The Derivation of Sardine Length Frequency Distributions from November Surveys

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The process followed to derive the sardine length frequency distributions from the November surveys is summarised as follows:

- Acoustic data are collected continuously between stations that are positioned 10 nmi apart. These data are therefore averaged over elementary sampling distance units (ESDU, also referred to as the interval) that have a length of approximately 10 nmi. In some cases, an interval is interrupted in order to conduct a species identification trawl, resulting in intervals of shorter length. The interval is the sample unit from which the mean density for each transect is derived.
- Trawls are undertaken during the survey in a subjective manner. The decision on when to trawl is based upon several factors, including: the detection of sufficient pelagic targets, changes in the characteristics of the echogram since the last trawl was conducted, proximity of the detected targets to previous trawls on the transect and adjacent transects, available time, weather, time of day, etc. These decisions are taken by the acoustic operator on board, often in consultation with the chief scientist and are highly dependent on their experience. The trawls undertaken during three recent November surveys are plotted together with the survey cruise track in Figures 1 to 3.
- During the on board allocation process, each acoustic interval (or section of interval) is assigned to a particular trawl. Each trawl has an associated species composition and species specific length frequency and length frequency sample mass. These are necessary to derive a density for each species present in the interval as the density calculation is based on a species specific target strength derived for a particular size of fish, and the relative weighting of this target strength to that of other species present in the trawl.
- In general though, the interval is allocated to the closest trawl if that trawl was conducted on targets having similar echogram characteristics. There are, however, several deviations from this practice; see examples in Coetzee and Merkle (2006).
- It is therefore possible for one trawl or part of one trawl to be assigned to intervals in more than one stratum.
- It is therefore also possible to have different trawls, or parts of trawls to be assigned to different species in the same interval.
- The data available for the estimation of sardine length frequency distributions consists of:

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i) a set of acoustic data in which the following are stored: species, interval, interval length, interval density, the trawl grid reference assigned to that interval, stratum and stratum acoustic biomass of species; all intervals of zero density are removed from this data base;
ii) a set of trawl data in which the following are stored: trawl date, trawl grid reference, species, length group, observed number of species in length group and length frequency mass, *LFmas*, which is the total weight, by species, of the fish sampled for the length frequency.

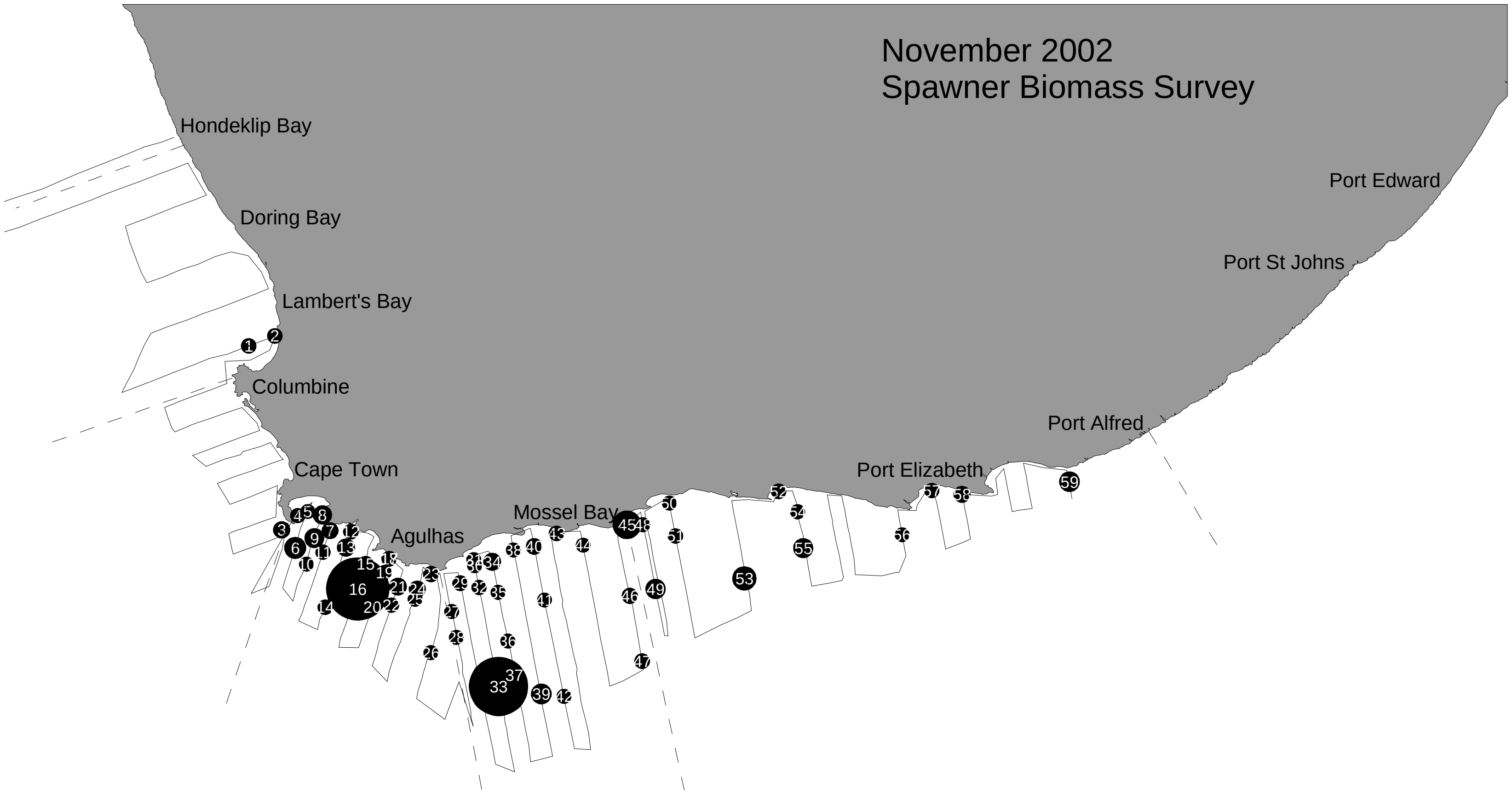
For each species:

- Each trawl within a stratum is assigned an acoustic weighting using the product of interval lengths (within the stratum) and densities to which that trawl has been assigned (Equation A.1).
- The length frequency mass, *LFmas*, of each trawl is then used to calculate a trawl weighting factor for each trawl (Equation A.2). This is a number without units. This weighting factor is graphically displayed and tabulated in Figures 1 to 3 for three recent November surveys.
- The weighted length frequency for each stratum is then calculated by weighting the observed numbers in each length class of each trawl by the trawl's weighting factor (Equation A.3).
- This weighted length frequency is then scaled using the strata's biomass and divided by the total acoustic weighting of the trawls in each stratum to give the total numbers in each length class for each stratum (Equation A.4).
- The sum of this scaled weighted length frequency (termed Raised Length Frequency, RLF) over all strata gives the total survey weighted length frequency (Equation A.5).

These RLFs are then combined with the Age-Length Keys (ALKs) to calculate an observed proportion of numbers-at-age for the survey (Equations B.1 to B.2):

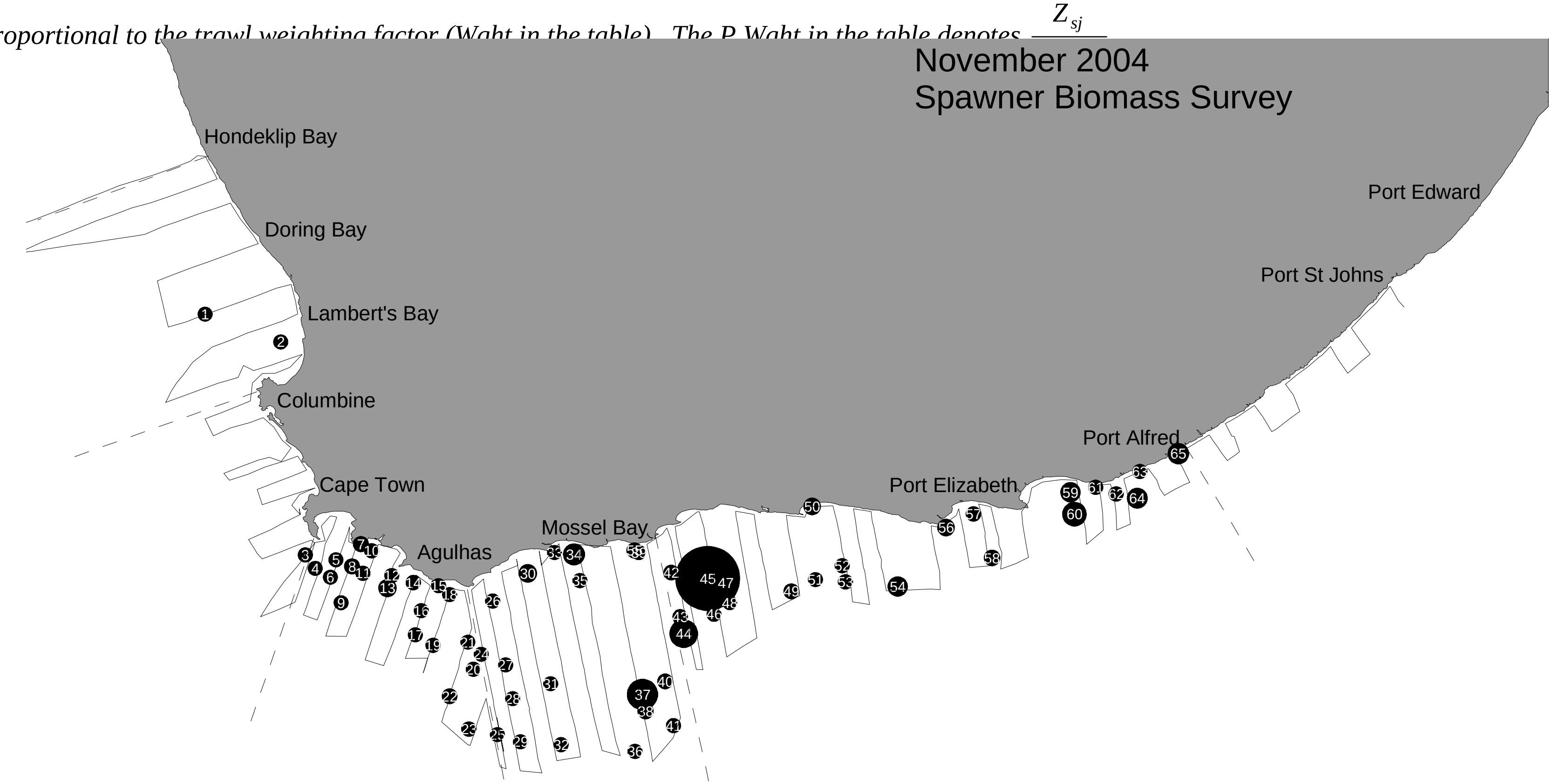
References

Coetzee, J.C., and Merkle, D. Some examples of acoustic echograms and allocation of intervals to trawls. MARAM International Stock Assessment Workshop, December 2008. MARAM IWS/DEC08/S/6.



No	STR	Wght	P Wght	**No**	STR	Wght	P Wght	**No**	STR	Wght	P Wght	**No**	STR	Wght	P Wght	**No**	STR	Wght	P Wght	**No**	STR	Wght	P Wght	**No**	STR	Wght	P Wght
1	A	155	0.5788	**7**	C	471	0.0736	**17**	C	21	0.1991		D	26	0.0001	**36**	D	62	0.0002	**47**	D	201	0.0007	**55**	D	1224	0.4760
	B	37	0.0224	**8**	C	430	0.0417	**18**	IC	210	0.0078	**28**	D	26	0.0000	**37**	D	21	0.0001	**48**	D	12	0.0006		E	740	0.3481
	IA	26	0.7462		IC	1012	0.2499	**19**	C	15	0.0038	**29**	D	201	0.0605	**38**	D	27	0.0000		ID	3	0.0012	**56**	E	6	0.0001
	IB	4	0.0116	**9**	C	1164	0.2352	**20**	C	196	0.0016		ID	219	0.5548	**39**	D	1364	0.0242	**49**	D	1270	0.0902	**57**	E	63	0.0001
2	A	182	0.4212	**10**	C	39	0.0102	**21**	C	716	0.1368	**30**	D	97	0.0022	**40**	D	430	0.0043	**50**	E	6	0.0118		IE	29	0.0002
	IA	14	0.2538	**11**	C	117	0.0034	**22**	C	93	0.0070	**31**	D	21	0.0001	**41**	D	5	0.0000		IE	14	0.0008	**58**	E	522	0.4698
3	B	568	0.9776	**12**	C	152	0.0522	**23**	C	173	0.0792		ID	10	0.0004	**42**	D	43	0.0003	**51**	E	151	0.0166		IE	201	0.1987
	IB	106	0.9884		IC	153	0.1329		IC	353	0.4113	**32**	D	114	0.0055	**43**	D	67	0.0012	**52**	E	5	0.0016	**59**	E	1345	0.0083
4	C	19	0.0010	**13**	C	779	0.1021	**24**	C	533	0.0907	**33**	D	10240	0.0312		ID	188	0.0277		IE	181	0.3558		IE	11	0.0004
	IC	49	0.0067	**14**	C	165	0.0001	**25**	C	43	0.0001	**34**	D	720	0.4159	**44**	D	32	0.0001	**53**	E	2174	0.4154				
5	C	12	0.0012	**15**	C	306	0.0768	**26**	C	41	0.0005		ID	187	0.1902	**45**	D	3170	0.1000	**54**	E	28	0.0103				
6	C	1661	0.0027	**16**	C	11164	0.0723	**27**	C	3	0.0000	**35**	D	53	0.0012	**46**	D	336	0.0104		IE	72	0.1619				

Figure 1. The November 2002 spawner biomass survey cruise track, with dots indicating the position of trawls undertaken. The size of the dots are proportional to the trawl weighting factor (Wght in the table). The P Wght in the table denotes $\frac{Z_{sj}}{\ }$



No	STR	Wght	P Wght
1	A	1	0.004
2	A	30	0.996
3	B	1	1.000
	IB	22	1.000
4	C	3	0.001
5	C	27	0.027
6	C	5	0.006
7	C	299	0.195
	IC	71	0.766
8	C	289	0.144
9	C	10	0.017

No	STI	Wght	P Wght
10	C	40	0.044
	IC	1	0.010
11	C	60	0.025
12	C	48	0.059
13	C	909	0.009
14	C	100	0.086
	IC	15	0.209
15	IC	7	0.007
16	C	7	0.000
17	C	6	0.005
18	C	19	0.012
19	C	73	0.003

No	STI	Wght	P Wght
20	C	3	0.000
	IC	29	0.007
21	C	2	0.000
22	C	222	0.233
23	C	120	0.006
24	D	2	0.000
25	D	10	0.003
26	D	35	0.010
	ID	2	0.003
27	D	14	0.006
28	D	6	0.000
29	D	24	0.002

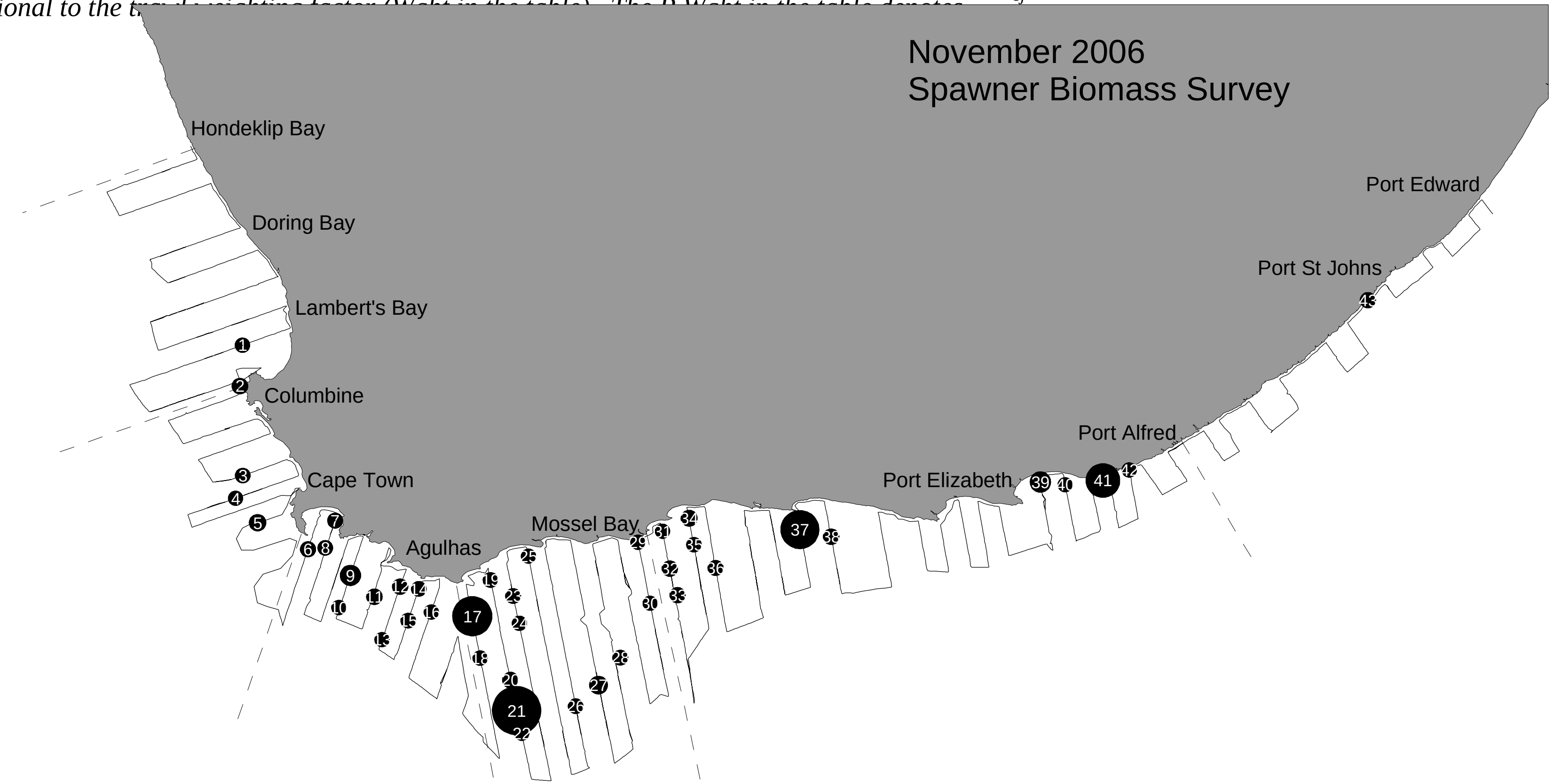
No	ST	Wght	P Wght
30	D	64	0.002
	ID	970	0.122
31	D	5	0.000
32	D	52	0.003
33	ID	5	0.001
34	ID	1927	0.377
	D	55	0.002
35	D	47	0.016
36	D	44	0.010
37	D	4450	0.124
38	D	336	0.392
39	D	10	0.000

No	ST	Wght	P Wght
40	D	229	0.193
41	D	50	0.046
42	D	57	0.031
	ID	182	0.497
43	D	111	0.001
44	D	3730	0.159
45	E	13639	0.063
46	E	25	0.000
47	E	16	0.000
48	E	14	0.000
49	E	252	0.054
50	E	695	0.042

No	ST	Wght	P Wght
	IE	575	0.383
51	E	15	0.000
52	E	53	0.002
53	E	85	0.001
54	E	1452	0.010
55	E	296	0.030
	IE	236	0.265
56	E	715	0.005
	IE	137	0.011
57	E	7	0.002
	IE	111	0.267
58	E	426	0.073

No	ST	Wght	P Wght
59	E	1468	0.044
60	E	2636	0.569
61	E	34	0.009
	IE	26	0.074
62	E	99	0.024
63	E	14	0.000
	IE	3	0.000
64	E	1595	0.072
	F	79	0.760
	IF	9	0.037
65	F	185	0.240
	IF	1745	0.963

Figure 2. The November 2004 spawner biomass survey cruise track, with dots indicating the position of trawls undertaken. The size of the dots are proportional to the trawl weighting factor (Wght in the table). The P Wght in the table denotes Z_{sj}



No	STR	Wght	P Wght	No	STR	Wght	P Wght	No	STR	Wght	P Wght	No	STR	Wght	P Wght	No	STR	Wght	P Wght
1	A	20	1.0000	**10**	C	22	0.0025	**20**	D	156	0.0014	**30**	D	3	0.0001	**39**	E	558	0.1198
	IA	5	0.0170	**11**	C	123	0.0596	**21**	D	3072	0.1416	**31**	D	4	0.0002		IE	2	0.0008
2	IA	133	0.9830	**12**	C	113	0.0451	**22**	D	4	0.0001		ID	0	0.0771	**40**	E	1	0.0001
3	B	51	0.0023	**13**	C	19	0.0006	**23**	D	68	0.0027	**32**	D	117	0.0065	**41**	E	3	0.0005
4	B	7	0.0012	**14**	C	54	0.0483	**24**	D	21	0.0000	**33**	D	110	0.0024		IE	1754	0.4903
5	B	202	0.9966		IC	26	0.5755	**25**	D	14	0.0000	**34**	E	165	0.0419	**42**	E	5	0.0000
6	C	91	0.1705	**15**	C	54	0.0059	**26**	D	60	0.0003		IE	17	0.0079		IE	1	0.0000
7	C	65	0.0002	**16**	C	28	0.0119	**27**	D	254	0.6077	**35**	E	40	0.0003		IF	2	0.0001
	IC	45	0.0035	**17**	D	2250	0.2339		E	326	0.7358	**36**	E	88	0.0034	**43**	F	21	1.0000
8	C	48	0.0990	**18**	D	29	0.0012	**28**	D	71	0.0010	**37**	E	76	0.0096		IF	103	0.9999
	IC	8	0.4210	**19**	D	60	0.0001	**29**	D	14	0.0007		IE	2148	0.5010				
9	C	545	0.5539		ID	26	0.3772		ID	1	0.5457	**38**	E	131	0.0886				

Figure 3. The November 2006 spawner biomass survey cruise track, with dots indicating the position of trawls undertaken. The size of the dots are proportional to the trawl weighting factor (Wght in the table). The P Wght in the table denotes $\frac{Z_{sj}}{\sum_j Z_{sj}}$.

Appendix A: The Equations Summarising the Calculation of the Weighted Length Frequencies

The acoustic weighting for each trawl sample *j* in stratum *s* is given by:

$$Z_{sj} = \sum_i L_{sji} \cdot \rho_{sji} \qquad \text{(A.1)}$$

where

L_{sji} is the mean interval length (nmi) for trawl sample *j* and interval (ESDU) *i* in stratum *s*, and

ρ_{sji} is the mean acoustic interval density (g.m^{-2}) for trawl sample *j* and interval (ESDU) *i* in stratum *s*.

To weigh individual trawls, one needs to convert the acoustic weighting factor into a factor in terms of numbers. The trawl weighting factor is given by:

$$Q_{sj} = \frac{Z_{sj}}{X_{sj}} \qquad \text{(A.2)}$$

where

X_{sj} is the length frequency mass (kg) of trawl sample *j* in stratum *s*.

The weighted length frequency in stratum *s* is the vector $\underline{\mathbf{T}}_s$, which has elements

$$T_{sl} = \sum_j T_{sjl} \cdot Q_{sj} \qquad \text{(A.3)}$$

where

T_{sjl} are the elements of the vector $\underline{\mathbf{T}}_{sj}$, being the observed numbers in length class *l* in trawl sample *j*, of stratum *s*.

The total numbers in stratum *s* is then the vector $\underline{\mathbf{L}}_s$, which has elements

$$L_{sl} = \frac{T_{sl} \cdot B_s}{\sum_j Z_{sj}} \qquad \text{(A.4)}$$

where

B_s is the biomass (kg) in stratum *s*.

The total numbers for the survey is then given by the vector $\underline{\mathbf{L}}^{tot}$, which has the elements

$$L_l^{tot} = \sum_s L_{sl} \qquad \text{(A.5)}$$

Appendix B: The Equations Summarising the Calculation of the Proportion-at-Age in the Survey

The total number of fish of age *a* in length class *l* is:

$$N_{la} = \frac{n_{la}}{\sum_a n_{la}} L_l^{tot} \qquad \text{(B.1)}$$

where

n_{la} is the number of otoliths in length class *l* allocated to age *a*.

The proportion numbers-at-age from the survey is then given by

$$p_a = \frac{\sum_l N_{la}}{\sum_a \sum_l N_{la}}. \qquad \text{(B.2)}$$