) to evaluate performance of alternate harvest strategies. Use benchmarks as indicators or to drive harvest rules.