

Appendix III

The Application of LFDA to Zimbabwe Lake Data

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Final Report

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1. Background and data set

In order to test the applicability of the LFDA suite of methods to African localities, two sets of data were obtained from Zimbabwe. Both came from man-made lakes and it was considered that, given the importance of the man-made lakes to the fisheries of Africa, a valid application of LFDA would give confidence for a wider usage for such fisheries throughout the continent.

The length frequency data obtained came from two different man-made lakes:

- (i) Fourteen months consecutive data for the kapenta, *Limnothrissa miodon* from lift net catches of the Sanyati Basin, Lake Kariba.
- (ii) Variable monthly samples from experimental poisoning of bay communities at seven locations around Lake Mcllwaine.

Both lift net and poisoning methods are relatively non-selective and should, therefore, provide suitable samples for length frequency analysis. The kapenta is a small clupeid which is essentially an annual species and supports a major 18,000 mt per annum fishery in Lake Kariba. Their wide significance is that they also support major fisheries in Lake Tanganyika, where they are endemic, and also in the man-made Lake Cabora-Bassa, downstream of Lake Kariba on the Zambesi system.

The rotenoned samples from Lake Mcllwaine comprise a wide variety of species, including tilapias, which form the main commercial catch from the lake. The significance of the fishery is its proximity to the major demand centre of Harare. The tilapias as a group, however, feature in most significant lake fisheries in Africa. Both data sets were provided courtesy of Dr Brian Marshall, University of Zimbabwe and neither have previously been analyzed.

A summary of the samples collected from Lake Mcllwaine is provided in Table 1.

2. Methodology

LFDA was used to estimate growth parameters and total mortality (Z) from the length data described in section 1. Certain samples from Lake Mcllwaine were discarded as they did not comprise a sufficient time series to make testing of the data worthwhile. For example, data were only collected at Myriophyllum Creek on two occasions, both during 1974. Additionally, certain time series had sample events where only a few individuals were caught and sampled, for example, *Labeo altivelis* at Research Bay. An attempt to fit the data for this location and species using LFDA was made, but the fit proved to be unsatisfactory. For these reasons, only species that were found on a large number of sample dates and in reasonable numbers, i.e. the more common species, *T. macrochir*, *T. rendalli* and *H. darlingi* were analyzed in detail.

The length distributions of *Limnothrissa* in the Sanyati Basin indicated some seasonality in growth. An attempt was made to fit the non-seasonal growth models in LFDA, but the results were unsatisfactory. As an alternative approach the data were divided into two 'seasons' and fitted separately. This produced much better results. This emphasised the advantage in having a factor to describe seasonal oscillations in the program which will be incorporated into the revised LFDA.

2.1 Summary of the findings during the application of LFDA

Lake Mcllwaine

Tilapia macrochir

Pelican Harbour:	SLCA - Boundary values only Projmat - L^∞ appears reasonable, but did not include individuals at over 300mm. Elefan - L^∞ appears better, as above, without the larger individuals. Z values appear similar between these two methods, but L^∞ and K are relatively different.
Research Bay:	SLCA - Fits made, but not very accurate. L^∞ is very high. Projmat - Fit better, but not perfect. L^∞ similar to Elefan and better when compared with results. Elefan - Fit reasonable. L^∞ as above. Z values vary widely.
Crocodile Creek:	SLCA - Boundary values only Projmat - Reasonable fit with data, L^∞ appears large, but does include the few larger individuals found. Elefan - Reasonable fit, L^∞ covers the majority of individuals found. Z values are similar between the two methods.
Lewin's Harbour:	SLCA - Fit moderate, L^∞ reasonable Projmat - Fit better, L^∞ reasonable Elefan - Good fit, L^∞ also most consistent with the data Z values comparable, but there are variations

Tilapia rendalli

Pelican Harbour:	SLCA - Boundary values only Projmat - Reasonable fit, L^∞ appears high but large individuals are present. Elefan - Fit not as good as Projmat, L^∞ appears slightly low. Z values appear similar between these two methods.
Research Bay:	SLCA - Boundary values only Projmat - Fit reasonable. L^∞ quite high when compared with data. Elefan - Fit better. L^∞ more comparable to data. Z values show some variation in Powell-Wetherall and Age-Slice.
Crocodile Creek:	SLCA - Reasonable fit, L^∞ appears low, Projmat - Reasonable fit with data, L^∞ appears slightly large, but does include the few larger individuals found. Elefan - Reasonable fit, L^∞ low compared to data. K value comparable to Projmat Z values vary. No Powell-Wetherall estimates could be made due to the extreme bi-modality of the graphs.
Lewin's Harbour:	SLCA - Boundary values only

Projmat - Fit reasonable, L^∞ slightly large. Many 'multiple maxima' found
 Elefan - Good fit, L^∞ also more consistent with the data
 Z values comparable for these two methods. Bi-modality again found on attempting the Powell-Wetherall method

Haplochromis darlingi

Pelican Harbour: SLCA - Fit not brilliant. L^∞ appears high
 Projmat - Reasonable fit, L^∞ better.
 Elefan - Fit reasonable, L^∞ comparable to data.
 Z values vary between methods.

Research Bay: SLCA - Boundary values only
 Projmat - Fit OK. L^∞ high when compared with data.
 Elefan - Fit better. L^∞ more comparable to data, if slightly low.
 Z values comparable in methods apart from Age-Slice.

Crocodile Creek: SLCA - Fit not brilliant, L^∞ appears consistent.
 Projmat - Reasonable fit with data, L^∞ appears large.
 Elefan - Good fit, L^∞ consistent.
 Z values comparable for Projmat and Elefan.

Lewin's Harbour: SLCA - Boundary values only
 Projmat - Fit not very good, L^∞ large.
 Elefan - Fit reasonable, L^∞ reasonable
 Z values vary.

Sanyati Basin

Season 1: SLCA - Boundary values only
 Projmat - Sensible result, good fit and L^∞ appears consistent
 Elefan - As for Projmat

Season 2: SLCA - Boundary values only
 Projmat - Sensible result, good fit and L^∞ appears consistent
 Elefan - As for Projmat

3. Results

The parameters obtained from LFDA for the Lake Mcllwaine datasets are shown in Tables 2 to 4. The results of the analysis of *Limnothrissa* length data for the two 'seasons' in the Sanyati Basin are shown in Table 5.

Table 2. Lake Mcllwaine *Tilapia rendalli*

Lengths in mm

Number in brackets under location shows the total number of fish sampled in the period

Shaded Age-Slice 'K' values are invalid, as the method can only be used if more than one distribution is present.

Pelican Harbour (797)		L inf	K	T o	Z		
					Beverton-Holt	Powell-Wetherall	Age-Slice
Method	SLCA	No Result					
	PROJMAT	680.71	0.1251	-0.166	1.56 +/- 0.861	0.09 (0.05)	Age 0: 1.534 Std Err: 0.72
	ELEFAN	209.47	0.1663	-0.72	1.02 +/- 0.654	0.17 (0.11)	Age 0: 1.807 Std Err: 0.894

Research Bay (2919)		L inf	K	T o	Z		
					Beverton-Holt	Powell-Wetherall	Age-Slice
Method	SLCA	No Result					
	PROJMAT	684.34	0.088	-0.434	0.77 +/- 0.289	0.14 (0.07)	Age 0: 1.974 Std Err: 0.355 Age 1: 1.717 Std Err: 1.867
	ELEFAN	287.21	0.2078	-0.5	0.56 +/- 0.237	0.60 (0.55)	Age 0: 2.530 Std Err: 0.432 Age 1: 0.552 Std Err: 1.496 Age 2: 2.508 Std Err: 2.459

Crocodile Creek (567)		L inf	K	T o	Z		
					Beverton-Holt	Powell-Wetherall	Age-Slice
Method	SLCA	252.22	0.44	-0.102	2.64 +/- 1.236	BIMODALITY	Age 0: -0.602 Std Err: 0.937
	PROJMAT	389.85	0.1001	-0.648	1.00 +/- 0.443	BIMODALITY	Age 0: -0.336 Std Err: 0.988 Age 1: -1.263 Std Err: 1.313
	ELEFAN	177.28	0.1317	-0.63	0.55 +/- 0.283	BIMODALITY	Age 1: -1.405 Std Err: 1.586 Age 2: 1.419 Std Err: 0.920 Age 3: -0.724 Std Err: 0.667

Lewin's Harbour (546)		L inf	K	T o	Z		
					Beverton-Holt	Powell-Wetherall	Age-Slice
Method	SLCA	No Result					
	PROJMAT	444.44	0.13	-0.413	1.59 +/- 0.666	BIMODALITY	Age 0: -0.078 Std Err: 1.804
	ELEFAN	377.78	0.144	-0.36	1.42 +/- 0.607	BIMODALITY	Age 0: 0.054 Std Err: 1.795

Table 3. Lake Mcllwaine *Tilapia macrochir*

Lengths in mm

Number in brackets under location shows the total number of fish sampled in the period.

Shaded Age-Slice 'K' values are invalid, as the method can only be used if more than one distribution is present.

Pelican Harbour (3458)		L inf	K	T o	Z		
					Beverton-Holt	Powell-Wetherall	Age-Slice
Method	SLCA	No Result					
	PROJMAT	254.77	0.1318	-0.128	0.77 +/- 0.717	0.26 (0.33)	Age 0: -2.524 Std Err: 1.76 Age 1: 2.815 Std Err: 1.556
	ELEFAN	150	0.25	-0.085	0.70 +/- 0.762	0.32 (0.43)	Age 0: -2.46 Std Err: 1.744 Age 1: 3.040 Std Err: 1.600 Age 2: 4.002 Std Err: 1.483
Research Bay (18849)		L inf	K	T o	Z		
					Beverton-Holt	Powell-Wetherall	Age-Slice
Method	SLCA	427.78	0.19	-0.244	1.89 +/- 0.964	0.35 (0.62)	Age 0: -0.498 Std Err: 2.098
	PROJMAT	261.11	0.15	-0.843	0.79 +/- 0.435	0.21 (0.38)	Age 0: -0.671 Std Err: 2.112 Age 1: 1.610 Std Err: 1.853
	ELEFAN	259.99	0.385	-0.2	2.07 +/- 1.133	0.15 (0.18)	Age 0: -0.421 Std Err: 2.105
Crocodile Creek (2471)		L inf	K	T o	Z		
					Beverton-Holt	Powell-Wetherall	Age-Slice
Method	SLCA	No Result					
	PROJMAT	356.11	0.1088	-0.711	1.23 +/- 0.559	0.03 (0.03)	Age 0: -1.243 Std Err: 1.334
	ELEFAN	123.01	0.3636	-0.76	1.05 +/- 0.588	0.03 (0.03)	Age 0: -1.224 Std Err: 1.336 Age 1: 1.160 Std Err: 1.459
Lewin's Harbour (1110)		L inf	K	T o	Z		
					Beverton-Holt	Powell-Wetherall	Age-Slice
Method	SLCA	265.66	0.6004	-0.021	4.94 +/- 3.580	0.60 (0.34)	Age 0: 0.902 Std Err: 1.084
	PROJMAT	229.58	0.6192	-0.067	4.27 +/- 3.160	0.26 (0.17)	Age 0: 0.900 Std Err: 1.092
	ELEFAN	145.8	0.6583	-0.3	2.50 +/- 2.041	0.22 (0.21)	Age 0: 0.901 Std Err: 1.142

Table 4. Lake Mcllwaine *Haplochromis darlingi*

Lengths in mm

Number in brackets under location shows the total number of fish sampled in the period

Shaded Age-Slice 'K' values are invalid, as the method can only be used if more than one distribution is present.

Pelican Harbour (1543)		L inf	K	T o	Z		
					Beverton-Holt	Powell-Wetherall	Age-Slice
Method	SLCA	416.67	0.23	-0.017	2.24 +/- 0.679	0.63 (0.28)	Age 0: 1.423 Std Err: 0.894
	PROJMAT	294.44	0.11	-0.911	0.68 +/- 0.215	0.15 (0.06)	Age 0: 1.481 Std Err: 0.828
	ELEFAN	182.79	0.1906	-0.04	0.65 +/- 0.232	0.39 (0.26)	Age 0: -1.011 Std Err: 1.089 Age 1: 3.082 Std Err: 0.831

Research Bay (6447)		L inf	K	T o	Z		
					Beverton-Holt	Powell-Wetherall	Age-Slice
Method	SLCA	No Result					
	PROJMAT	388.89	0.08	-0.051	0.63 +/- 0.139	0.11 (0.08)	Age 0: 1.829 Std Err: 1.126 Age 1: 1.621 Std Err: 2.289
	ELEFAN	172.22	0.272	-0.68	0.76 +/- 0.202	0.14 (0.12)	Age 0: 0.968 Std Err: 1.138 Age 1: 2.032 Std Err: 2.574

Crocodile Creek (1236)		L inf	K	T o	Z		
					Beverton-Holt	Powell-Wetherall	Age-Slice
Method	SLCA	182.03	0.5663	-0.042	2.54 +/- 1.193	0.57 (0.54)	Age 0: -0.647 Std Err: 0.487
	PROJMAT	299.5	0.1125	-0.736	0.95 +/- 0.408	0.23 (0.23)	Age 0: 0.038 Std Err: 0.468
	ELEFAN	163.33	0.233	-0.68	0.90 +/- 0.436	0.28 (0.31)	Age 0: 0.103 Std Err: 0.492 Age 1: -0.606 Std Err: 1.753

Lewin's Harbour (2413)		L inf	K	T o	Z		
					Beverton-Holt	Powell-Wetherall	Age-Slice
Method	SLCA	No Result					
	PROJMAT	355.56	0.04	-0.243	0.41 +/- 0.143	0.07 (0.04)	Age 1: 0.301 Std Err: 1.520 Age 2: 1.945 Std Err: 0.912 Age 3: 1.467 Std Err: 1.033 Age 4: -1.312 Std Err: 1.378
	ELEFAN	227.67	0.2189	-0.48	1.13 +/- 0.417	0.31 (0.23)	Age 0: 0.479 Std Err: 1.137 Age 1: -0.705 Std Err: 1.732

Table 5. Sanyati Basin *Limnothrissa (Kapenta)*

Lengths in mm

Data shows seasonality. Thus split the data into two seasons

Shaded Age-Slice 'K' values are invalid, as the method can only be used if more than one distribution is present.

Season 1		L inf	K	T o	Z		
					Beverton-Holt	Powell-Wetherall	Age-Slice
Method	SLCA	No Result					
	PROJMAT	59.02	2.032	-0.282	0.63 +/- 0.365	0.44 (0.37)	Age 0: 1.696 Std Err: 0.567
	ELEFAN	58.83	2.0704	-0.32	0.63 +/- 0.371	0.75 (0.38)	Age 0: 1.685 Std Err: 0.568
Season 2		L inf	K	T o	Z		
					Beverton-Holt	Powell-Wetherall	Age-Slice
Method	SLCA	No Result					
	PROJMAT	59.63	1.7887	-0.296	0.77 +/- 0.551	0.14 (0.04)	Age 0: -4.67 Std Err: 1.026 Age 1: -0.20 Std Err: 0.520
	ELEFAN	61.99	1.2033	-0.4	0.61 +/- 0.391	0.24 (0.19)	Age 0: -5.57 Std Err: 1.271 Age 1: -1.80 Std Err: 0.533 Age 2: -3.36 Std Err: 0.722 Age 3: 2.284 Std Err: 0.645

4. Discussion

In general the "Amoeba" method of finding the maximum peak was only useful (on this data) if the range of K and L_{∞} values had been narrowed down manually using the score function table. This is stated in the manual, but it's importance when using 'real' data becomes apparent.

SLCA frequently located the highest score function towards the edge of the range selected. When the range was modified to take account of this, another 'boundary value' was given, and the process was repeated until the values of K and L_{∞} were unrealistic. Of the 14 data sets 9 gave no result using SLCA, due to this phenomenon. Fits on the Sanyati Basin data, which gave good results using Projmat and Elefan, gave no result with SLCA.

With certain data sets maximum/minimum score values were identified within a specified range of K and L_{∞} , but when the range was focused in on this location, the optimum score moved to a new pair of parameter values, which were not within the original range. For example, if a peak was originally found at $K=0.5$, with 0.1 intervals in the range, the peak could be between approximately 0.45 and 0.55. However, on focusing the range, the peak may have been found at $K=0.65$, which would have corresponded to 0.6 in the original search. Projmat appeared to show this phenomenon on testing certain data. The problem was usually overcome by visually comparing the growth curves of different parameter sets with the original length distributions.

5. Conclusion

Both Projmat and Elefan performed well on good data. SLCA was less successful and was unable to find reasonable parameter estimates for many of the datasets tested. It is clear that even at these latitudes, a program which takes into account seasonal changes in growth rate would be advantageous.