Compilation of Stock Assessment Information or Skeena River Steelhead: Habitat-Based Escapement Estimation

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Abstract

Geographic information from the BC Watershed Atlas and juvenile steelhead surveys from the Sustut, Kispioc, Bulkley and upper Skeena rivers were used to update a model of steelhead trout carrying capacity estimation in the Skeena drainage. The existing spreadsheet model was updated with new information on physical characteristics of stream reaches and sub-models used to estimate fry capacities were calibrated and compared to original estimates of capacities.

Table of Contents

Table of Figures

List of Tables

1 Introduction

This assessment was initiated to update the Skeena river steelhead escapement targets set by Tautz *et al.* (1992). The original spreadsheet model estimated fry capacities in tributaries of the Skeena watershed by way of a relationship between maximum fry densities and a combination of alkalinity and fork length (Ptolemy 1993). The model estimated useable stream widths and applied productivity (fry/m^2) estimates to the net area (usable width x length) of each stream. Record escapement in 1998 provided the impetus to sample some of the more productive rivers and to compare observed fry densities with predicted capacities. It is assumed that record escapement will result when fry densities approach capacity, possibly exceeding the spreadsheet estimates of maximum fry capacity in some tributaries and falling short of predictions in other streams. The Sustut and Bulkley rivers (Bustard 2000) and the Kispiox and Upper Skeena (Williamson 2002) were surveyed in late summer of 1999. The surveys measured fry densities within sample plots. Depth and velocity measures were also recorded and used to obtain useable area estimates within the plots. This assessment applies the results of those surveys to the original Tautz *et al.* (1992) spreadsheet model to provide an indication of where the original model may have been biased.

2 Data Summary

The following describes the data used to augment the 1992 Skeena spreadsheet model:

- Macroreach data in the form of GIS shapefiles downloaded from 1:50,000 BC watershed atlas for the Babine, Bulkley, Kispiox, Kalum, lower Skeena, middle Skeena, upper Skeena, Morrice, Sutstut, and Zymoetz watersheds.
- FISS locations of observed Steelhead activities.
- FISS observed obstructions (falls, cascades, culverts, etc…).
- Electro-fishing depletion data from sites in the Kispiox and Skeena (Williamson 2002) and Bulkley and Sustut (Bustard 2000)
- Stream depth and velocity gradients data from sites in the Kispiox, Skeena, Bulkley and Sustut (same surveys as electro-fishing).

The Tautz et al. (1992) model identified 75 fry-bearing reaches. Survey data was available for 18 sites in the Kispiox, 20 sites in the Skeena, 30 sites in the Bulkley and 33 sites in the Sustut. The surveys took place in the following locations and reaches:

Seg	Survey	River	Reach description	# Sites
1	Williamson (2002)	Skeena	Zymoetz to Bulkley	4
28	Bustard (2000)	Bulkley	To Morice	30
54	Williamson (2002)	Skeena	Bulkley to Sustut	11
55	Williamson (2002)	Kispiox	To Sweetin (470-5072)	10
56	Williamson (2002)	Kispiox	To East Kispiox (7347)	4
58	Williamson (2002)	McCully	To 1557-756	2
59	Williamson (2002)	Cullon	To Kuitan (2457-691)	2
70	Williamson (2002)	Skeena	Sustut to Duti	3
71	Bustard (2000)	Sustut	Mouth to Asitka	6
72	Bustard (2000)	Sustut	Asitka to Moosevale	16
73	Bustard (2000)	Sustut	Moosevale to Johanson	11
75	Williamson (2002)	Kluatantan	To Jenkins	2

Table 1: Segment description and data summary.

3 Methods

New empirical information was used to re-evaluate spreadsheet cell values for the reaches for which the information was available. Average values over all sample locations were used to update the following:

- Stream length
- Stream width
- Age 1+ fork length
- Site alkalinity
- Density per weighted useable area (WUA)

Macroreach data was used to produce shapefiles representing the reaches identified by Tautz *et al.* (1992). Reaches identified in Schedule A: Appendix 2 were extracted from the 1:50,000 watershed atlas macroreach data and saved as separate shapefiles. FISS fish observations were queried to separate observed steelhead and rainbow trout activity. FISS databases were also queried to include only obstructions that could limit migration. Falls over 5 meters were separated from cascades and smaller falls. All macroreach linework, fish observations and obstructions were converted to ArcView shapefile format. The resulting maps are shown in Figures 1 and 2.

Shapefiles were created for each individual reach (seg1.shp, seg2.shp, etc…). Shapefiles of the 75 reaches were merged into a single shapefile (skeenast.shp). This shapefile was exported in a MS Access database and queried to obtain the length of each reach. These lengths were used to update the Skeena spreadsheet (see Figure 1). Useable stream area is an important measure that determines the amount of habitat available for fry. Tautz *et al.* (1992) assumed a useable width that was a portion of the total width, which was in turn determined by a hydrological model that was based on the flow characteristics of each reach and a relationship to upstream catchment areas. Field measures recorded both the channel width as well as the wetted width at each site. An average of these measures was calculated for each reach.

Electro-fishing surveys recorded fork lengths of salmonid species (Bustard 2000, Williamson 2002). These were extracted from Excel spreadsheets and summarized in Access tables. Queries were produced to summarize the survey data for each reach. The summaries include average fry abundance and fork length for each reach. Electro-fishing surveys also measured conductivity (COND). This was used to calculate total alkalinity (TALK) in the spreadsheet using the relationship TALK = 0.4 COND. The relationship TALK = 7E-10 $pH^{12.181}$ (Ron Ptolemy, pers comm.) was not used because it estimated total alkalinity values 2 or more times higher than the Tautz *et al.* (1992) values.
Fry habitat suitability curves were used to calibrate the width of the survey site to the width that is theoretically habitable by steelhead fry. The useable area of the survey site was then calculated as WUA = HSI * SITE_WIDTH * SITE_LENGTH. The fry density per unit useable area (FPU) was then calculated by dividing the abundance by WUA. FPU was then used to calculate the number of fry that the reach could support.

The Skeena spreadsheet was updated with the FPU caculated from the electro-fishing surveys. For reaches that had no surveys to establish an estimate of useable width, the total alkalinity measure used by Tautz *et al.* (1992) was used to estimate FPU.

3.1 Calculation of Useable width for WUA estimates

The Bulkley, Sustut, Kispiox and Skeena rivers were surveyed in late summer for fry and parr densities as well as for depth and velocity (Bustard 2000, Williamson 2002). Hydraulic information was collected along a transect line established at the widest section of the site. Water depth, mean velocity and a bed material descriptor were recorded at 0.5 m intervals along the transect line to the outside edge of the net. In the case of the Bulkley and Sustut rivers, additional measurements were made beyond this point at 1 m intervals to a point that the channel could no longer be comfortably waded. A second transect line was established on the mainstem sites on the opposite side of the river. For these rivers, it was possible to estimate the useable width across the entire width.

Using HSI curves for depth and velocity gradients obtained from the contract monitor (Ptolemy pers. comm..), site width was scaled to useable width by multiplying each transect cell length by the corresponding HSI value and adding the useable lengths of the transects. This useable transect length was multiplied by the site width to get the total useable area of the site. This was used as the basis for estimating the density of fry per unit useable area from electro-fishing samples. The useable widths for entire reaches were obtained by taking the average of the useable widths of all sites. This result was used in lieu of the useable width value in the Tautz spreadsheet.

The survey information was applied in two ways to examine the sensitivity of the model update to both of these new sources of information:

1. By applying surveyed useable widths without surveyed FPU.
2. By applying surveyed useable widths with surveyed FPU.

4 Results

The Tautz *et al.* spreadsheet identified specific reaches as potential fry habitat. A map of the distribution of steelhead observations indicates that most fall within the identified reaches. Similarly, identified reaches are not above any identified barriers (see Figures 1 and 2).

A compilation of the macroreach data indicates that a few reaches were estimated to be longer that the GIS summary in this analysis. Three large discrepancies were found:

1. Original spreadsheet overestimated the length of the lower Skeena by 22 kilometers.
2. Original spreadsheet underestimated the length of Kitwancool by 20 kilometers.
3. Original spreadsheet overestimated the length of Buck creek by 20 kilometers.

There were also several minor underestimates (approximately 1 km each). The total net difference, including small and large discrepancies came to 16 kilometers of length underestimated by Tautz (1992).

Additionally, the following differences were observed:

- Alkalinity obtained from observed conductivity was predominantly higher than the original estimates (see Figure 3).
- Observed fork lengths of 1+ steelhead were approximately the same as original estimates with the exception of the lower Skeena mainstem, where observed fork length was about 40% lower (see Figure 5).
- Observed Skeena mainstem and Sustut fry densities per weighted useable area (FPU) were far lower than the original estimates (see Figure 6).

- Mainstem Kispiox densities per weighted useable area were higher than original estimates.
- When surveyed fork length of age 1+ steelhead and alkalinity estimates are applied, estimated densities per weighted useable area (FPU) are higher for mainstem Skeena and Kispiox reaches, but lower for Bulkley and Sustut reaches (see Figure 8).

The application of surveyed useable width, fry per useable area, alkalinity and fork length of age 1+ steelhead had the following results (see Figure 9):

- Fork length and alkalinity values slightly increased the predicted number of returning adults.
- Using the fry per weighted useable area information reduced the predicted number of returning adults by approximately 30%.
- When the Skeena mainstem and Sustut reaches are separated from the remainder of the surveyed reaches, they account for most of the reduction in adult production.

Tautz *et al.* (1992) produced a summary of production estimates using a stock recruitment approach (see Table 2). This table is reproduced when empirical alkalinity measurements, updated reach lengths and useable widths were applied (see Table 3). The resulting adult capacity, spawners at MSY and recruits at MSY are summarized in Figure 12. Despite the fact that there were several differences, the total escapement is roughly the same at approximately 22K spawners originally vs. 24K spawners predicted from the empirical update.

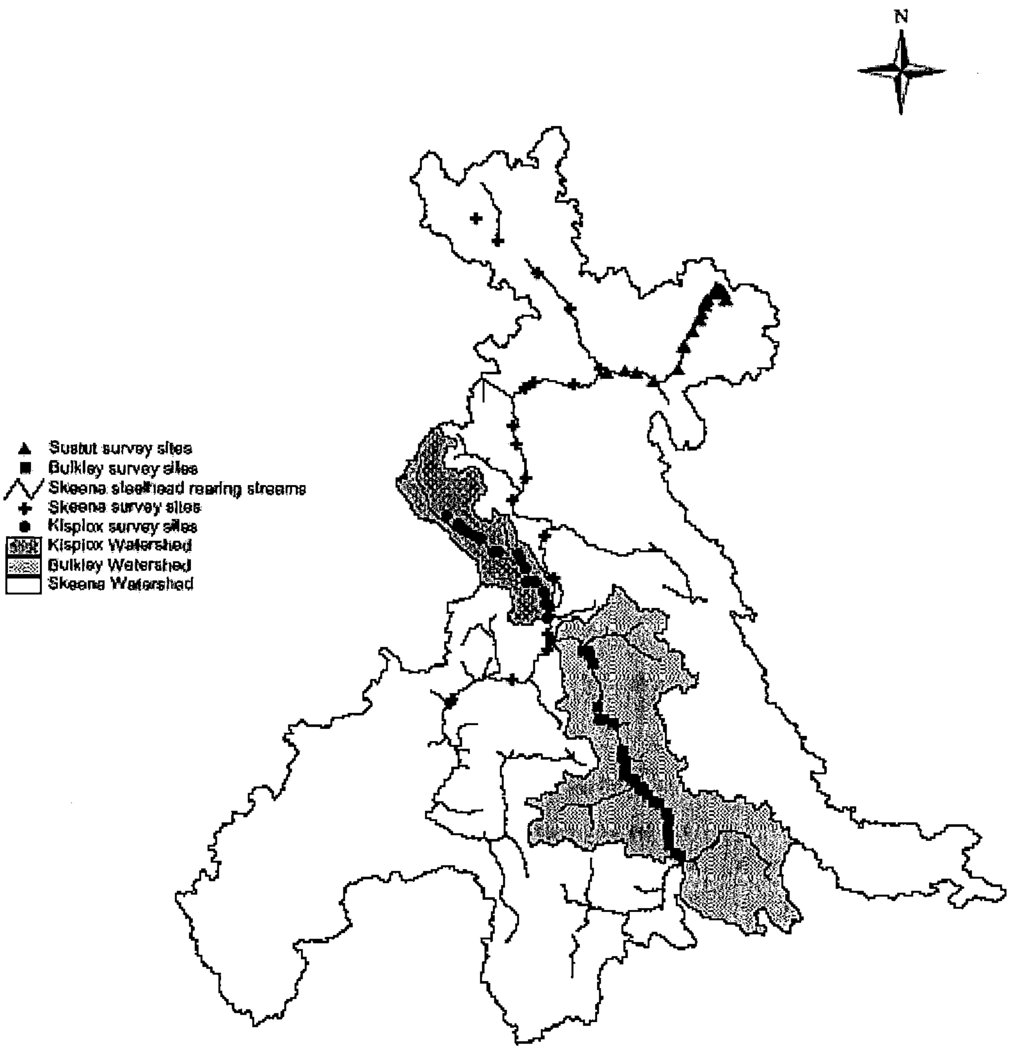

Figure 1: Skeena river watershed and main features.

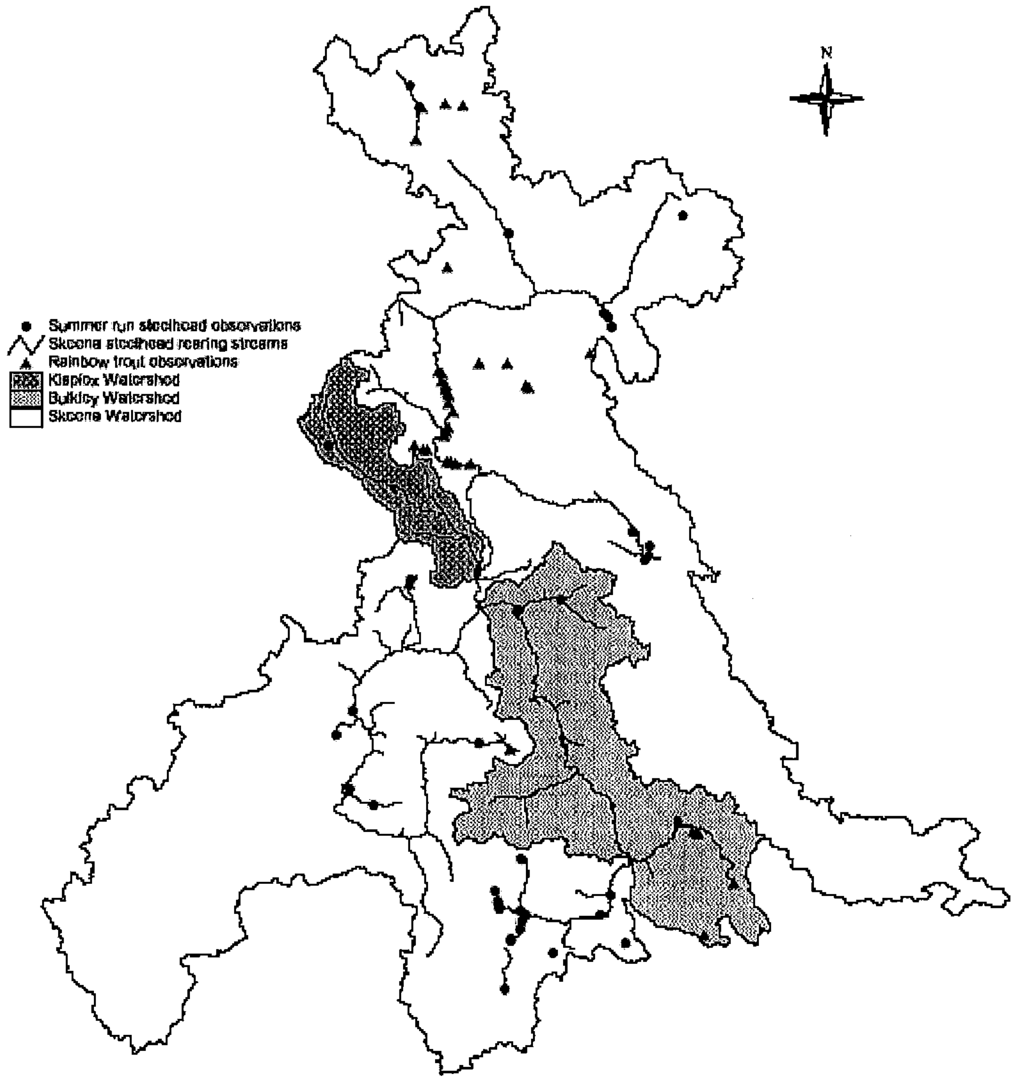

Figure 2: Skeena river summer run steelhead distributions.

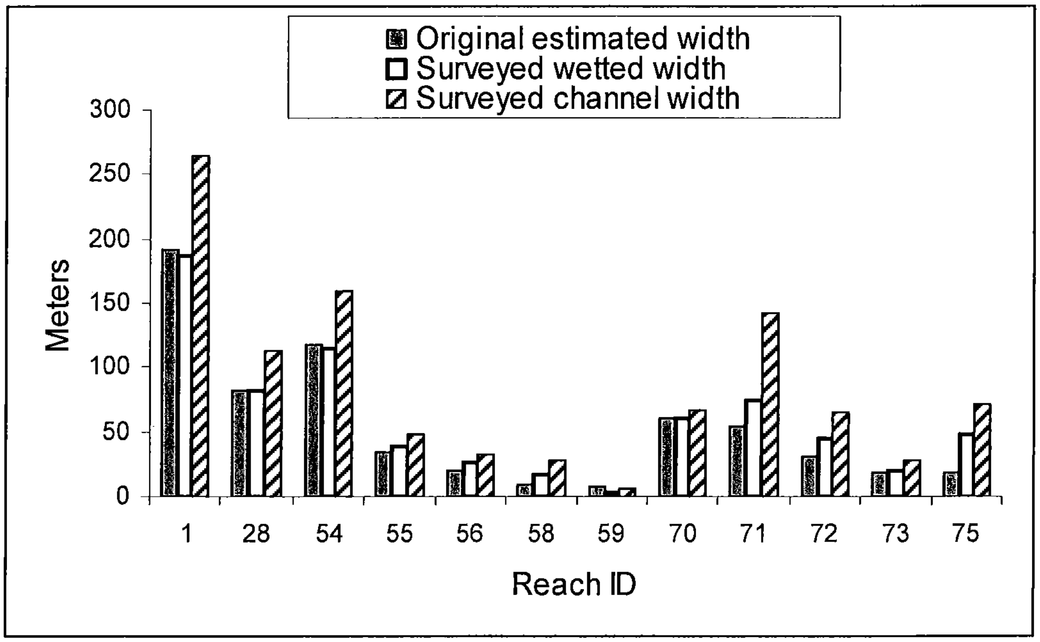

Figure 3: Comparison of estimated and surveyed stream widths. See Table 1 for description of reach ID's.

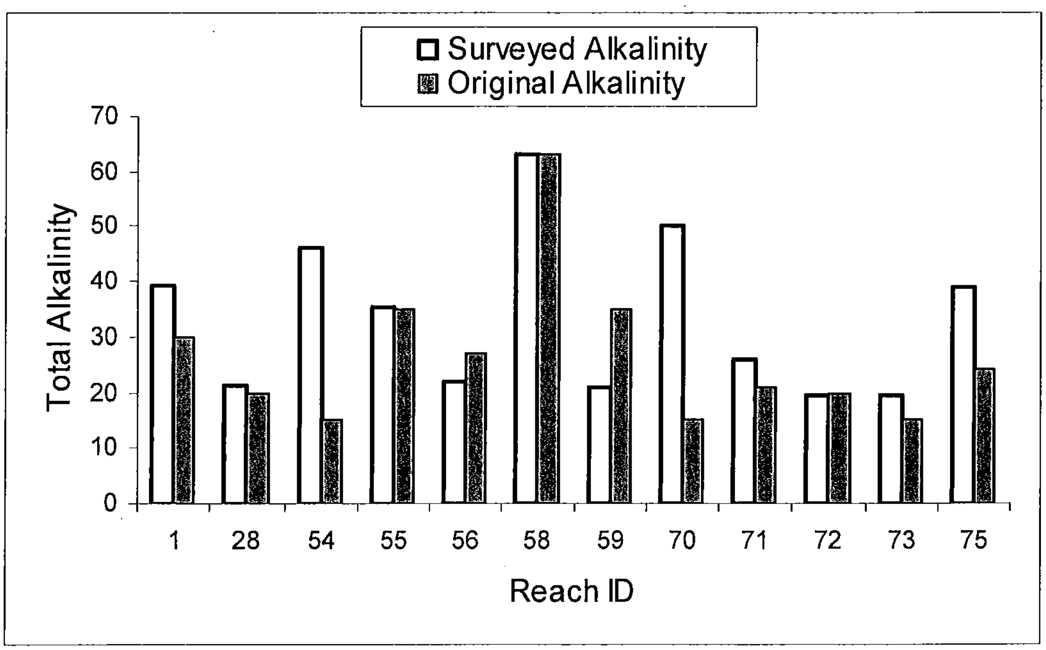

Figure 4: Comparison of original alkalinity and recent surveys. See Table 1 for description of reach ID's.

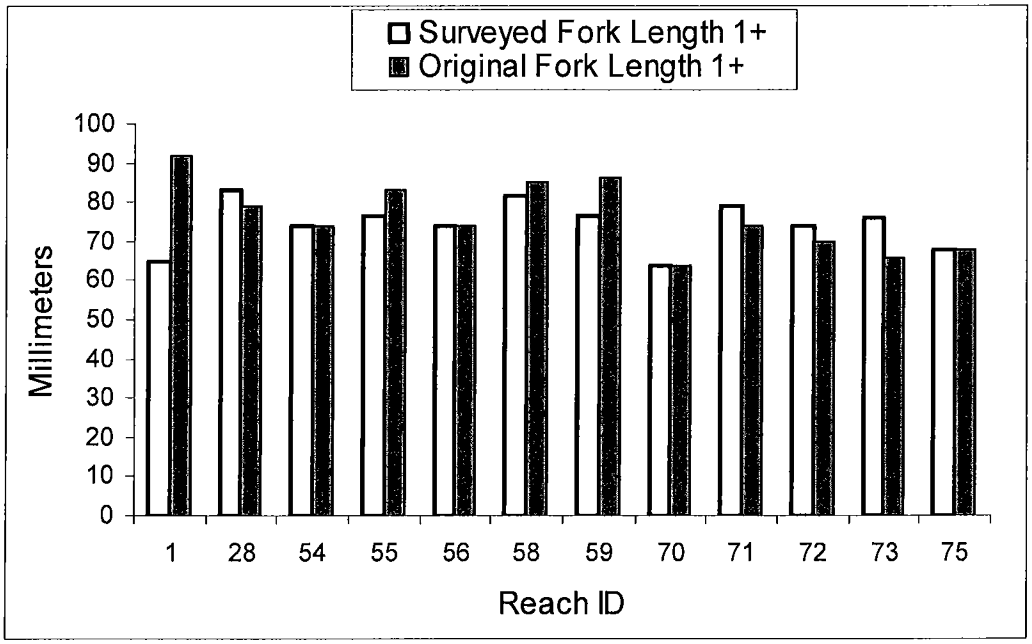

Figure 5: Comparison of estimated and observed fork lengths of age 1+ steelhead. See Table 1 for description of reach ID's.

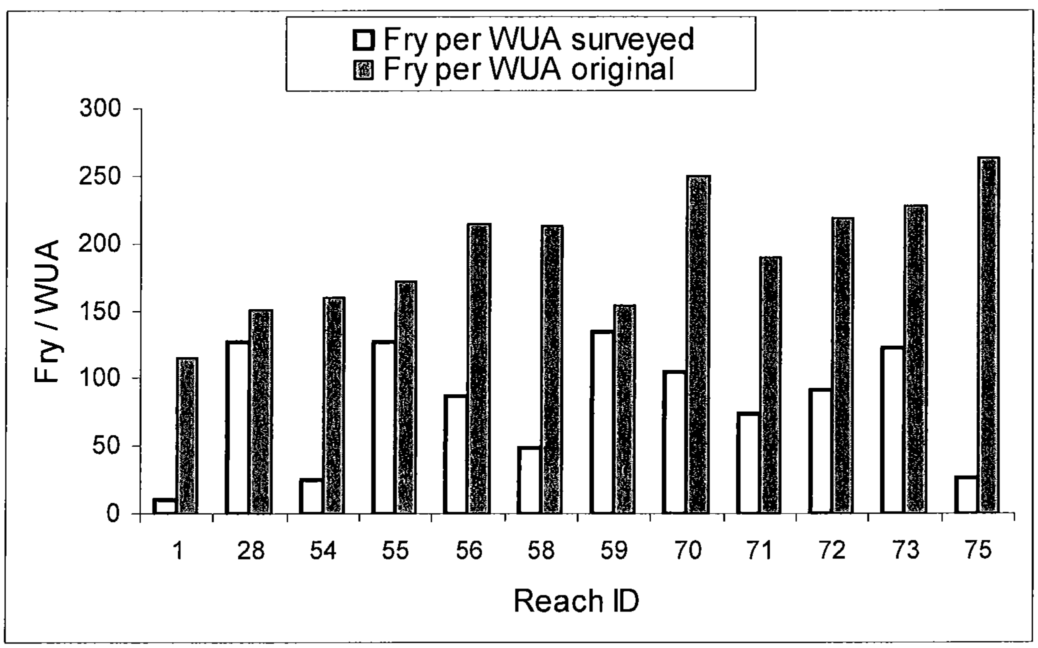

Figure 6: Comparison of estimated and observed fry per weighted useable area. See Table 1 for description of reach ID's.

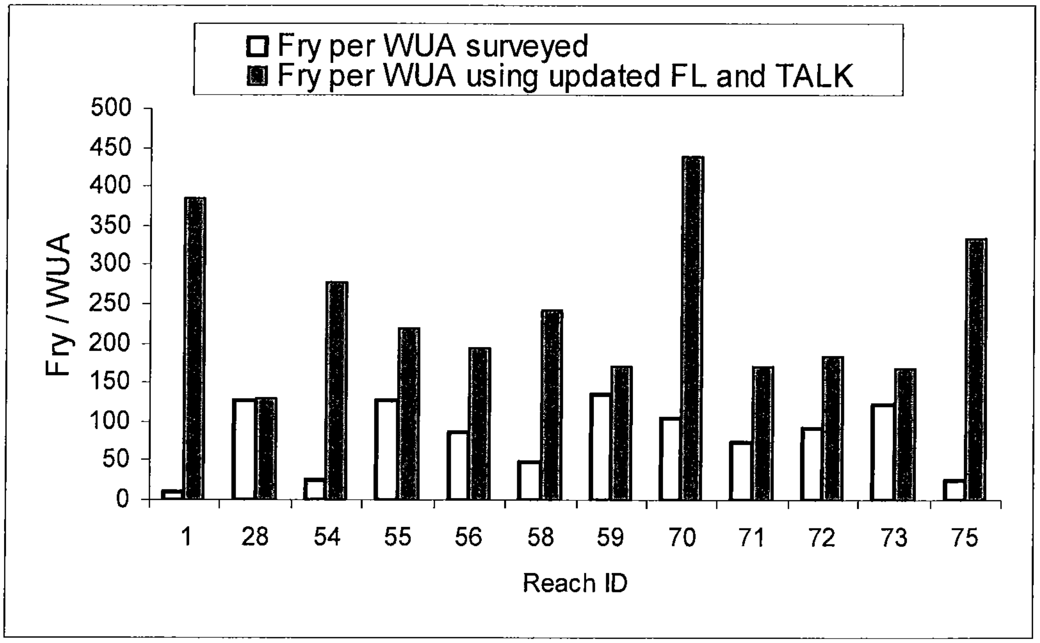

Figure 7: Comparison of updated estimated fry per weighted useable area and observed fry per weighted useable area. See Table 1 for description of reach ID's.

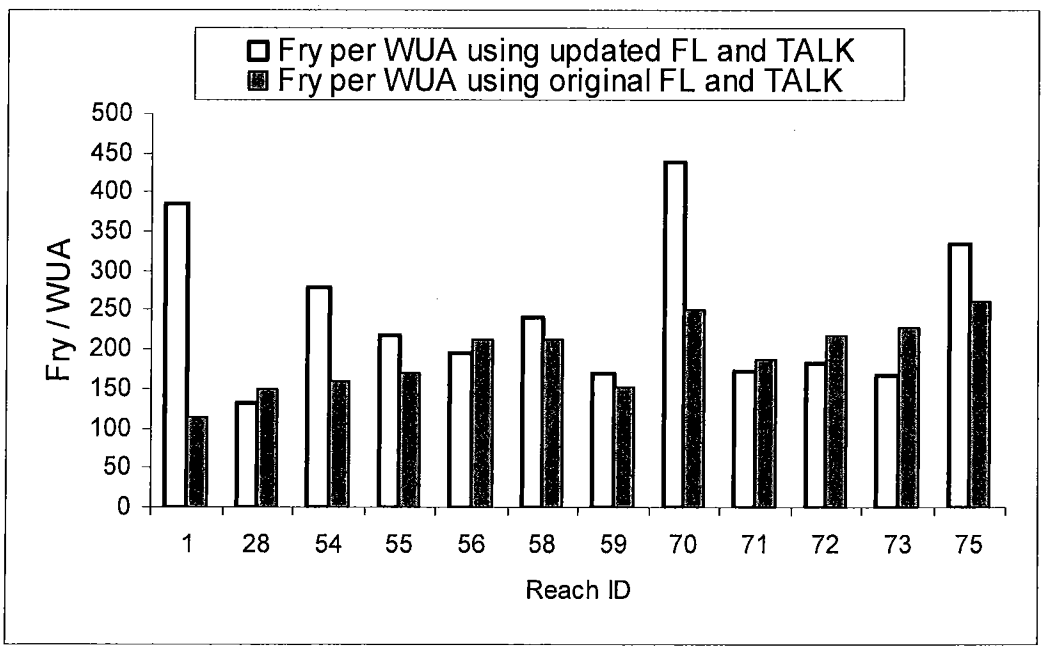

Figure 8: Comparison of updated vs. original prediction of fry per weighted useable area derived from fork length and alkalinity. See Table 1 for description of reach ID's.

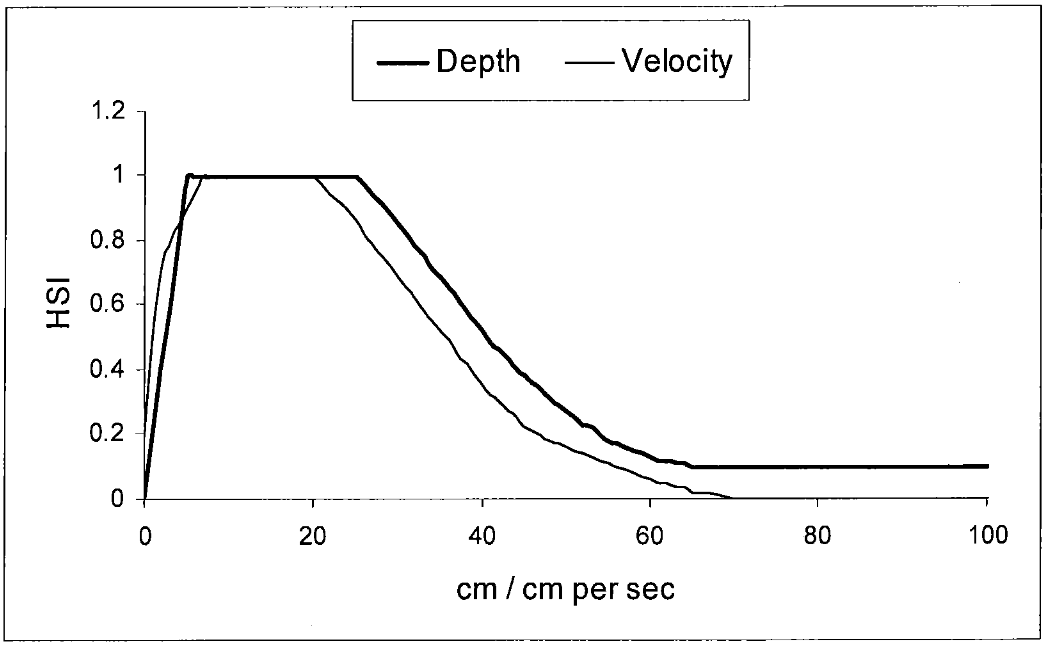

Figure 9: Habitat suitability curves used to establish steelhead fry suitability. See Table 1 for description of reach ID's.

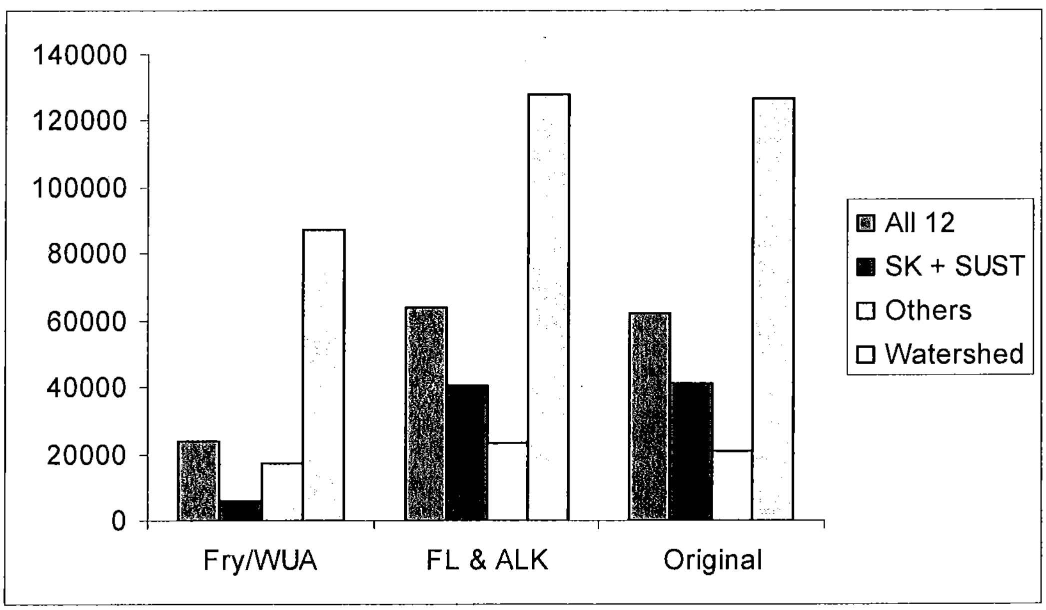

Figure 10: Predicted number of adults under MSY with a habitat capacity approach, broken down by reach groups. The cumulative adults produced by the 12 surveyed reaches are shown together. The cumulative adults is also broken down by Skeena (SK) and Sustut (SUST) as well as the others in the 12 surveyed reaches. The total watershed adult production is also shown for reference.

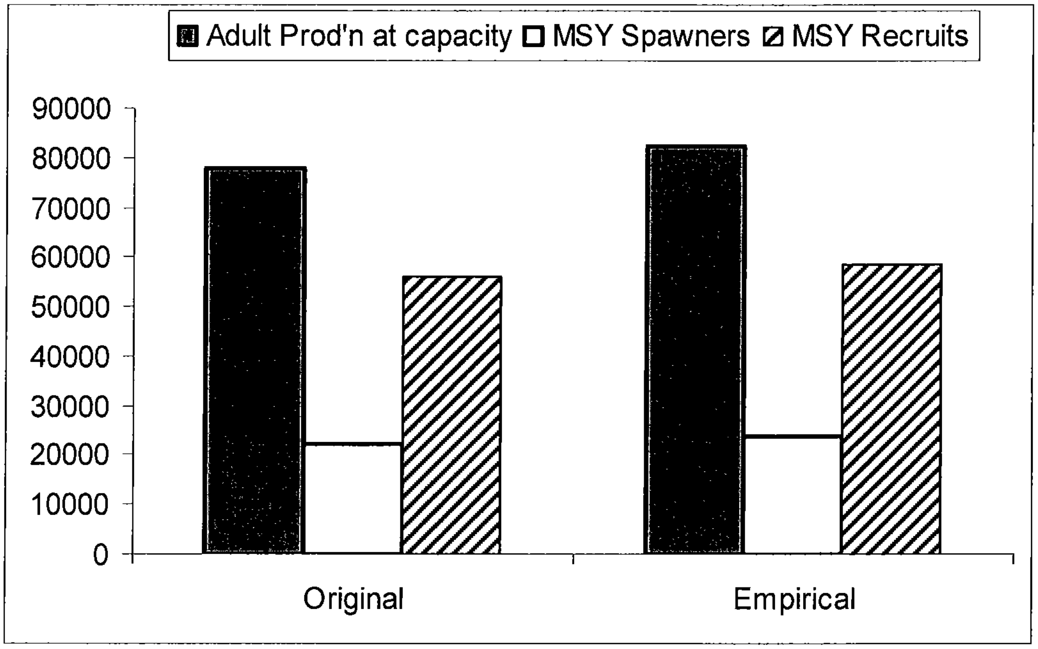

Figure 11: Comparison of predicted MSY production between original Tautz *et al.* (1992) spreadsheet model and empirically updated model using stock recruitment approach. See Table 1 for description of reach ID's.

5 Discussion

The calibration of the Skeena spreadsheet was intended to provide an indication of the biases present in the prediction of useable habitat and the capacities of individual streams. These biases begin with fundamental physical measurements of stream lengths and widths, and continue to the stage of adult marine survival rates.

The survey data showed that the Skeena spreadsheet model may have overestimated some stream lengths and underestimated others. Overall, errors in lengths did not appear to be systematically biased in any particular direction. Error in length appeared to be approximately compensatory. The model was designed to calculate and average useable area over long stretches of a given reach. Because the surveys only sampled the width once at each site and did not cover sufficient expanses of the reaches, the measurements may therefore not be representative of an average across the entire reach. It is also possible that sampling was not random.

Most of the surveyed reaches only sampled depth and velocity gradients across the width of the survey site, as opposed to using a cross section of the entire river. The Bulkley is the only surveyed area where transect data was taken across the entire width of the river. As such, reach 28 is the only one to be empirically tested for useable width.

The productivity estimates based on habitat suitability, alkalinity and useable area indicate that some reaches overestimated capacity in the original spreadsheet estimates. However, with the exception of the Bulkley, sampling was not performed over significant portions of reaches. The lower Skeena only had 4 sites over a stretch of 130 km, whereas the Bulkley survey had 30 sites over 166 km. Alkalinity can be estimated by using pH or conductivity. The recorded measurements of both of these field measures appeared inconsistent. The assumption would be that the two field measures would be roughly correlated, whereas it appeared that there was considerable error in one or both field measures since they were not well correlated. The assumption is that two field measures that estimate alkalinity should at least be correlated to one another, but no relationship between the two was evident. Therefore, it appears that field estimates of alkalinity may be questionable. A possible solution to this may be to take multiple samples of pH or conductivity and use the average sampled value to estimate alkalinity. Considering the importance of this single measurement to estimate production, an experiment should be conducted to evaluate the effectiveness of field measurements.

There is also the possibility that the abundance estimates were biased negatively. Many of the depletions indicated that an insufficient portion of fish had been removed. In many cases, a second pass of electro-fishing produced up to 30% of the number of fish as the first count. In some cases, a second pass of 50% of the time of the first pass was still yielding comparable catches. Additionally, the depletions did not account for the fact that different amounts of effort were being applied on the second pass. A preliminary analysis of the data using a Poisson depletion estimator that incorporates removal effort indicates that in some cases the abundance estimator used by Williamson (2002) and Bustard (2000) was underestimating the abundance by as much as 20%, but likely not more. To assess the possible effect of such an underestimate, a further analysis would have to be performed, but there is a strong indication that such an underestimate has occurred.

There were many examples where empirical data produced results that predicted a lower capacity than the Tautz *et al.* (1992) estimates, but there were several counter examples that yielded higher estimates. Empirical updates using the habitat capacity approach were far more pessimistic than when using the stock recruitment approach. This can be largely attributed to the fact that the habitat capacity model is very sensitive to fork length estimates, alkalinity and weighted useable area estimates. Given the fact that several of the empirically updated production figures indicate lower that predicted production, it would be advisable to collect further data on abundances in the lower Skeena and to assess where sampling biases may have occurred and verify if abundance underestimation may be the cause of low productivity estimates. Stock recruitment approach predicts that 2,000 more spawners are needed to operate at MSY which is less pessimistic that the habitat capacity approach, but is still an indication that a higher escapement may be required.

Table 2: Original estimates of steelhead trout production in the Skeena river watershed. Us describes allowable harvest at MSY, A describes Beverton-Holts A value, Ps describes number of spawners at MSY, and Rs describes recruits at MSY. Production is adjusted for space and alkalinity relative to Keogh river. Table shows prediction of original Skeena spreadsheet by Tautz *et al.* (1992).

	Theoretical useable Area x100 m2	Total alkalinity (mg/l)	Adjust 1	Growth season (days)	Smolt age Years	Adjust 2	Smolt yield at capacity	Adult production at capacity	Mean eggs/fish	Fry to smolt at MSY (%)	Recruits per fish at MSY	Us	A	Ps	Rs
Mainstem															
Lower Skeena	15802	30.0	1.37	137	3.5	0.72	90264	12637	2615	8.37	3.06	0.67	0.89	3109	9528
Middle Skeena	16268	15.0	0.97	135	3.5	0.71	64549	9037	2615	8.12	2.97	0.66	0.89	2275	6762
Upper Skeena	4179	15.0	0.97	100	4.4	0.52	12307	1723	2644	4.41	1.63	0.39	0.62	655	1068
Tributuaries															
Zymoetz	11041	19.2	1.10	113	4.0	0.58	40982	5737	2444	5.62	1.92	0.48	0.73	1963	3775
Lower Tribs	2805	30.0	1.37	102	4.3	0.53	11875	1662	2444	4.58	1.57	0.36	0.59	648	1015
Kitwanga	1651	35.0	1.48	102	4.3	0.53	7552	1057	2615	4.58	1.68	0.40	0.64	395	662
Kitseguecla	1308	40.0	1.58	122	3.8	0.63	7568	1059	2615	6.57	2.41	0.58	0.83	311	748
Bulkley	22559	35.8	1.50	138	3.5	0.73	142033	19885	2374	8.5	2.83	0.65	0.87	5199	14686
Suskwa	2113	35.2	1.48	120	3.9	0.62	11267	1577	2830	6.35	2.52	0.60	0.84	449	1129
Morice	9256	27.9	1.32	123	3.8	0.64	45096	6313	1868	6.68	1.75	0.43	0.67	2298	4015
Kispiox	8542	35.7	1.49	127	3.7	0.66	48738	6823	2906	7.14	2.90	0.66	0.88	1747	5076
Babine	6185	35.0	1.48	145	3.3	0.77	41017	5742	2762	9.44	3.65	0.73	0.92	1235	4508
Upper Tribs	2696	20.0	1.12	100	4.4	0.52	9169	1284	2644	4.41	1.63	0.39	0.62	488	796
Sustut	3764	20.0	1.12	105	4.2	0.55	13340	1868	2853	4.85	1.94	0.48	0.73	636	1232
Upper Sustut	2258	20.0	1.12	95	4.5	0.50	7373	1032	2644	3.99	1.48	0.32	0.54	417	615
Kluantantan	1203	24.0	1.22	100	4.4	0.52	4482	628	2644	4.41	1.63	0.39	0.62	238	389
Totals	**111630**	**0**	**0**	**0**	**0**	**0**	**557612**	**78066**	**0**	**0**	**0**	**0**	**0**	**22062**	**56004**

Table 3: Updated estimates of steelhead trout production in the Skeena river watershed. Us describes allowable harvest at MSY, A describes Beverton-Holts A value, Ps describes number of spawners at MSY, and Rs describes recruits at MSY. Production is adjusted for space and alkalinity relative to Keogh river. Table shows calculations including observed alkalinity, observed reach lengths, and observed useable widths.

	Theoretical useable Area x100 m2	Total alkalinity (mg/l)	Adjust 1	Growth season (days)	Smolt age Years	Adjust 2	Smolt yield at capacity	Adult production at capacity	Mean eggs/fish	Fry to smolt at MSY (%)	Recruits per fish at MSY	Us	A	Ps	Rs
Mainstem															
Lower Skeena	11405	39.2	1.57	137	3.5	0.72	74469	10426	2615	8.37	3.06	0.67	0.89	2565	7860
Middle Skeena	14148	46.2	1.70	135	3.5	0.71	98566	13799	2615	8.12	2.97	0.66	0.89	3473	10326
Upper Skeena	7360	50.1	1.77	100	4.4	0.52	39625	5548	2644	4.41	1.63	0.39	0.62	2107	3440
Tributuaries															
Zymoetz	11204	20.3	1.13	113	4.0	0.58	42711	5980	2444	5.62	1.92	0.48	0.73	2046	3934
Lower Tribs	2882	30.0	1.37	102	4.3	0.53	12204	1708	2444	4.58	1.57	0.36	0.59	666	1043
Kitwanga	2674	32.5	1.43	102	4.3	0.53	11785	1650	2615	4.58	1.68	0.40	0.64	616	1034
Kitseguecla	1354	40.0	1.58	122	3.8	0.63	7830	1096	2615	6.57	2.41	0.58	0.83	322	774
Bulkley	18137	35.1	1.48	138	3.5	0.73	113070	15830	2374	8.5	2.83	0.65	0.87	4138	11691
Suskwa	2095	33.3	1.44	120	3.9	0.62	10860	1520	2830	6.35	2.52	0.60	0.84	432	1088
Morice	9489	40.6	1.59	123	3.8	0.64	55771	7808	1868	6.68	1.75	0.43	0.67	2842	4966
Kispiox	7519	34.8	1.47	127	3.7	0.66	42337	5927	2906	7.14	2.90	0.66	0.88	1518	4409
Babine	6205	36.3	1.51	145	3.3	0.77	41880	5863	2762	9.44	3.65	0.73	0.92	1261	4602
Upper Tribs	2696	20.0	1.12	100	4.4	0.52	9169	1284	2644	4.41	1.63	0.39	0.62	488	796
Sustut	2868	21.0	1.15	105	4.2	0.55	10412	1458	2853	4.85	1.94	0.48	0.73	496	961
Upper Sustut	1957	19.5	1.10	95	4.5	0.50	6311	884	2644	3.99	1.48	0.32	0.54	357	527
Kluantantan	2521	38.8	1.56	100	4.4	0.52	11947	1673	2644	4.41	1.63	0.39	0.62	635	1037
Totals	**104515**						**588947**	**82453**						**23964**	**58489**

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