Electric Survey: Materials and Methods

Sampling Locations

Prior to actual field sampling in May 2001, we erected six strata in estuarine systems along the South Carolina coast. These included the lower and upper Edisto Rivers, the Combahee River, The upper Ashley River, the upper Cooper River and the North Santee River. Winyah Bay replaced the North Santee stratum in November 2003. The Upper Edisto and Combahee River strata were freshwater; the others had salinities that were generally less than 10 ppt.

The shoreline of each stratum was partitioned into 926-m (0.24-nautical miles) long intervals. Prior to each monthís sampling, sites were chosen from a table of random numbers without replacement. The number of potential sites varied according to the strata. These were: North Santee River = 82; Upper Cooper River = 63; Upper Ashley River = 80; Lower Edisto River = 88; Upper Edisto River = 86; Combahee River = 232; Winyah Bay = . Variability in the number of sites in some of the locations was caused by drought conditions that occurred over the southern United States during this decade. Since light rainfall reduced freshwater runoff and allowed the penetration of tidal salt water further upriver, additional sites were added to these locales so that sampling was conducted at salinities ~12 ppt and lower. The effectiveness of the shocking unit declined as salinity increased beyond ~12 ppt. Sampling intensity by location and year is in Table 1. It should be noted that when a sampling trip was made during the drought, the exact locations of the sampling stations was not known until we arrived at the various sites due to salinity variables. A sufficient number of alternate sites were chosen randomly prior to the trip to compensate for this problem.

Sampling Methodology

At each randomly chosen site, a transect near the shoreline was made with the tidal current in a Smith-Root electrofishing boat (Smith-Root, Inc., 14014 NE Salmon Creek Avenue, Vancouver, WA 98686). We chose went with the current rather than against it because stunned fishes would surface and float with the tide. They could be easily dip-netted. If we went against the tide, the stunned fishes would come to the surface under and/or behind the boat and make their capture very difficult. Straight shorelines were sampled by shocking at idle-speed approximately 1.5 to 3-m from the bank. More complex locations that contained submerged trees, remnants of old docks, mouths of tributaries and sloughs required more maneuvering with the boat to insure all areas were sampled.

Table 1. Number of yearly electrofishing collections made by year and stratum. Beginning in 2004, Winyah Bay was substituted for the North Santee River.

Stratum	Year								
	2001	2002	2003	2004	2005	2006	2007	2008	Total
Ashley	41	71	72	64	65	66	62	59	500
Cooper	36	71	68	71	66	64	67	62	505
U. Edisto	37	63	70	69	66	66	67	56	494
L. Edisto	41	66	61	64	54	63	60	40	449
Combahee	37	61	59	60	55	57	62	54	445
N. Santee	41	71	36	-	-	-	-	-	148
Winyah	-	-	6	51	57	65	43	52	274
Total	233	403	372	379	363	381	361	323	2815

Initial testing with the electrical settings on the generator indicated that an input of ~3,000 watts of pulsed direct current yielded good collections of fishes without causing significant obvious damage to them. In the oligohaline and freshwater areas, low conductivity required higher voltage and lower amperage settings to achieve the desired power level, Data Analysis

Not all strata were sampled each month over the course of the survey either because of weather or mechanical problems with the boatís electrical system. To develop an estimate of the abundance of red drum in the survey, the annual arithmetic means, standard deviations and standard errors were calculated on untransformed and transformed (ln[number + 1]) catches. Even though the design was stratified random sampling, the approach used in this analysis was thought to be appropriate due to the variability in the salinity in some strata. This required flexibility in station location and added significant more sites to a river, i.e., the Combahee River that had over 200 sites.

Total lengths in mm were converted to total lengths in inches (tlinch = truncated (tlmm/10) x 0.3937) since previous red drum assessments have used inches as their measurement unit. Note that the lengths are the maximum total lengths rather than relaxed TLís or centerline lengths. Age determinations were based either on modal progression of the lengths of the catch or examination of scales. Scales are not the best structure to use in determining age in red drum. They are, however, satisfactory for the younger ages (0 to 4) which form the bulk of the catch in this survey. Age-length keys were developed by month and applied to the length frequency distributions of the red drum caught by month and year. This assumes that the between year differences in size at age in a given month were small enough to not significantly impact the conversions of lengths to age.

To obtain the annual age composition of the catch, the monthly ages were summed over a calendar year to obtain the annual age composition. These were assigned to the appropriate yearclasses based on an August-September spawning season. The percent contribution of each of the yearclasses was multiplied by the annual arithmetic and transformed mean values to obtain a ìrecruitment indexî of the newly recruited yearclass each sampling year. For example, the recruitment index for calendar year 2001 would be the catch per transect of red drum for that year multiplied by the number of the 2000 yearclass in that yearís catch. Catch curves were constructed for each cohort where there were sufficient data to follow that yearclass through time.

Results

Catch data for the survey are in Appendix 1. Individual specimen data (lengths, etc) are in appendix 2. Length frequency summaries and age length keys are in Appendix 3. Age composition data are in Appendix 4.

Red drum were taken in 1291 of the 2815 collections (45.9%) made during the electric survey through November 2008. The frequency distribution of the catches followed a negative binomial distribution with large catches (>20 fish/sample) being extremely rare (Table 2). There was a statistically significant difference in the frequency of occurrence of red drum in the sampling strata ((2 = 601.6, df = 6). Collections made in Winyah Bay encountered this species in 83.2% of the collections; those strata designated as freshwater (Combahee and Upper South Edisto River) still provided habitat for red drum (Table 3). Samples in these freshwater strata encountered red drum in only 7.9 % (Upper South Edisto River) and 37.8% (Combahee River) of the stations. The freshwater strata were included in this analysis since the highly variable salinities caused by the lack of freshwater runoff resulted in the salt wedge pushing far inland. Even though salinities were very low in these areas, generally >1 ppt, there were sufficient salts present to allow the red drum to osmoregulate properly.

The annual mean CPUE was highest in 2003 and lowest in 2007 (Table 4; Figure 1 and 2). Since the catches were made up of 4 to 5 yearclasses, the annual averages failed to provide a clear picture of annual recruitment. The application of monthly age-length keys for red drum captured each month and year gave an indication of the contribution of each yearclass to the catch and their decline over time.

whereas in higher salinity areas with greater conductivity, lower voltage and higher amperage were necessary to achieve the proper intensity.

The boat produced an electric field that flowed between the anodes (the conductive booms that are set forward of the bow) and the cathode (the aluminum hull of the boat). Fish affected by the electric field generally swim towards the anode. This attraction to the anode is called electrotaxis; as they approach the anode, the current causes the relaxation of their body musculature resulting in a loss of equilibrium. Fish that touch the anode experience tetany, i.e., the complete contraction of their muscles resulting in immobility. Once removed from the electrical field, the effects generally dissipate rapidly for most fish held in the on-board tank.

Fishes were removed from the tank, sorted to species, counted, measured and weighed. Red drum were marked with sequentially numbered internal anchor tags (<550-mm total length [TL] or shoulder dart tags (>550-mm TL) and released at the site of capture. Individuals less than 25-cm TL were measured and released without being tagged.

Temperature and dissolved oxygen were measured with a Yellow Springs Instrument model 550 DO meter at the end of the transect. Salinity was estimated with a temperature compensated refractometer. A Secchi disc was then lowered to provide a measure of water clarity. Weather observations were noted and recorded.

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Table 2. Frequency distribution of the number of red drum taken in electrofishing collections in coastal South Carolina.

Number in Sample	Frequency	Percent	Cumulative Percent
0	1524	54.1	54.1
1	401	14.2	68.4

2	243	8.6	77.0
3	163	5.8	82.8
4	123	4.4	87.2
5	80	2.8	90.0
6	60	2.1	92.1
7	35	1.2	93.4
8	31	1.1	94.5
9	24	0.9	95.3
10	24	0.9	96.2
11	15	0.5	96.7
12	11	0.4	97.1
13	13	0.5	97.6
14	12	0.4	98.0
15	8	0.3	98.3
16	6	0.2	98.5
17	7	0.2	98.8
18	5	0.2	98.9
19	4	0.1	99.1
20	7	0.2	99.3
21 - 30	10	0.4	99.7
31 –40	5	0.2	99.9
41 – 50	3	0.1	99.95
51 +	1	0.05	100.0

Table 3. Table 3. Frequency of occurrence of red drum in various estuarine systems for 2001 through November 2008.

Stratum	Present	Absent	Total
Ashley River	331	169	500
Cooper River	303	202	505
Upper S. Edisto	39	455	494
Lower S. Edisto	153	296	449
Combahee	168	277	445
North Santee	69	79	148
Winyah Bay	228	46	274

Total	1291	1524	2815

The annual mean CPUE was highest in 2003 and lowest in 2007 (Table 4; Figure 1 and 2). Since the catches were made up of 4 to 5 yearclasses, the annual averages failed to provide a clear picture of annual recruitment. The application of monthly age-length keys for red drum captured each month and year gave an indication of the contribution of each yearclass to the catch and their decline over time.

Table 4. Table 4. Annual arithmetic and transformed (ln[x + 1]) CPUE (catch per transect station) for red drum in the electric survey. Mean = arithmetic mean; sd = its standard deviation; ln mean = mean ln([number + 1]; ln sd = its standard deviation; present = number of stations with red drum; samples = total number of stations.

Year	mean	sd	ln mean	ln sd	present	Samples
2001	1.99	3.0	0.72	0.82	117	233
2002	2.14	3.64	0.72	0.85	203	403
2003	2.34	4.51	0.7	0.91	165	372
2004	2.10	5.51	0.6	0.86	162	379
2005	1.97	4.44	0.62	0.83	171	363
2006	1.52	3.55	0.52	0.76	156	381
2007	1.31	2.25	0.54	0.70	157	361
2008	2.19	4.75	0.69	0.84	160	323

The transformed mean values showed the same general trend as the untransformed annual means; both indicated a downward trend in catches from 2004 through 2007. As has been seen in other surveys, the catch per set generally showed the same trend as the frequency of occurrence with more stations collecting red drum when annual means were higher. This was significantly correlated in the transformed data

Age 1 red drum generally accounted for the greatest percentage of the total fish caught during each year (Table 5 and Figure 4). To obtain an index of recruitment for a yearclass during a sampling year (the 2000 yearclass would be first fully recruited to the survey in 2001), the percent contribution of the newly recruited yearclass was multiplied by that yearís annual mean catch per sample. The index was highest

Table 5. Age composition of the annual catches of red drum in the electric survey. Data derived by the use of modal progression of length frequency data and scale analysis to generate monthly age-length keys.

Year	Age						
	0	1	2	3	4	5	6
2001	0.65	84.28	13.36	1.08	0.65	0	0
2002	0.46	55.97	38.82	3.82	0.81	0.12	0
2003	0	51.09	35.82	9.76	3.21	0.11	0
2004	1.00	27.10	56.09	10.66	4.64	0.50	0.70
2005	0.28	36.16	36.02	16.83	7.93	2.09	0.17
2006	0.86	35.33	37.22	16.81	8.58	1.03	0
2007	1.27	50.10	34.39	9.13	4.46	0.64	0.43
2008	0	42.32	45.50	6.17	4.45	1.58	0

In order to obtain an estimate of the instantaneous rate of total mortality for red drum taken during the electric survey, standard catch curves were generated for each of the cohorts for which there were sufficient data. Z ranged from 0.71 for the 1999 cohort (yearclass) to a high of 1.17 for the 2002 cohort with a mean for the period of 0.95 (Figure 6). In classical fisheries work, the instantaneous rate of total mortality (Z) is the sum of the instantaneous rate of natural mortality (M) and the instantaneous rate of fishing mortality (F), i.e., $Z = F + M$. For these data, however, the values for Z probably represent both of the above plus a ‘disappearance’ factor where some of the fishes that were found upriver moved downriver to other locations. To confirm or refute this concept, the tag-recapture data for fishes marked in various areas of these estuaries need to be examined to determine if indeed there is movement.

Figure 1. Annual mean catch per transect in numbers for red drum; filled circle = mean; vertical bars = +/- one standard error of the mean; dashed line = mean for period as a reference.

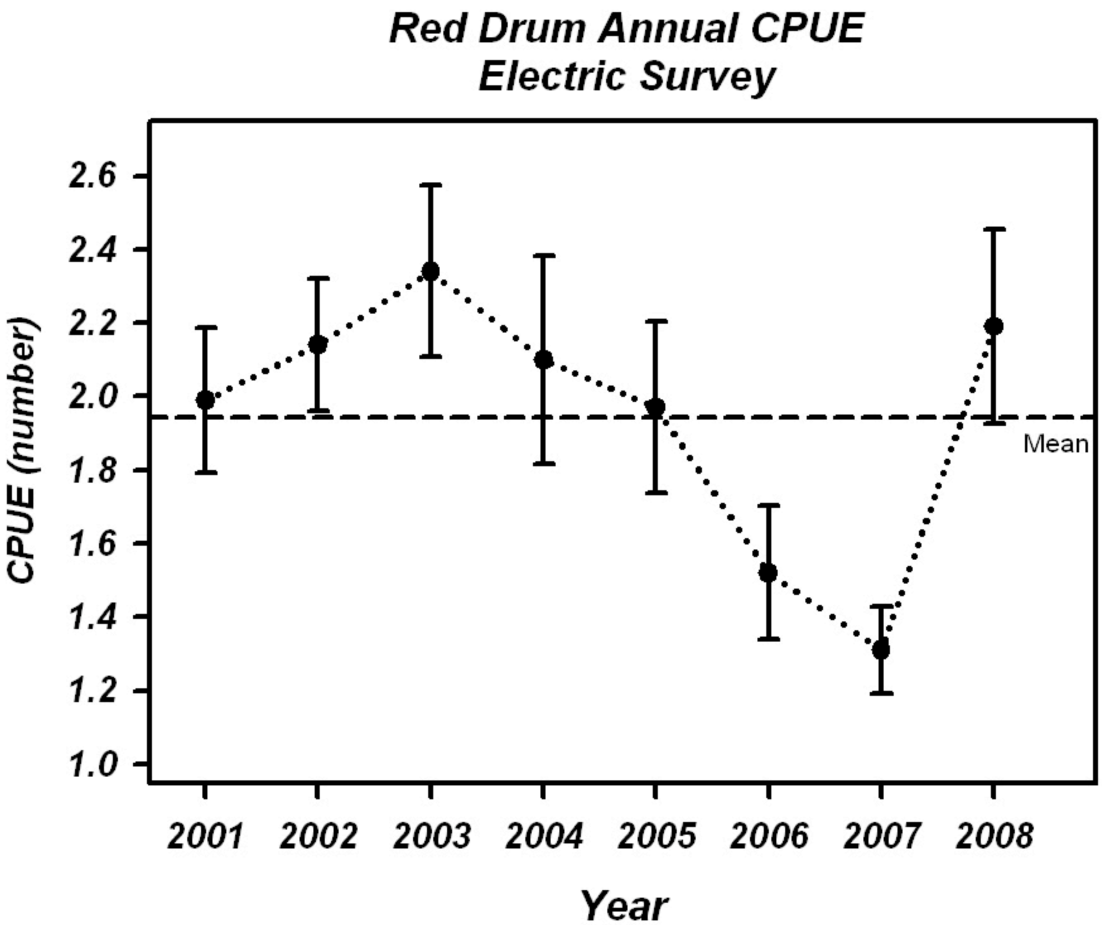


Figure 2. Annual mean ln[number + 1] per transect for red drum; see above for symbols

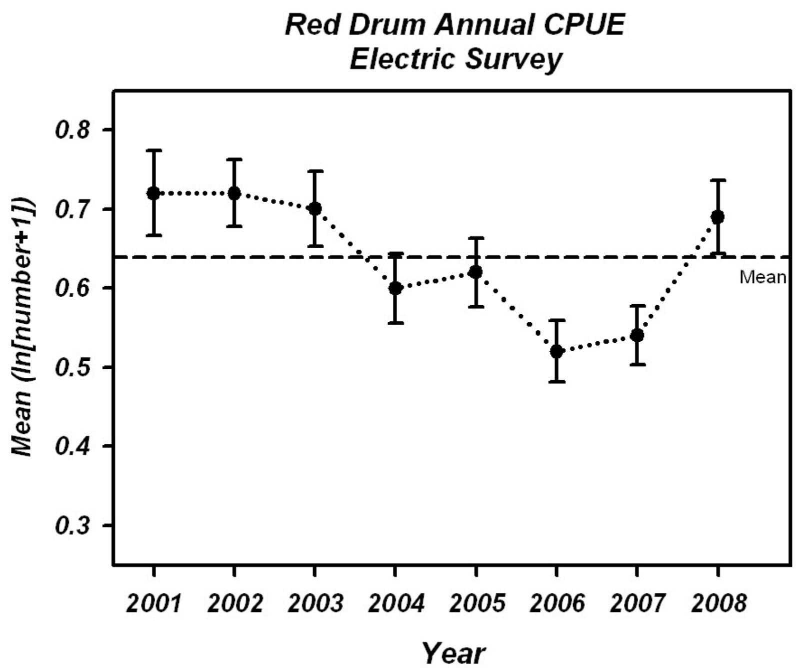


Figure 3. Relationship of the transformed annual mean CPUE and the percent occurrence of red drum in electric collections. Numerical values on graph = corresponding year

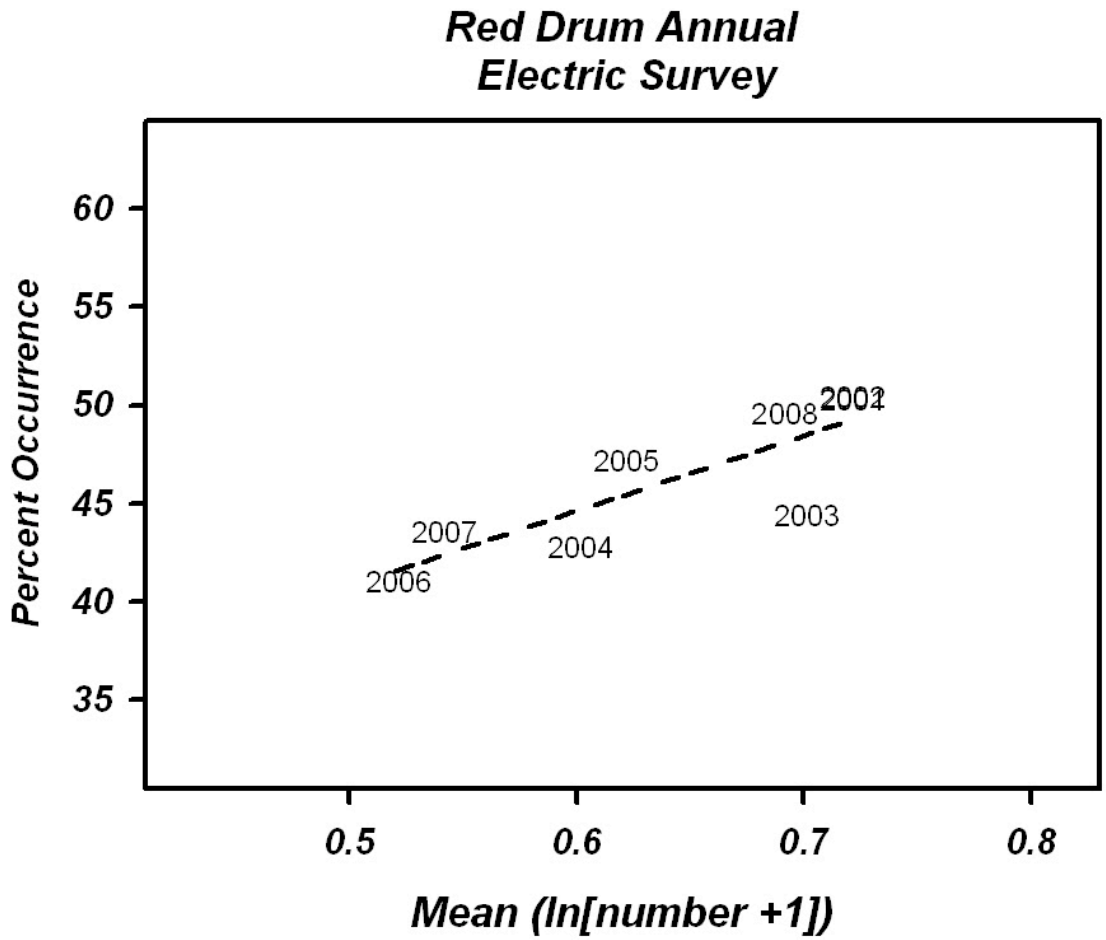


Figure 4. Age composition of the red drum taken in the electric survey by year. See above for methodology.

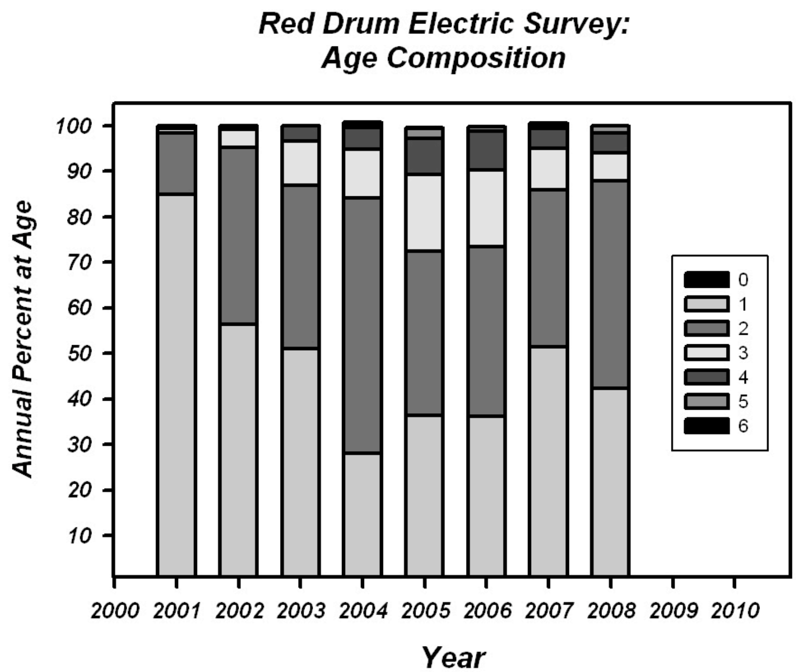

Red Drum Electric Survey:
Age Composition
Annual Percent at Age
100
90
80
70
60
50
40
30
20
10
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
Year
0
1
2
3
4
5
6

Figure 5. Recuitment index for red drum collected in the electric survey. Numbers in figure represent yearclasses. Dashed line is the long-term mean.

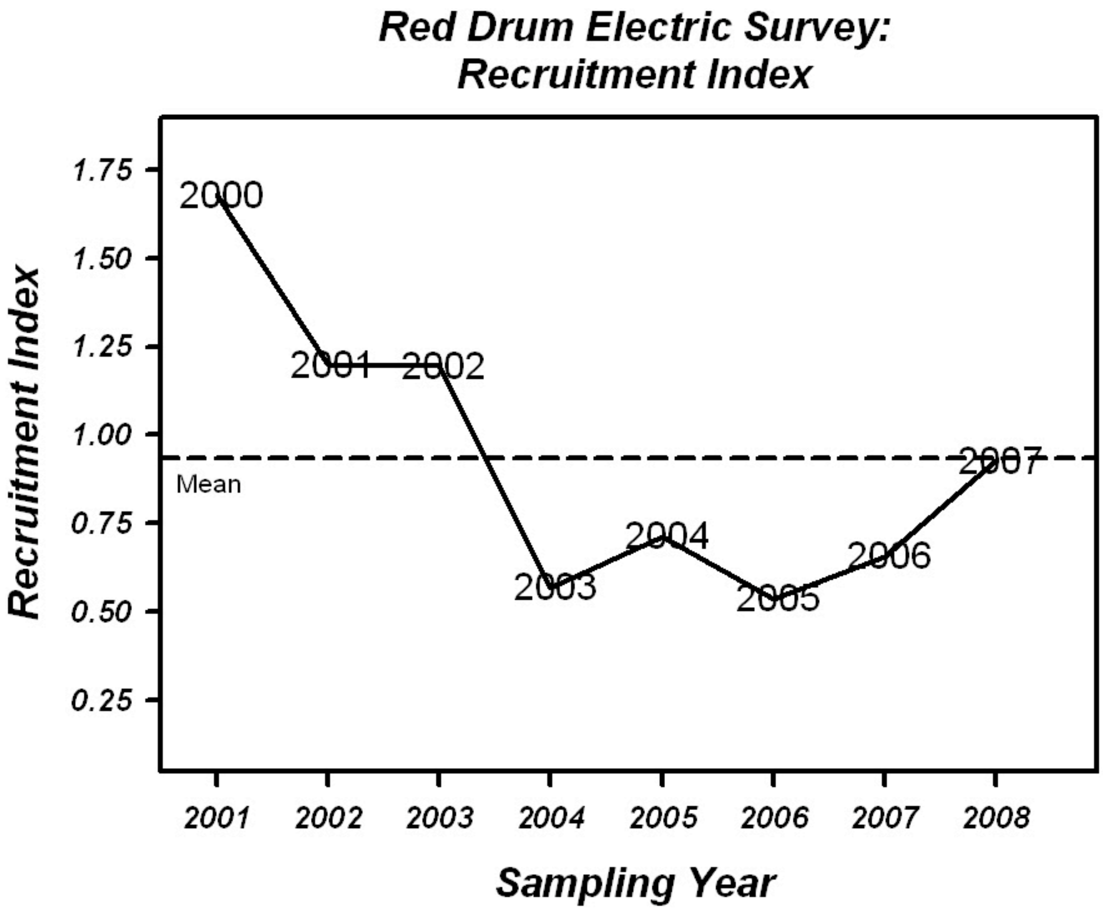
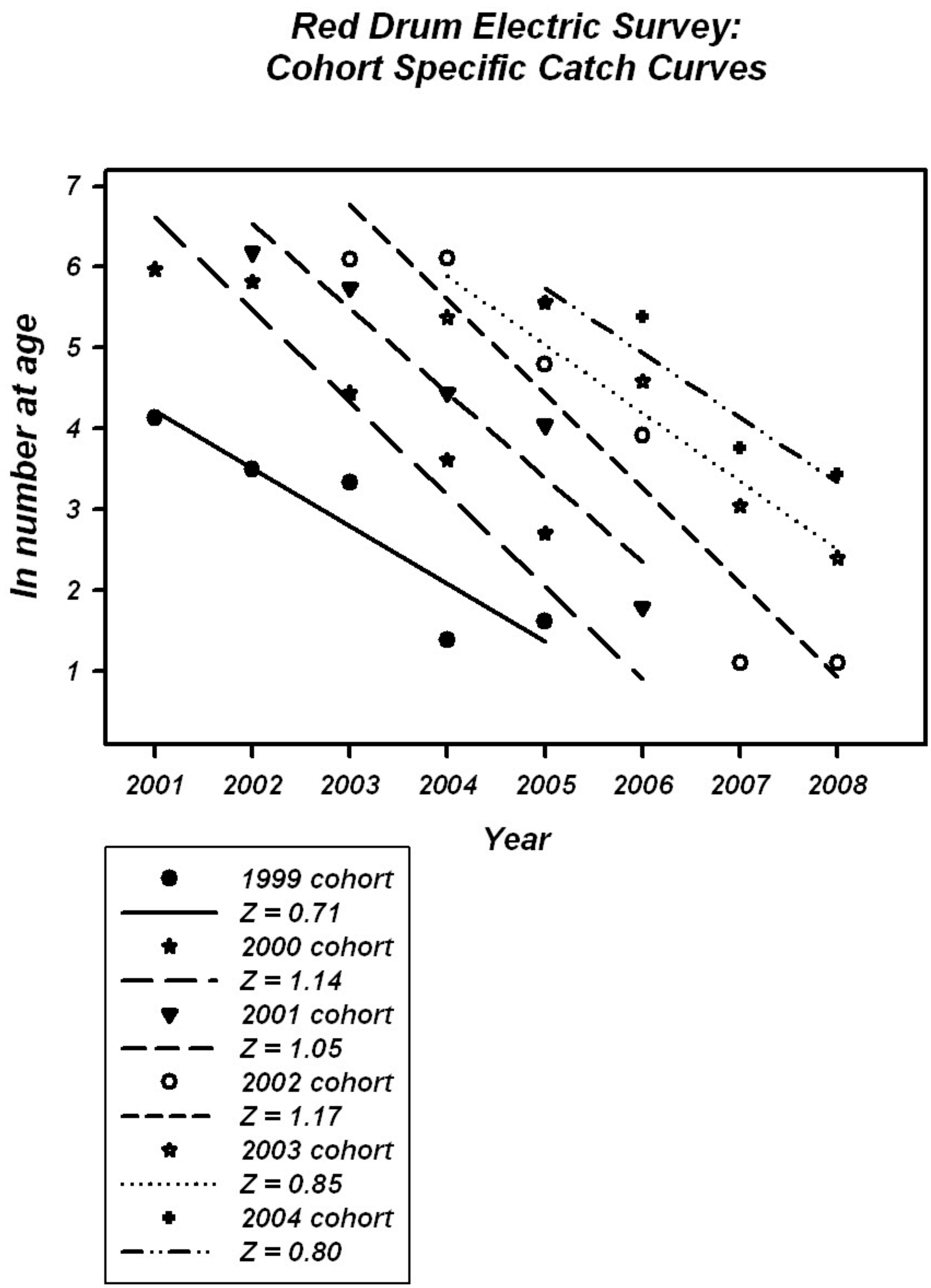


Figure 6. Cohort specific catch curves for red drum for the electric survey. See legend for details.


Red Drum Electric Survey:
Cohort Specific Catch Curves
ln number at age
7
6
5
4
3
2
1
2001
2002
2003
2004
2005
2006
2007
2008
Year
1999 cohort
Z = 0.71
2000 cohort
Z = 1.14
2001 cohort
Z = 1.05
2002 cohort
Z = 1.17
2003 cohort
Z = 0.85
2004 cohort
Z = 0.80