Habitat-based abundance benchmarks for Lake Sockeye CU's in the Skeena Watershed

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Introduction

Although stock-recruit analysis has been the main method for establishing benchmarks for lake sockeye Conservation Units (CU's) in the Skeena watershed to date (Korman and Cox-Rogers 2012), habitat-based abundance benchmarks may have application as well. For example, the lake rearing capacity estimates (Rmax juveniles and Smax spawners) from the photosynthetic rate (PR) model of Shortreed et al (2000) and Cox-Rogers et al (2010) can be used to independently assess status and develop benchmarks. Holt et al (2009) endorse using carrying capacity to develop salmon CU benchmarks, especially in cases where estimates of Smsy are not available because recruitment and/or productivity data are missing or uncertain. Where stock-recruit data are available, independent Smax priors from habitat studies can help establish better estimates of intrinsic productivity in stock-recruit analyses (Walters et al 2008) as applied by Grant et al (2011) and Korman and Cox-Rogers (2012). Finally, where data on spawner abundance are not available or are of poor quality (e.g. the majority of BC sockeye CU's) juvenile abundance may provide a rough indication of spawning status (Holt et al 2009).

For Skeena sockeye lakes, data on juvenile abundance has been collected from rotational acoustic surveys since the mid-1990's (Cox-Rogers et al 2010) and is routinely compared against juvenile rearing capacity estimates (Rmax) for general status assessment. Escapement survey data (where available) can also be compared against Smax spawners for assessing general status. In this paper, provisional upper and lower benchmarks from PR-based Rmax and Smax for Skeena sockeye lakes are suggested, and recent status relative to these benchmarks is compared.

Data

Habitat-based Rmax and Smax estimates for Skeena sockeye lakes come from Cox-Rogers et al (2010), with recent updates provided by Jeremy Hume on file (Cultus Lake Research Unit, Cultus Lake, British Columbia, unpublished). Juvenile sockeye density estimates for Skeena sockeye lakes come from fall fry acoustic surveys following the methods referenced in Cox-Rogers et al (2010). Skeena sockeye lakes are acoustically surveyed on a rotational basis with scheduling outlined in the core stock-assessment plan for North Coast sockeye lakes (English et al 2006). Adult spawning escapement series for Skeena sockeye lakes come from the most recent assessment by English et al (2011) for the years 1980-2010, and are the same as used in Korman and Cox-Rogers (2012).

Methods

The habitat-based spawning abundance benchmarks in this paper follow the abundance metric guidelines developed in Holt et al (2009). A possible lower habitat-based benchmark on spawning escapement, approximate to Sgen of Holt et al (2009, Figure 5) would be ~15% of Smax spawning capacity as estimated from the PR model. A possible upper habitat-based benchmark on spawning escapement, approximate to Smsy of Holt et al (2009, Figure 5) would be ~55% of Smax spawning capacity as estimated from the PR model. Holt et al (2009, Figure 5) note Smsy is approximately 40% of equilibrium replacement capacity (Scap), but as Smax is lower than Scap, a higher percentage of Smax corresponds to the same Smsy point.

Guidelines for developing benchmarks for juvenile abundance relative to Rmax have not been developed (Holt et al 2009). Conceptually they should be matched to stock-recruit relationships. In the example shown in Figure 5 of Holt et al (2009), Sgen generates approximately 35% Rmax recruitment, while Smsy generates ~90% Rmax recruitment. However, this relationship will vary depending upon stock productivity and differences in average juvenile to adult survival among stocks. For the purposes of this paper, the benchmark guidelines being used for Smax spawners was also applied to juveniles; that is, a possible lower benchmark on juvenile abundance was set to 15% of Rmax lake rearing capacity, and a possible upper benchmark on juvenile abundance was set to 55% of Rmax lake rearing capacity. There is some precedence for this approach as Wood (1999) also suggested using 10%-15% of Rmax juveniles as a “lower reference point” both for juveniles and for the spawners producing them in his evaluations of Skeena sockeye lakes. Further evaluations of appropriate juvenile benchmarks are expected.

Results

Table 1 summarizes the most recent juvenile Rmax and adult Smax estimates for surveyed Skeena sockeye lakes. Table 2 reports acoustic juvenile density estimates for surveyed Skeena sockeye lakes obtained to date. Figures 1 and 2 shows the general freshwater productivity (mean PR) and estimated juvenile lake rearing capacity (Rmax) estimates for Skeena sockeye lakes. Figure 3 shows juvenile stock status for Skeena sockeye lakes surveyed over the 2000-2010 period plotted against lower and upper Rmax benchmarks. Figure 4 shows spawning stock status for Skeena sockeye lakes (2005-2010 average) plotted against lower and upper Smax benchmarks. Figure 5 shows a simple traffic light analysis (red/yellow/green) for spawning status assessed against lower and upper Smax benchmarks for Skeena sockeye lakes 1980-2010.

Not surprisingly, there is substantial diversity among Skeena sockeye rearing lakes as reflected by the wide range of primary productivities they exhibit (Figure 1). As primary productivity is strongly correlated to food supplies and smolt production in sockeye lakes (Shortreed et al 2000), there is also wide variation in estimated maximum rearing capacities (Rmax in kg/hectare) among Skeena sockeye lakes (Figure 2). For example, the least productive Skeena sockeye lakes (Kluyaz, Motase) produce about 75% less smolt biomass per hectare than the most productive Skeena sockeye lakes (Babine, Kitwanga).

The rearing capacity estimates in Figure 2 assume lake rearing capacity, and not spawning ground capacity or predation, is the primary limitation to juvenile production in Skeena sockeye lakes. In cases where this is not so, PR model estimates of Rmax and Smax for Skeena lakes will be biased high and will need to be adjusted downwards to account for other limiting factors. However, preliminary examination of the very limited ancillary spawning capacity data for Skeena lakes (last column Table 1) is somewhat inconclusive regarding what actual or "better" spawning capacities might be, especially as they do not take possible lake spawning habitat into account.

Habitat-based juvenile status in the Skeena sockeye lakes surveyed to date is variable across the watershed (Figure 3), with 5 of 15 surveyed lake CU's being less than 15% of Rmax rearing capacity (red), 7 of 15 surveyed lake CU's being less than 55% of Rmax rearing capacity (yellow), and 3 of 15 lake CU's being greater than 55% of rearing Rmax capacity (green). Lakes with poor or concerning juvenile status include Bear, Lakelse, Kitsumkalum, Morice, and Swan.

Habitat-based spawning status (2005-2010) in the Skeena sockeye lakes surveyed to date is also variable across the watershed (Figure 4), with 4 of 14 surveyed lake CU's being less than 15% of Smax spawning capacity (red), 4 of 14 surveyed lake CU's being less than 55% of spawning capacity (yellow), and 6 of 14 lake CU's being greater than 55% of spawning capacity (green). Lakes with poor or concerning spawning status include Bear, Kitwanga, Morice, and Swan.

One might expect greater correspondence between juvenile status shown in Figure 3 compared to adult spawning status shown in Figure 4. For example, Alastair Lake scores "yellow" and "green" for juvenile and spawning status respectively; while Kitsumkalum Lake scores "red" and "green" for juvenile and adult spawning status respectively. Overall, a higher proportion of surveyed lakes are below the upper benchmark when scored for juvenile abundance compared to spawning abundance. Note that CU status on both metrics is associated with wide confidence limits that, in many cases, overlap lower and upper benchmark boundaries.

Part of the explanation may be the time period being assessed for spawning abundance (2005-2010) does not properly align with the spawners that actually produced the surveyed juvenile abundances (all of the 2000's), and so some caution is needed in interpretation. It is also possible that factors affecting juvenile status are different than those affecting spawning status. Other sources of error would include incorrect Rmax/Smax estimates due to spawning ground limitation, incorrect conversion factors being used to estimate Smax spawners, and/or errors in the escapement data series being used to assess status.

Finally, this analysis does not provide status for some Skeena sockeye lake CU's that are data deficient or difficult to monitor. For example, while estimates of Rmax and Smax actually exist for almost all Skeena sockeye lake CU's (Table 1), some smaller lakes (Atna, Dennis, Aldrich, Kluatantan, Kluayaz, Sicintine, etc, Table 2) are difficult to regularly monitor because of small size and/or location. Status for data deficient CU's can perhaps be inferred from geographically similar CU's that are being monitored (Holt et al 2009). A similar approach is taken by Korman and Cox-Rogers (2012), who suggest using a hierarchical Bayesian model to provide the distribution of productivities for 16 Skeena sockeye lake CU's where stock-recruit data is missing.

Conclusions

The results of the habitat-based assessments presented here can be compared against those from stock-recruit based status assessments (Figure 12 of Korman and Cox-Rogers 2012) or against synoptic-survey assessments now being completed (Blair Holtby, DFO, pers comm.). As with all metrics currently being used to evaluate status and develop benchmarks for salmon CU's in British Columbia under the Wild Salmon Policy (abundance, trends in abundance, distribution, and fishing mortality, Holt et al 2009) different assessments of WSP status (colors) by metric, or approaches within metrics, can be expected (Holt et al 2009, Grant et al 2011). It is anticipated that assigning overall CU status and establishing benchmarks for Skeena sockeye CU's will require consideration of all technical assessments conducted to date.

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Lake	Cultus Lab Limnological Assessment	Cultus Lab Juvenile Assessment	**Rmax estimated (2012) Sm. Biomas (kg/ha)**	Rmax 95% lower Sm. Biomas (kg/ha)	Rmax 95% upper Sm. Biomas (kg/ha)	Smax estimated spawners	Smax 95% lower spawners	Smax 95% upper spawners	Smax estimated (1952) spawners
Alastair	1996	1994	8.27	5.03	11.51	23437	14250	32624	37000
Lakelse	2003	2003	6.00	3.65	8.35	35916	21837	49995	95000
Swan	2002	2002	2.95	1.79	4.11	21432	13031	29833	15000
Stephens	2002	2002	8.70	5.29	12.11	7069	4298	9840	
Club	2002	2002	3.60	2.19	5.01	589	358	820	
Morice	2002	2002	6.00	3.65	8.35	191362	116348	266376	
Atna	no	no							
Maxan	no	no							
Slamgeesh	2001	2001	2.30	1.40	3.20	423	257	589	
Kitwanga	2003	2003	17.00	10.34	23.66	36984	22486	51482	
Kalum	1996	1993	2.70	1.64	3.76	20531	12483	28579	42000
McDonnel	2001	2002	4.30	2.61	5.99	4072	2476	5668	
Dennis	2001	2001	5.30	3.22	7.38	1091	663	1519	
Aldrich	2001	2001	4.20	2.55	5.85	1116	679	1553	
Johanson	2004	2004	5.00	3.04	6.96	2723	1656	3790	
Sustut	2004	2004	2.70	1.64	3.76	2775	1687	3863	
Bear	2003	2003	5.30	3.22	7.38	40532	24643	56421	16000
Asitka	no	no							
Morrison	1996	1994	8.20	4.99	11.41	44587	27109	62065	
Babine	1995	1995	10.00	6.08	13.92	1808245	1099413	2517077	
Azuklotz	2003	2003	6.60	4.01	9.19	5933	3607	8259	
Damshilgwit	2001	2001	2.30	1.40	3.20	423	257	589	
Johnston	2005	2005	5.40	3.28	7.52	4125	2508	5742	
Kluatantan	no	no							
Kluayaz	2004	no							
Sicintine	2004	no							
Spawning	no	no							
Motase	2003	2003	1.10	0.67	1.53	1764	1073	2455	
Bulkley	no	no							

Note Rmax and Smax are the averages of available Cultus lab capacity estimates provided by Hume 2012 for the following lakes:
Lakelse, Swan. Morice, Kitwanga, Bear
Note Damshilgwet Rmax/Smax is using Slamgeesh

Table 1. Estimated Rmax juvenile (smolt biomass in kg/hectare) and Smax spawners (n) from the PR model for surveyed Skeena sockeye lakes, with associated 95% confidence limits. Updated data from Cox-Rogers et al (2010). Also shown, (last column), are independent estimates of spawning capacity (Scap) from visual survey estimates for some Skeena sockeye lakes conducted in Brett (1952).

	Cultus Lab Surveys	Cultus Lab Surveys	SFC Surveys	SFC Surveys	SFC Surveys	SFC Surveys	Avg Survey	
	reported	reported	reported	reported	reported	reported	Density (2000's)	
Lake	Sm. Biomas (kg/ha)	Sm. Biomas (kg/ha)	Sm. Biomas (kg/ha)	Sm. Biomas (kg/ha)	Sm. Biomas (kg/ha)	Sm. Biomas (kg/ha)	Sm. Biomas (kg/ha)	Prop Rmax
Alastair	3.39			1.77		1.9	1.84	0.22
Lakelse	1.90	0.95	0.80	1.10	0.60	0.70	0.83	0.14
Swan	0.63	0.38			0.10		0.24	0.08
Stephens		1.88			3.10		2.49	0.29
Club		0.11					0.11	0.03
Morice	0.17	0.16		0.13			0.14	0.02
Atna								
Maxan								
Slamgeesh		1.96					1.96	0.85
Kitwanga	0.18							
Kalum	0.20			0.50		0.2	0.35	0.13
McDonnel		0.90	2.00	1.00	1.20	2.00	1.42	0.33
Dennis								
Aldrich								
Johanson	0.37	2.41			0.60		1.51	0.30
Sustut	1.58	0.10			1.20		0.65	0.24
Bear	0.36	0.38	0.10				0.24	0.05
Asitka								
Morrison	1.62							
Babine								
Azuklotz		1.82		0.50			1.16	0.18
Damshilgwit		1.96					1.96	0.85
Johnston		3.04			5.10		4.07	0.75
Kluatantan								
Kluayaz								
Sicintine								
Spawning								
Motase		0.06		0.40			0.23	0.21
Bulkley								

Table 2. Measured juvenile densities (smolt biomass in kg/hectare) for surveyed Skeena sockeye lakes. The 2000's average and the proportion Rmax this represents.

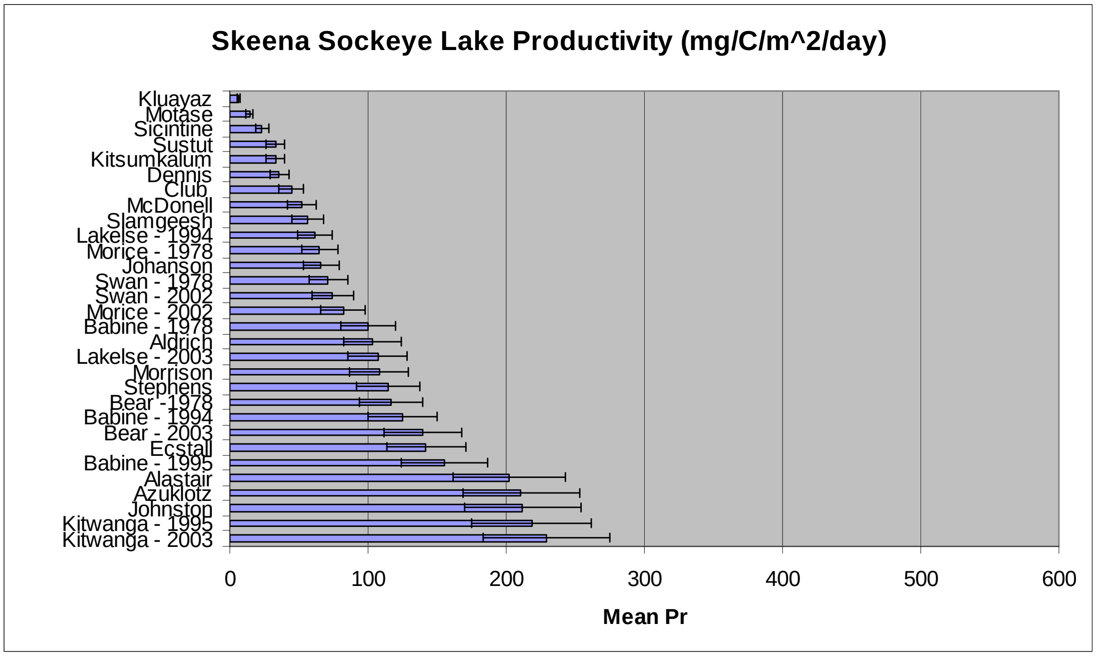

Figure 1. Productivity of Skeena sockeye lakes, assessed from measured mean seasonal photosynthetic rate. Data from Cox-Rogers et al (2010) with updates provided by DFO's Cultus Lake Research Unit (2012).

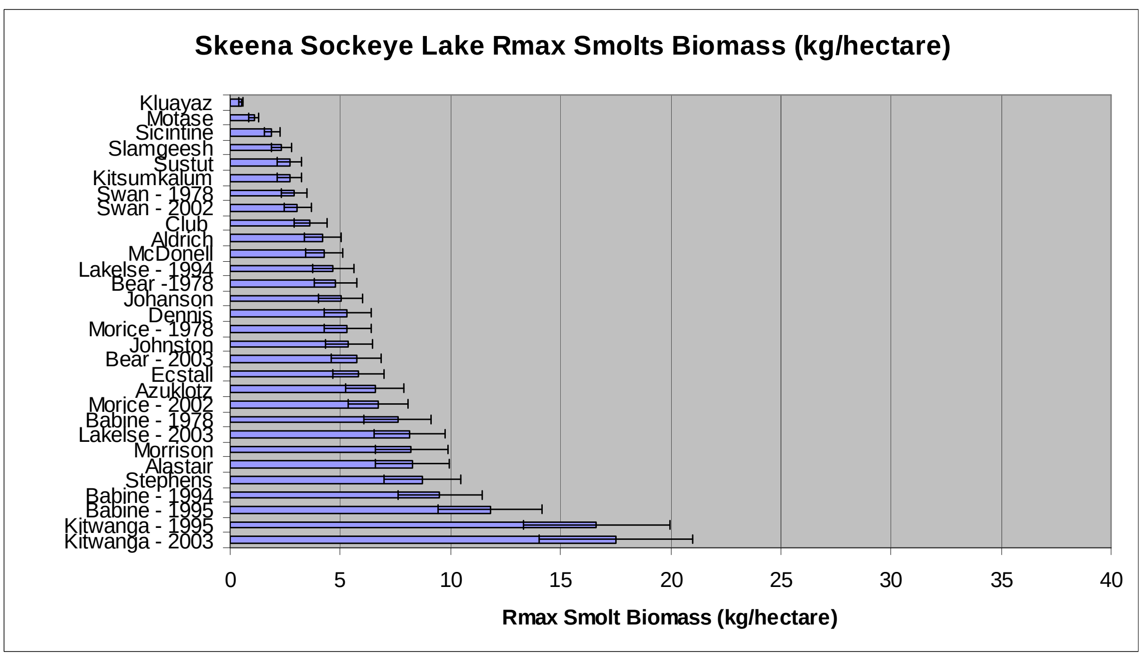

Figure 2. Maximum juvenile rearing capacity of Skeena sockeye lakes (Rmax smolt biomass as kg/hectare), estimated from the PR model. Data from Cox-Rogers et al (2010) with updates provided by DFO's Cultus Lake Research Unit (2012).

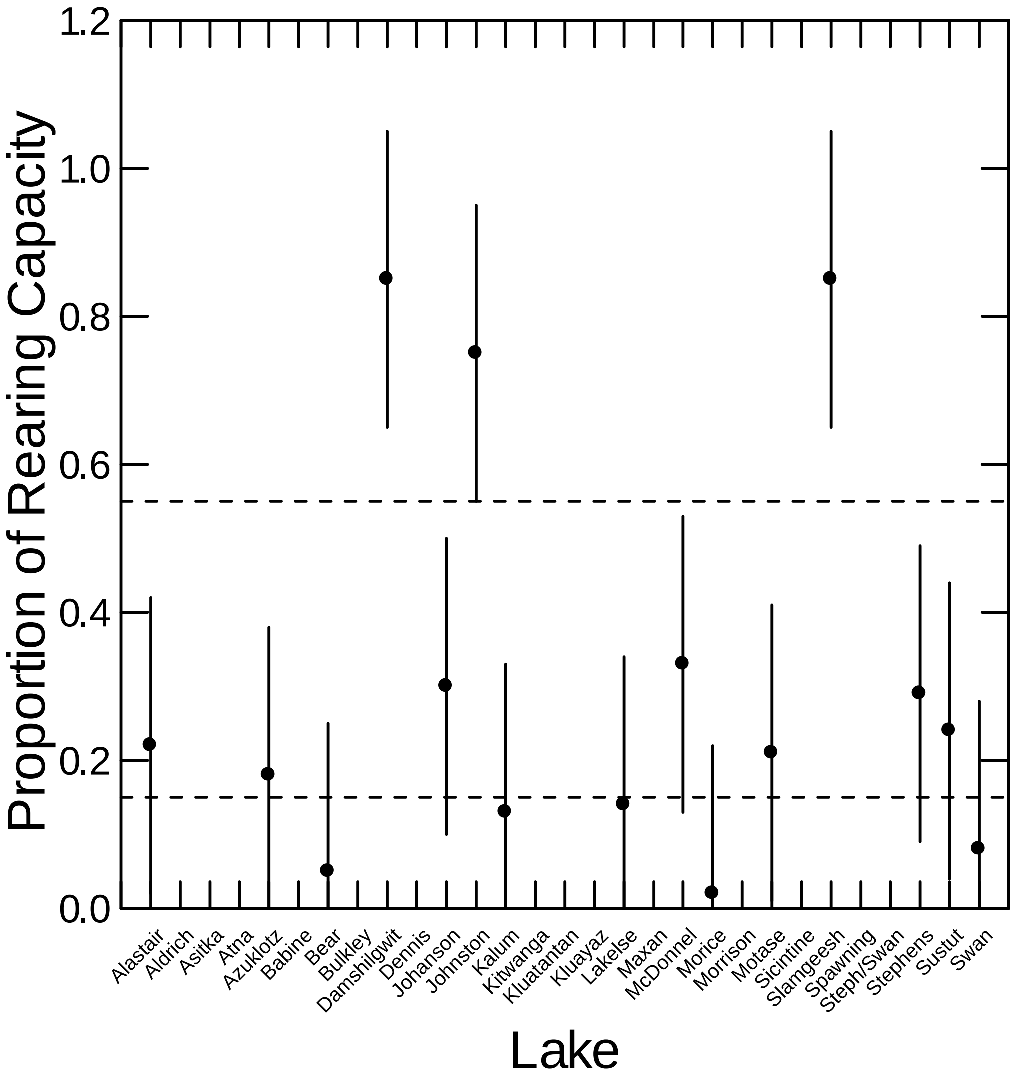

Figure 3. Current juvenile abundance status of Skeena sockeye lakes expressed as proportion of Rmax lake rearing capacity. Shown are the averages (dots) for available surveys conducted from 2000-2011, with 95% confidence limits about the averages incorporating uncertainty in the Rmax estimates. The upper dashed line represents a possible upper juvenile abundance benchmark of 55% Rmax rearing capacity. The lower dashed line represents a possible lower juvenile abundance benchmark of 15% Rmax rearing capacity.

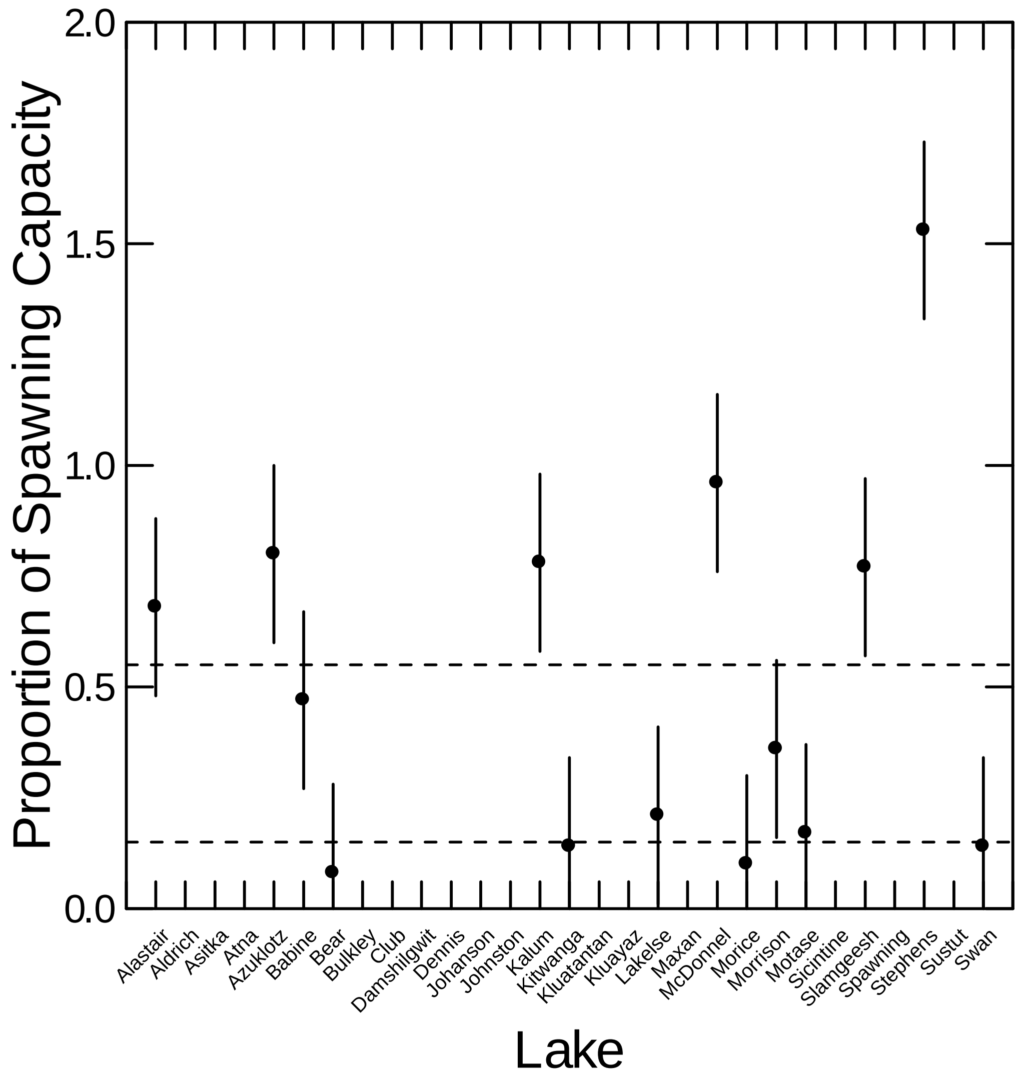

Figure 4. Current adult spawning abundance status of Skeena sockeye lakes expressed as proportion of habitat-based Smax spawning capacity. Shown are the averages (dots) for from 2005-2010, with 95% confidence limits about the averages incorporating uncertainty in the Smax estimates. The upper dashed line represents a possible habitat-based upper spawning abundance benchmark of 55% Smax spawning capacity, which is similar to Smsy of Holt et al (2009) The lower dashed lines represents a possible habitat-based lower spawning abundance benchmark of 15% Smax spawning capacity, which is similar to Sgen of Holt et al (2009).

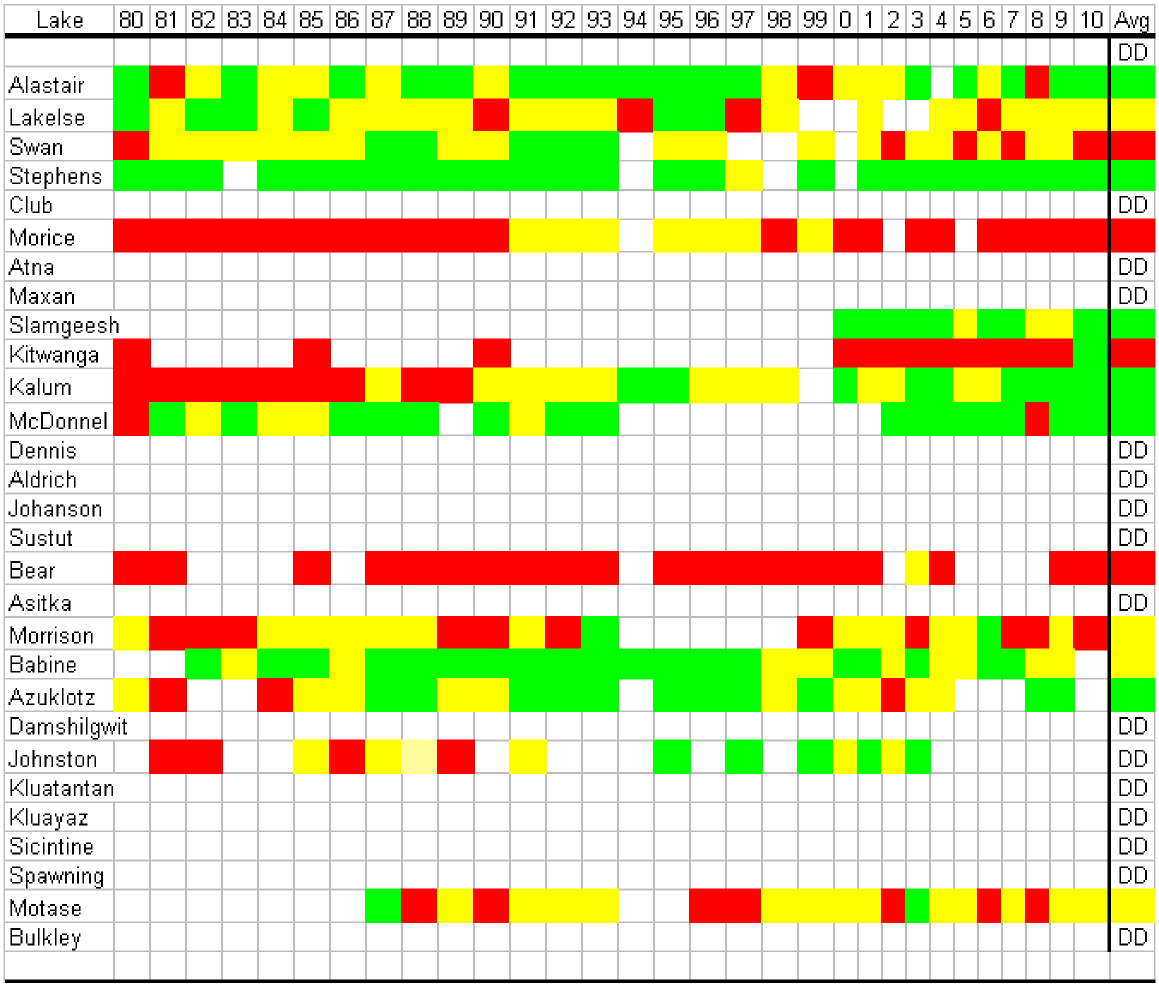

Figure 5. Traffic light analysis of spawning abundance status for Skeena sockeye lakes 1980-2010 (columns), based on spawning escapement data presented in English et al (2011). Cells shaded red represent spawning abundance in that year less than a lower benchmark of 15% of habitat-based Smax, which is approximate to Sgen of Holt et al (2009). Cells shaded green represent spawning abundance in that year greater than an upper benchmark of 55% of habitat-based Smax, which is approximate to Smsy of Holt et al (2009). Cells shaded yellow represent status between the lower and upper benchmarks. The last column reports status for recent (2005-2010) average spawning abundance, which is also plotted in Figure 4. (DD = data deficient).