

Empirical estimates of abundance indices and standard deviation for longfin smelt from the bay study otter and mid-water trawl surveys

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Introduction

Indices of abundance and associated standard deviations for different life stages are calculated for longfin smelt from the Bay Study survey data. The empirically based abundance indices (I_y) are averages of indices based on two survey methods, mid water trawl and otter trawl, and normalized by the average of each survey method index over all years sampled. The indices are weighted by the area in each region. Within a region, the index is an average of the station specific average CPUE.

Methods

Index

$$I_{m,r,y} = \frac{1}{S_{m,r,y}} \sum_{s \in r} \frac{1}{N_{m,r,y,s}} \sum_{i \in s} \frac{C_{s,i}}{E_{s,i}}$$

$$I_{m,y} = \sum_r w_{m,r} I_{m,r,y}$$

$$I_y = 0.5 \left(\frac{I_{OT,y} Y_{OT}}{\sum_y I_{OT,y}} + \frac{I_{MWT,y} Y_{MWT}}{\sum_y I_{MWT,y}} \right)$$

Where

$C_{s,i}$ is the catch of smelt at station s in tow i

$E_{s,i}$ is the survey effort at station s in tow i

$w_{m,r}$ is the smelt habitat in region r associated with survey method m

Y_m is the number of years of survey data with survey method m

$S_{m,r,y}$ is the number of stations for method m , in region r , during year y

$N_{m,r,y,s}$ is the number of tows in station s for method m , in region r , during year y

Bootstrap

The bootstrap is carried out by randomly resampling each tow with replacement. The samples are drawn from the same survey method, same year, and same station. The number of random samples for each method, year, and station are equal to the number of samples in the original data. The index is calculated as described above. The procedure is repeated 1000 times and the mean and standard deviation of the index is calculated for each year.

Application

The method was applied to the Bay Study mid water trawl (MWT) and otter trawl (OT) data for longfin smelt. Data is available for 1980 to 2012. Regions 6 and 7 were not used because they have low catches of longfin smelt and are considered outside the main longfin smelt habitat area. Stations 324 and 326 were removed from the analysis because they have very few tows (Table A1). A few stations did not have tows from 1979 to 1986, but these were retained in the analysis.

Three indices were calculated:

- a) Age zero longfin in June and July.
- b) Age zero/one year old longfin from October to March
- c) Age one/two year old longfin from November to March

Age is defined based on January 1. The year of the index is based on the first month used in the index. For (b), zero year olds were used for October to December and one year olds for January to March. The corresponding year was reduced by one for the one year olds. For (c), one year olds were used for October to December and two year olds and older for January to March. The corresponding year was reduced by one for the two year olds. The use of older ages means that the index starts in 1979, although it also means that 1979 and 2010 have less data covering less months than the other years.

The regional weighting factors used in the analysis differ between the two gears (Table 1). There is no data for the MWT in 1994, so the normalization (dividing by the mean) does not use exactly the same years for each survey method.

Results

Figure 1 shows the mean and 95% confidence interval from the bootstrap analysis. Table 2 shows the estimate index and the bootstrap mean and standard deviation. There is substantial variation in the indices. The bias was generally small and the standard deviations were moderate. The annual signal is reasonably consistent between the two survey methods (Figure 2). There is also a reasonable amount of consistency across months used within each index (Figure 3). The most inconsistency among months occurs in the November-March one year old index, but this may be due to uncertainty caused by much lower catch rate for this age group. The longfin smelt index calculated from the FMWT is consistent with the Bay Study index of one year olds for October to March. However, the longfin smelt indices calculated from the summer tow net and the 20mm surveys for delta smelt show some inconsistencies with the Bay Study indices (Figure 4). There are also inconsistencies between the June-July and October-March zero year old indices from the Bay Study.

The estimated value for the November-March one year old index in 2010 is zero, which makes estimating the standard deviation impossible using the bootstrap method or any other method for that matter. However, it should be noted that this year only has data for November and December and not for January-March.

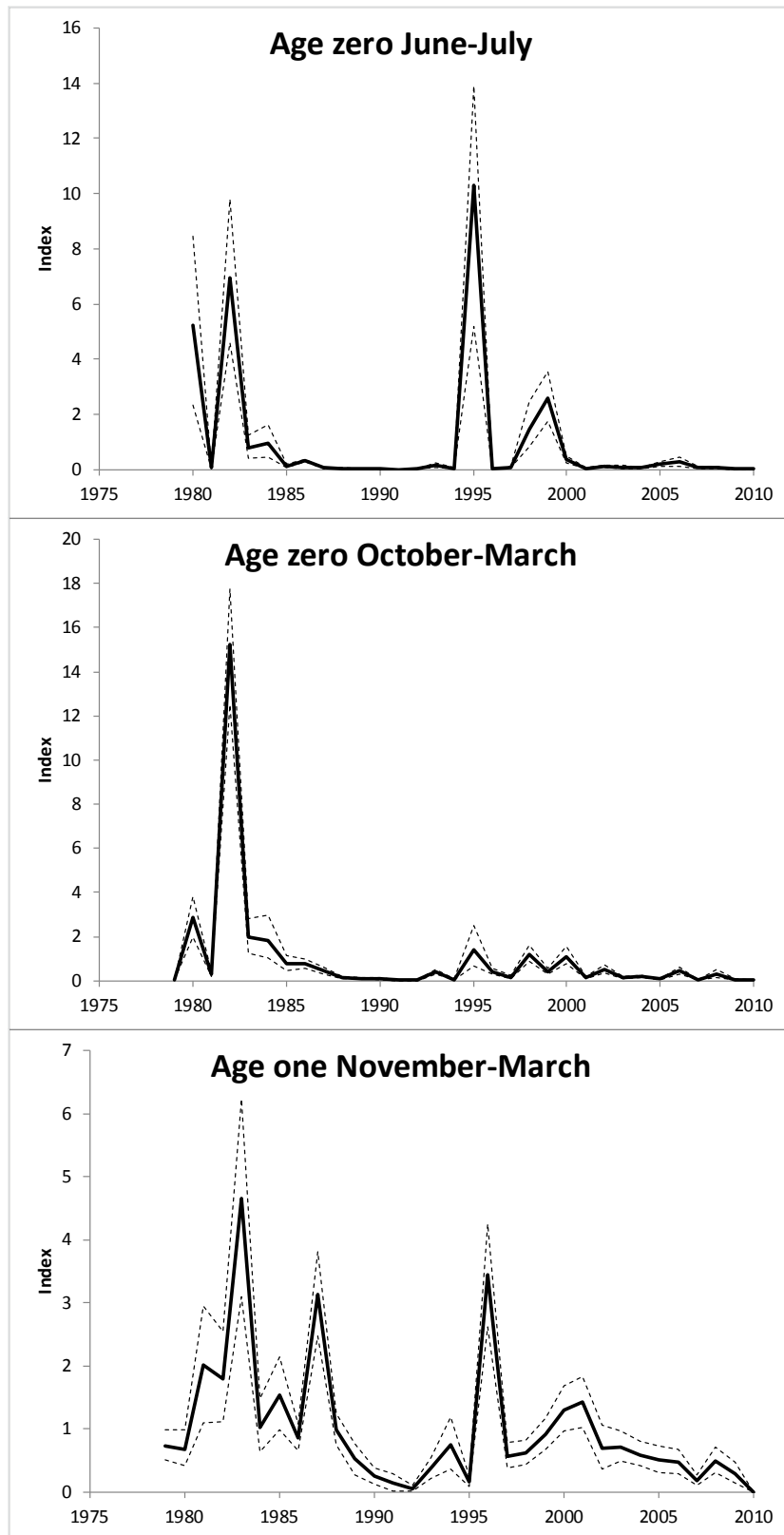


Figure 1. Mean, 2.5% and 97.5% percentiles from the bootstrap analysis.

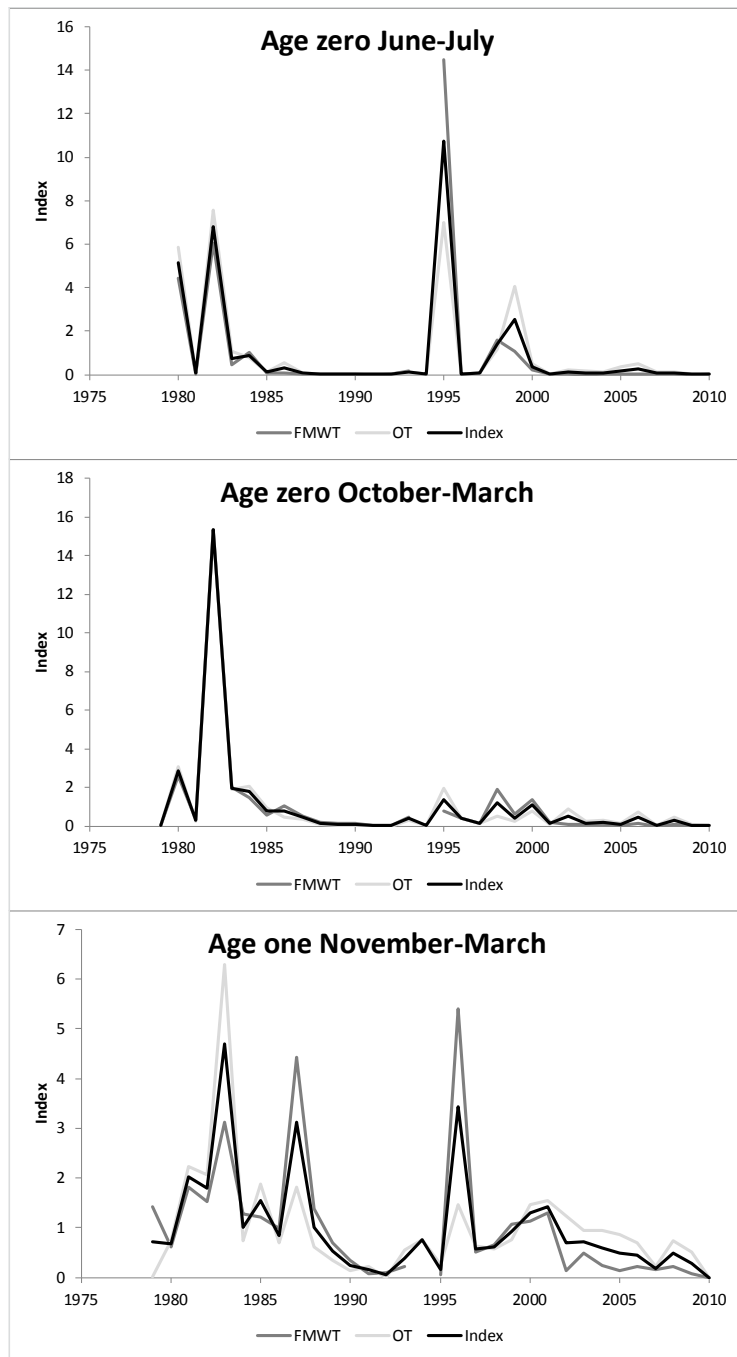


Figure 2. Estimated indices for the two survey methods compared to the combined index.

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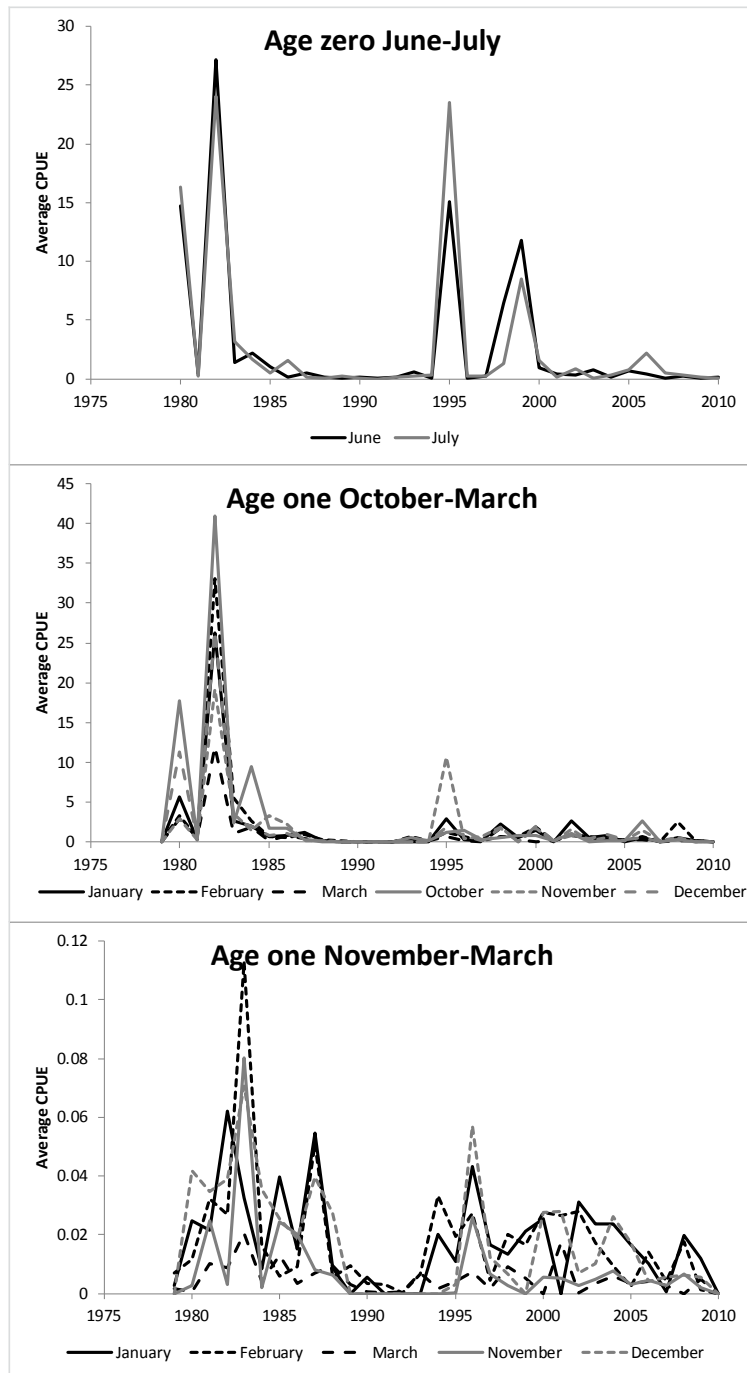


Figure 3. Average CPUE across station and survey method by month for the three indices.

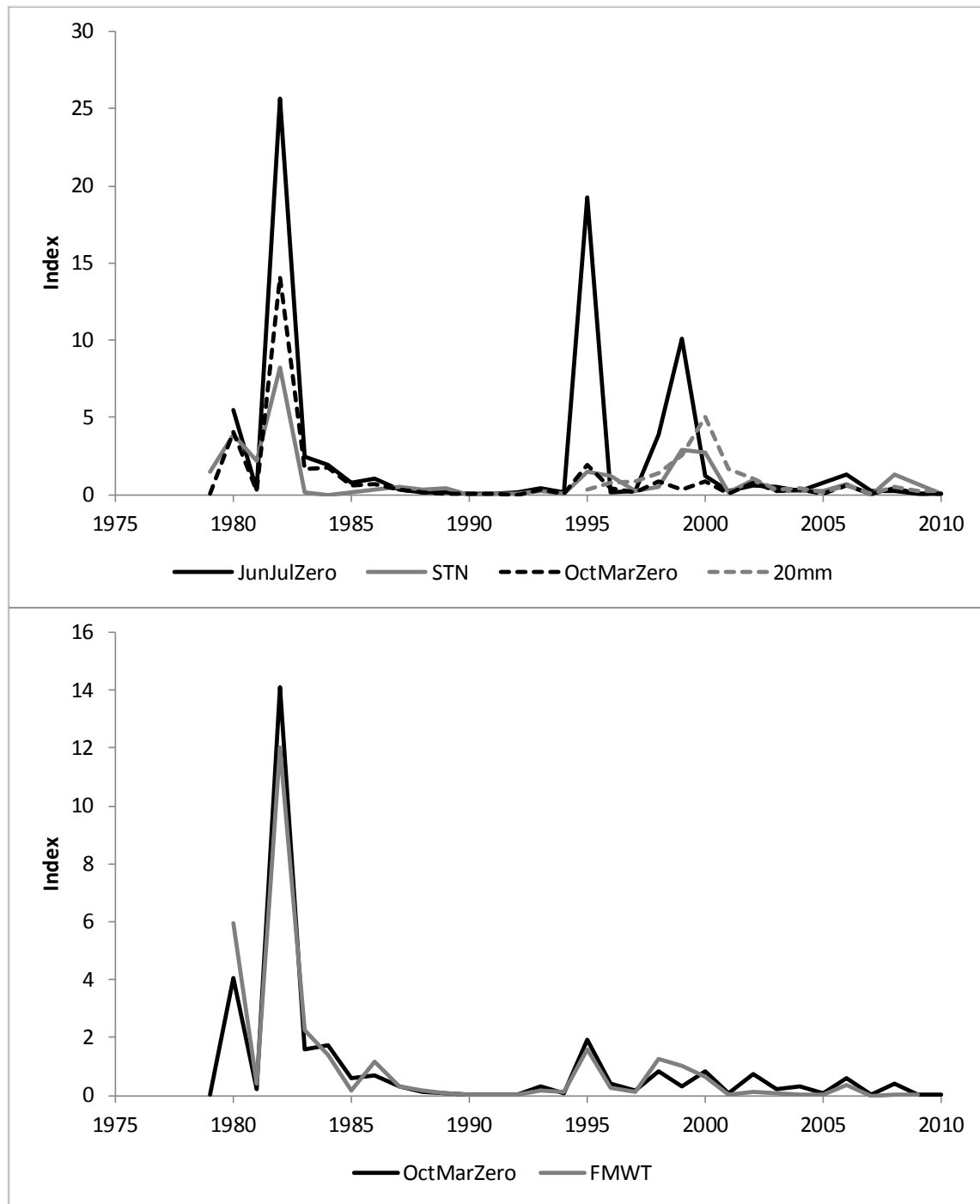


Figure 4. Comparison of the estimated abundance indices from the Bay Study with the FMWT, summer tow net, and 20mm survey used for delta smelt.

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Table 1. Regional weighting factors for the two gears

	(Region = 1) South Bay	(Region = 2) Central Bay	(Region = 3) San Pablo Bay	(Region = 4) Suisun Bay	(Region = 5) West Delta
MWT	1505.38	2865.13	861.4	471.64	253.68
OT	250.15	216.34	153.54	55.29	28.01

Table 2. Calculated index and the mean and standard deviation from the bootstrap analysis.

Year	ZeroJunJul			ZeroOctMar			OneNovMar		
	Index	Ave	sd	Index	Ave	sd	Index	Ave	sd
1979				0.0331	0.0333	0.0107	0.7192	0.7238	0.1233
1980	5.1476	5.2076	1.5409	2.8356	2.8468	0.4773	0.6713	0.6783	0.1477
1981	0.0547	0.0557	0.0115	0.2950	0.2968	0.0607	2.0285	2.0136	0.5007
1982	6.8117	6.9624	1.3385	15.3305	15.2233	1.3453	1.7892	1.7864	0.3752
1983	0.7620	0.7852	0.2237	1.9521	1.9548	0.3863	4.7031	4.6582	0.8349
1984	0.9038	0.9363	0.2885	1.7791	1.8015	0.5173	1.0086	1.0197	0.2147
1985	0.1125	0.1150	0.0316	0.7559	0.7659	0.1668	1.5442	1.5447	0.2931
1986	0.3066	0.3107	0.0276	0.7587	0.7625	0.1071	0.8505	0.8554	0.1070
1987	0.0563	0.0586	0.0139	0.4398	0.4452	0.0736	3.1280	3.1267	0.3503
1988	0.0393	0.0404	0.0105	0.1428	0.1439	0.0209	1.0000	0.9918	0.1303
1989	0.0330	0.0338	0.0069	0.1040	0.1058	0.0170	0.5225	0.5199	0.1222
1990	0.0159	0.0167	0.0048	0.0796	0.0803	0.0172	0.2466	0.2502	0.0628
1991	0.0058	0.0059	0.0019	0.0246	0.0250	0.0075	0.1477	0.1479	0.0821
1992	0.0251	0.0259	0.0070	0.0187	0.0186	0.0047	0.0515	0.0510	0.0230
1993	0.1390	0.1458	0.0399	0.3818	0.3842	0.0591	0.3773	0.3815	0.0892
1994	0.0435	0.0433	0.0115	0.0526	0.0533	0.0133	0.7560	0.7520	0.2145
1995	10.7355	10.3199	2.4034	1.3684	1.3766	0.5097	0.1588	0.1623	0.0451
1996	0.0297	0.0302	0.0071	0.4150	0.4147	0.0644	3.4402	3.4501	0.4272
1997	0.0733	0.0758	0.0136	0.1623	0.1644	0.0300	0.5671	0.5700	0.1010
1998	1.3879	1.4528	0.4202	1.2049	1.2102	0.1910	0.6114	0.6111	0.0990
1999	2.5614	2.6070	0.4719	0.4287	0.4293	0.0715	0.9177	0.9178	0.1221
2000	0.3448	0.3535	0.0724	1.0919	1.1100	0.1974	1.2974	1.3035	0.1806
2001	0.0335	0.0344	0.0092	0.1221	0.1223	0.0281	1.4272	1.4259	0.2035
2002	0.1144	0.1160	0.0277	0.4976	0.4997	0.0934	0.6954	0.6955	0.1770
2003	0.0954	0.0941	0.0378	0.1480	0.1489	0.0208	0.7192	0.7156	0.1204
2004	0.0542	0.0542	0.0123	0.2077	0.2088	0.0311	0.5862	0.5869	0.0967
2005	0.1773	0.1807	0.0481	0.0760	0.0763	0.0166	0.4980	0.5064	0.1117
2006	0.2704	0.2696	0.0837	0.4385	0.4413	0.0795	0.4572	0.4691	0.1024
2007	0.0741	0.0755	0.0261	0.0261	0.0263	0.0074	0.1859	0.1875	0.0421
2008	0.0645	0.0656	0.0149	0.2755	0.2766	0.1147	0.4800	0.4814	0.1089
2009	0.0232	0.0230	0.0067	0.0497	0.0496	0.0108	0.2921	0.2916	0.0826
2010	0.0254	0.0263	0.0100	0.0302	0.0301	0.0079	0.0000	0.0000	0.0000

Appendix

Table A1. Number of tows per station.

	Year																															
Station	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	0	1	2	3	4	5	6	7	8	9	10
101	10	22	24	24	24	24	26	22	24	24	14	18	18	18	17	12	19	21	24	24	20	22	22	22	26	24	24	24	22	23	24	14
102	10	22	24	24	24	24	26	22	24	24	14	18	18	18	17	12	19	21	24	24	20	22	22	22	26	24	24	24	22	24	24	14
103	10	22	24	24	24	24	26	22	24	24	14	18	18	18	17	12	19	21	24	24	20	22	22	22	26	24	24	24	22	24	24	14
104	8	20	24	24	24	24	26	22	24	24	14	18	18	18	17	12	19	21	24	24	20	22	22	22	26	24	24	24	22	24	24	14
105	10	20	24	24	24	24	26	22	24	24	14	18	18	18	17	12	19	21	24	24	20	22	22	22	26	24	24	24	22	24	24	14
106	10	22	23	24	24	24	26	22	24	24	14	18	18	18	17	12	19	21	24	24	20	22	22	22	26	24	24	24	22	24	24	14
107	10	22	24	24	24	24	26	22	24	24	14	18	18	18	17	12	19	21	24	24	20	22	22	22	26	24	24	24	22	24	24	14
108	10	14	24	24	24	24	26	22	24	24	14	18	18	18	17	12	19	21	24	24	20	22	22	22	26	24	24	24	22	24	24	14
109	10	22	24	24	24	24	26	22	24	24	14	18	18	18	17	12	19	21	24	24	20	22	22	22	26	24	24	24	22	24	24	14
110	9	20	24	21	24	24	26	22	24	24	14	18	18	18	17	12	19	21	24	24	20	22	22	22	26	24	23	24	22	24	24	14
140	0	0	0	0	0	0	0	0	12	24	14	18	18	18	17	12	19	21	24	24	20	22	22	20	26	24	24	24	22	24	24	14
142	0	0	0	0	0	0	0	0	12	24	14	18	18	18	17	12	19	21	24	24	20	22	22	22	26	24	24	24	22	24	24	14
211	10	20	24	24	24	24	26	22	24	24	14	18	18	18	17	12	19	21	24	24	20	22	22	22	26	24	24	24	22	24	24	14
212	10	21	23	24	24	24	26	22	24	24	14	18	18	18	17	12	19	21	24	24	20	22	22	22	26	24	24	24	22	24	24	14
213	8	17	15	14	23	24	26	22	24	24	14	18	18	18	17	12	19	21	24	24	20	22	22	22	26	24	24	24	22	24	24	14
214	10	21	23	24	24	24	26	22	24	24	14	18	18	18	17	12	19	21	24	24	20	22	22	21	26	24	24	24	22	24	24	14
215	10	20	23	24	24	24	26	22	24	24	14	18	18	18	17	12	19	21	24	24	20	22	22	22	26	24	24	24	22	24	24	14
216	10	22	22	24	24	24	26	22	24	24	14	18	18	18	17	12	19	21	24	24	20	22	22	21	26	24	24	24	22	24	24	14
243	0	0	0	0	0	0	0	0	12	24	14	18	18	18	17	12	19	21	24	24	20	22	22	22	26	24	24	24	22	24	24	14
244	0	0	0	0	0	0	0	0	12	24	14	18	18	18	17	12	19	21	24	24	20	22	22	22	26	24	23	24	22	24	24	14
317	0	8	24	24	24	24	26	22	24	24	14	18	18	18	17	12	19	24	24	24	20	22	22	24	23	24	24	24	22	24	24	14
318	10	20	23	24	24	24	26	22	24	24	14	18	18	18	17	12	19	24	24	24	20	22	22	22	26	24	24	24	22	24	24	14
319	0	8	23	24	24	24	26	22	24	24	14	18	18	18	17	12	19	24	24	24	20	22	22	24	24	24	24	24	22	24	24	14

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320	8	24	23	24	24	24	26	22	24	24	14	18	18	18	17	12	19	24	24	24	20	22	22	24	24	24	24	24	22	24	24	14
321	8	24	24	24	24	24	26	22	24	24	14	18	18	18	17	12	19	24	24	24	20	22	22	24	24	24	24	24	22	24	24	14
322	8	22	22	24	24	24	26	22	24	24	14	18	18	18	17	12	19	24	24	24	20	22	22	24	24	24	24	24	22	24	24	14
323	8	24	22	23	24	24	26	22	24	24	14	18	18	18	17	12	19	24	24	24	20	22	22	24	24	24	24	24	22	24	24	14
324	8	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
325	8	24	24	24	24	24	26	22	24	24	14	18	18	18	17	12	19	24	24	24	20	22	22	22	26	24	24	24	22	24	24	14
326	8	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
345	0	0	0	0	0	0	0	0	12	24	14	18	18	18	17	12	19	24	24	24	20	22	22	22	26	24	24	24	22	24	24	14
346	0	0	0	0	0	0	0	0	12	24	14	18	18	18	17	12	19	24	24	24	20	22	22	24	24	24	24	24	22	24	24	14
427	7	23	24	24	24	24	26	22	24	24	14	18	18	18	17	12	19	21	21	24	20	22	22	24	24	24	24	24	22	24	24	14
428	7	24	22	24	24	24	24	24	24	24	14	18	18	18	17	12	19	20	21	24	20	22	22	24	24	24	24	24	22	24	24	14
429	8	24	22	24	24	24	24	24	24	24	14	18	18	18	17	12	19	20	21	24	20	22	22	24	24	24	24	24	22	24	24	14
430	8	22	24	24	24	24	24	24	24	24	14	18	18	18	17	12	19	20	21	24	20	22	22	24	24	24	24	21	22	24	24	14
431	8	22	24	24	24	24	24	24	24	24	14	18	18	18	17	12	19	20	21	24	20	22	22	24	24	24	24	24	22	24	24	14
432	8	24	23	24	24	24	26	22	24	24	14	18	18	18	17	12	19	20	21	24	20	22	22	24	24	24	24	24	22	24	24	14
433	8	23	24	24	24	24	24	24	24	24	14	18	18	18	17	12	19	20	21	24	20	22	22	24	24	24	24	24	22	24	24	14
447	0	0	0	0	0	0	0	0	12	24	14	18	18	18	17	12	19	21	21	24	20	22	22	24	24	24	24	24	22	24	24	14
534	8	22	24	22	24	24	24	24	24	24	14	18	18	18	17	12	19	20	21	24	20	22	22	24	24	24	24	24	22	24	24	14
535	8	24	23	24	23	24	24	24	24	24	14	18	18	18	17	12	19	20	21	24	20	22	22	24	24	24	24	24	20	24	24	14
736	7	23	24	24	23	24	24	24	24	24	14	18	18	18	17	12	19	20	21	24	20	22	22	24	24	24	24	24	18	22	24	14
837	8	24	24	24	23	24	24	24	23	24	14	18	18	18	17	12	17	20	21	24	20	22	22	24	24	24	24	24	20	24	24	14

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Table A2. Number of tows by station and region.

Station	Region						
	1	2	3	4	5	6	7
101	676	0	0	0	0	0	0
102	677	0	0	0	0	0	0
103	677	0	0	0	0	0	0
104	673	0	0	0	0	0	0
105	675	0	0	0	0	0	0
106	676	0	0	0	0	0	0
107	677	0	0	0	0	0	0
108	669	0	0	0	0	0	0
109	0	677	0	0	0	0	0
110	0	670	0	0	0	0	0
140	487	0	0	0	0	0	0
142	0	489	0	0	0	0	0
211	0	675	0	0	0	0	0
212	0	675	0	0	0	0	0
213	0	650	0	0	0	0	0
214	0	674	0	0	0	0	0
215	0	674	0	0	0	0	0
216	0	674	0	0	0	0	0
243	0	489	0	0	0	0	0
244	0	488	0	0	0	0	0
317	0	0	655	0	0	0	0
318	0	0	677	0	0	0	0
319	0	0	655	0	0	0	0
320	0	0	679	0	0	0	0
321	0	0	680	0	0	0	0
322	0	0	676	0	0	0	0

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323	0	0	677	0	0	0	0
324	0	0	22	0	0	0	0
325	0	0	680	0	0	0	0
326	0	0	24	0	0	0	0
345	0	0	492	0	0	0	0
346	0	0	492	0	0	0	0
427	0	0	0	672	0	0	0
428	0	0	0	670	0	0	0
429	0	0	0	671	0	0	0
430	0	0	0	668	0	0	0
431	0	0	0	671	0	0	0
432	0	0	0	672	0	0	0
433	0	0	0	672	0	0	0
447	0	0	0	486	0	0	0
534	0	0	0	669	0	0	0
535	0	0	0	0	669	0	0
736	0	0	0	0	664	0	0
750	0	0	0	0	0	415	0
751	0	0	0	0	0	417	0
752	0	0	0	0	0	417	0
760	0	0	0	0	0	361	0
761	0	0	0	0	0	362	0
762	0	0	0	0	0	361	0
837	0	0	0	0	667	0	0
853	0	0	0	0	0	0	419
863	0	0	0	0	0	0	361
864	0	0	0	0	0	0	362
865	0	0	0	0	0	0	357