Analysis of B. Everett Jordan Lake Largemouth Bass Mortality and Catch-at-Age Trends, 1989-2016

Federal Aid in Sport Fish Restoration
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Abstract. In 2018, Commission biologists compiled and analyed historical Largemouth Bass Micropterus salmoides data collected from B. Everett Jordan Lake (Jordan Lake). Preliminary data exploration indicated variable, yet slower, recruiment of younger age classes to the largest size classes of the popuation. Age/growth analysis remained constant, yet the oldest age class (6-10) strength appeared to increase with time, as Largemouth Bass seemed to be living longer. Additionally, PSD-P values increased between 2004-2016 from 33.3% to 47.8%. With these indicators in mind, additional analyses were conducted on the catch-at-age patterns within these data to investigate temporal trends in mortality within the population. Log normalized catch curves were created for each year of data and mortality rates (Z & A) were estimated using regressions of the catch of each curve's decending limb. Estimated rates of annual total mortality (A) were variable (mean = 32.4 ± 4.4% SE). While early visualizations suggested a change in size distribution and mortality over time, with older/larger individuals surviving longer, these additional analyses revealed that significant changes have not occurred over time. Instead, the changes in proportion of older/larger fish are likely due to large scale changes in fish collection methodology and increased capture efficiency of preferred length individuals through time. These analyses confirm that even with perceived increases in angling effort, the Largemouth Bass fishery at Jordan Lake has remained stable with above average population characteristics.

B. Everett Jordan Reservoir (Jordan Lake) is a 13,942-acre impoundment at the confluence of the Haw River and New Hope Creek in Chatham County located approximately 30 miles west of Raleigh, NC. Jordan Lake was impounded in 1982 by the United States Army Corps of Engineers (Wilmington District). The lake provides drinking water for eight surrounding municipalities and provides flood control for many cities along the Cape Fear River downstream to Fayetteville and Wilmington, NC.

Jordan Lake, located in the Triangle Region of North Carolina (Durham, Orange, and Wake counties), is a popular destination for Largemouth Bass anglers. In 2019, the lake received national coverage when one of the top bass fishing tournament trails, Major League Fishing™, included the lake in one of its national tour events. Local bass anglers frequent Jordan Lake daily during the spring and fall.

Most contemporary Largemouth Bass anglers practice catch and release (Hessenauer 2015). In Largemouth Bass tournaments, penalties for dead fish cause anglers to take every precaution necessary to keep fish alive and healthy. Voluntary release rates for Largemouth Bass have increased over the last three decades (Myers et al. 2008) and social behaviors of anglers have impacted fisheries for most species (Arlinghaus et al. 2007). These factors hold true for Largemouth Bass fisheries in the Southern U.S. where anglers have made changes in common angling practices that frequently include catch and release of Largemouth Bass. While these changes have not been a surprise to fishery managers who have watched the behaviors change, the shift has driven an examination to determine if there are any population level impacts of a perceived increase in individual longevity.

While the efforts to minimize fishing mortality have likely been successsful, increased longevity of individual fish may result in larger populations of bass with higher levels of interspecific competetion. In some situations, more competition or a more abundant Largemouth Bass population could lower the chances of trophy potential (Sass et al. 2018), which could lead to overcrowding and lower overall growth potential. The main goal of this analysis was to use routine monitoring data to draw statistical conclusions about mortality and growth trends over many years for a popular Largemouth Bass fishery.

Methods

The North Carolina Wildlife Resources Commission (Commission) performs population surveys of the Largemouth Bass population in Jordan Lake every three to six years. Surveys began in 1983, only one year after the reservoir was filled. Survey frequency has varied over time from one to five years between surveys with surveys conducted more infrequently since 2006. Age data is well documented with 30.3% of Largemouth Bass in the dataset having a physically assigned age verified by sagittal otoliths.

Largemouth Bass were sampled periodically throughout the 31-year timeframe using shoreline electrofishing surveys for 65,444 unique sampling events. Site selection methodologies varied based on personnel involved in sampling. Typical sites were chosen within three distinct zones of the reservoir (Figure 1). Site lengths varied widely covering 500-1,280 m of shoreline and site-specific sampling times also varied widely between 600-2,400s of pedal time per site. Fish were collected using Smith-Root© boat mounted electrofishers (Vancouver, WA) throughout all sampling years. Sampling was conducted using 500–1,000 V and 3–4 amps of pulsed DC electrical currents. All fish collected were measured to obtain total length (mm) and 82.2% of Largemouth Bass were weighed (g). Normally, a subsample of fish was sacrificed for age determination using otoliths. However, otoliths were not collected in 2001 or 2002 for unknown reasons.

Because of the highly varied sampling protocols through time, no site/group specific comparisons or contrasts were attempted using this dataset. Instead, each whole survey was treated as a single replicate if the survey were conducted between the months of March and May. This excluded 191 Largemouth Bass from the database which were sampled during the Fall seasons of 1991 and 1992. Otolith confirmed age data was compiled into a single database with all available corresponding lengths and weights. Weights were missing for some individuals, but those fish were still included if a length value was present. Surveys prior to 1989 were omitted from all analysis as any differences earlier than this would likely be due to a developing fishery in the newly formed reservoir as the nutrient supply normalized (Hall et al. 1999). In all, 20 survey years were included in the analysis totaling 9,426 individual Largemouth Bass (Table 1). Sample sizes per replicate year varied between 184 individuals (2002) and 1,146 (1994).

An age-length key was created for the entire historical dataset based on the actual ages of fish aged via otolith ring counts. For years when partial ages were estimated, the age was always rounded up to the next year (e.g., 2.4 = 3 years). Age data was uploaded to the R statistical program (R Core Team 2019) and the Fishery Stock Assessment (FSA) package was used to apply a von Bertalanffy growth model expanding ages to all individuals >150 mm TL. Once an age was assigned to all the fish in the dataset, catch-at-age data was built by subsetting for each survey year. The catch counts were then log normalized and the ‘catchCurve’ function of the FSA package was used to create simple linear regression models of the catch count data for each year.

Estimates of instantaneous and annual mortality, parameters *Z* and *A* respectively, were calculated using linear models where:

$$Z = \log(\text{Catch at } t) - \log(\text{Catch at } t{+}1) \quad \text{and}$$

$$A = Z - e^{-z}$$

Following the methods of Ogle (2016), the descending limbs of each catch curve were weighted and population parameters $\hat{Z}$ and $\hat{A}$ were calculated via regression as the final estimates of mortality for each year that was surveyed. All analyses were performed using the Fisheries Stock Assessment 'FSA' and 'gdata' packages in R.

A simple linear regression was also used to determine if the group of bass most susceptible to mortality, elevated harvest, and interspecific competition influenced catch count data and age estimates through time. Age-3 fish within the dataset were subset and a linear trendline was fit to this new dataset. A trendline was then fit to the data in order to test for a statistically significant slope through time. Studying for a trend at age-3 allowed for a rudimentary test of growth of the group of fish that were most likely to be harvested throughout this period.

Results

In general, catch-at-age trends follow the predictable pattern of many balanced black bass fisheries with highest catch being that of 2- and 3-year-old bass incrementally declining to the oldest ages. Catch counts for survey years were all similar after the data were log-normalized (Appendix A). The only outlying years were in 1994 where an abnormally high catch of all age classes (Figure 2) was used to aid a relative weight study, and during 2000 when scheduling constraints caused lower than normal sampling effort. Nevertheless, catch of Largemouth Bass aged 2 to 6 log-scaled to between 3.0–5.8 individuals during all years and 3.1–5.1 for years with typical levels of effort after data normalization.

Instantaneous population mortality ($\hat{Z}$) was estimated to be 0.34 ± 0.06 (mean ± SE). Annual mortality (*A*) estimates indicate that almost one third of the population was lost within each estimated year. The grand mean for annual mortality across all estimated survey years combined was $\hat{A}$ = 32.4% (SE = 4.4%; Table 2). Annual mortality estimates ranged between 23% and 42% with no discernable trends through time (Table 2; Figure 3). Pinpointing three separate points in time also indicate no major changes in observed annual mortality. 1989 began with a slightly higher annual mortality of 34.1%, while later years show that more standardized sampling indicates no significant changes throughout time with 1999 and 2016 both being just under 29% of the lake's Largemouth Bass being lost in a year (Figure 4).

Age-3 Largemouth Bass had a total length range between 225 - 446 mm, a mode of 324 mm, and averaged 334 mm TL. The linear trendline fit to the data indicates no significant changes through time across the entire time series of 32 years [$R^2 < 0.001$, $p = 0.22$] (Figure 5). Size structure plots for each sample year are seen in Appendix B where varying catch rates with little noticeable patterns can be observed throughout this period.

Discussion

Mortality estimates in this analysis, $\hat{Z}$= 0.34, were within those published for other Largemouth Bass fisheries in the Southern United States which ranged from $\hat{Z}$= 0.2–2.4 (Allen et al. 2008). Instantaneous mortality estimates for Jordan Lake were well within expected values for a popular fishery with what is currently presumed to be a high exploitation rate. Additionally, since Largemouth Bass older than age-10 were rare throughout the survey years, natural factors and compensatory angling mortality may still be outweighing minimal harvest levels and increased fish care as is indicated by Allen et al. (2008) and Myers et al. (2008). The range of total annual mortality estimates for all years varied by only 10%. This small variation is inferably explained by sampling conditions and timing/water temperatures instead of changes in angler behavior or harvest rates.

The influence of catch and growth of age-3 Largemouth Bass over time was minimal. The simple regression of the age-3 class indicates that there was no significant trend in the data of the most susceptible age group. As a result, there was likely no impact on expanding ages using data from prior surveys as a change in the growth of this group would likely have compounding/additive effects to the growth of older age classes through time. Mean and median total length of age-3 Largemouth Bass varied by no more than 6-mm across all years. More research is needed to determine the optimal way to extrapolate ages to all the fish with unassigned ages in large datasets with multiple years of sampling effort. Future investigation is also needed to test for the most appropriate way to subset the data and compare survey years with varying levels of electrofishing time, otolith collections, and varying numbers of captures of the most and least numerous age classes.

While it is suspected that Jordan Lake experiences high fishing pressure, there is no empirical data available to confirm this. The North Carolina Division of Parks and Recreation and the Commission's Land and Water Access section, operators of most of the boat ramps on Jordan Lake, have data on the number of boats launched and weigh-in permits issued for their ramps, but these datasets do not contain any data on fish catches and harvest. During the most recent creel survey, anglers expended an estimated 50,545.80 hours of targeted Largemouth Bass fishing effort for Jordan Lake between 2009-10 (S. Mycko, unpublished data). Additional creel data is needed to estimate current exploitation rates during the coming decades.

After repeatable protocols were put into place, substantial changes in the total annual mortality ($\hat{A}$) and growth patterns of Largemouth Bass in Jordan Lake over time were not detected. However, written standardized protocols have been in place only since 2006 and survey results will continue to be added to this dataset in the future. Biologists will continue to monitor populations and analyze data in a similar manner to the methods used in the present study in attempts to manage for a healthy population of Largemouth Bass in Jordan Lake. The reservoir is currently categorized as eutrophic by the North Carolina Division of Water Resources (NCDEQ 2020) and the high levels of nutrients in the reservoir likely sustain a very large population of all fish species within the system. The high productivity of the water is likely an influence on the sustained stable/balanced population for so long in the face of increasing anthropogenic pressures. Further investigations are needed to ultimately test the extent of the compensatory mortality model for Jordan Lake in the face of increasing nutrification.

Management Recommendations

- Continue to monitor the Largemouth Bass population in Jordan Lake on a routine basis.
- Maintain consistent sampling protocols when feasible for continued tracking of mortality and growth rates in future years.
- Future analyses are needed to determine if current sampling protocols are adequate to track mortality and growth rates across longer/generational time periods.
- Alternative methods of assigning ages and subsetting data will be experimented with as more NC lake datasets begin to be analyzed in 2022-2023.
- Invasive species such as Alabama Bass *Micropterus* henshalli and Blue Catfish *Ictalurus furcatus* will undoubtedly be introduced into Jordan Lake. New species will likely increase competition with game fish that are currently present. It will be vital to monitor the impact that any new invasion may have on the lake’s populations of native sport fishes.

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Table 1.—Effort and total catch of Jordan Lake Largemouth Bass for each examinied survey years.

Year	Effort (Seconds)	Total Catch (n)
1989	62,276	677
1990	61,400	791
1991	54,413	439
1992	56,125	694
1993	41,006	435
1994	65,427	1045
1995	40,224	486
1996	28,071	397
1997	27,858	401
1998	16,093	176
1999	15,710	282
2000	8,114	95
2001	28,728	487
2002	15,592	184
2004	27,695	396
2006	20,672	383
2008	NA	602
2010	27,000	429
2015	18,000	378
2016	18,000	306
Total	**579,970**	**9,083**

Table 2. — Instantaneous (Z) and annual mortality (A) estimates for Jordan Lake Largemouth Bass derived for each examined survey year.

Year	$\hat{Z}$	$\hat{A}$ (%)	Sample Size
1989	0.3360	34.06	677
1990	0.3517	31.77	791
1991	0.3200	32.46	439
1992	0.3461	31.82	694
1993	0.3362	30.71	435
1994	0.4649	38.24	1,046
1995	0.4592	41.75	486
1996	0.3607	34.03	397
1997	0.2007	30.52	401
1998	0.2936	31.77	176
1999	0.2927	23.71	282
2000	0.2780	24.50	95
2001	0.3841	35.94	487
2002	0.3964	40.82	184
2004	0.3322	31.17	396
2006	0.3146	29.89	383
2008	0.3262	32.47	602
2010	0.3580	32.82	429
2015	0.3451	29.92	378
2016	0.2993	29.18	306

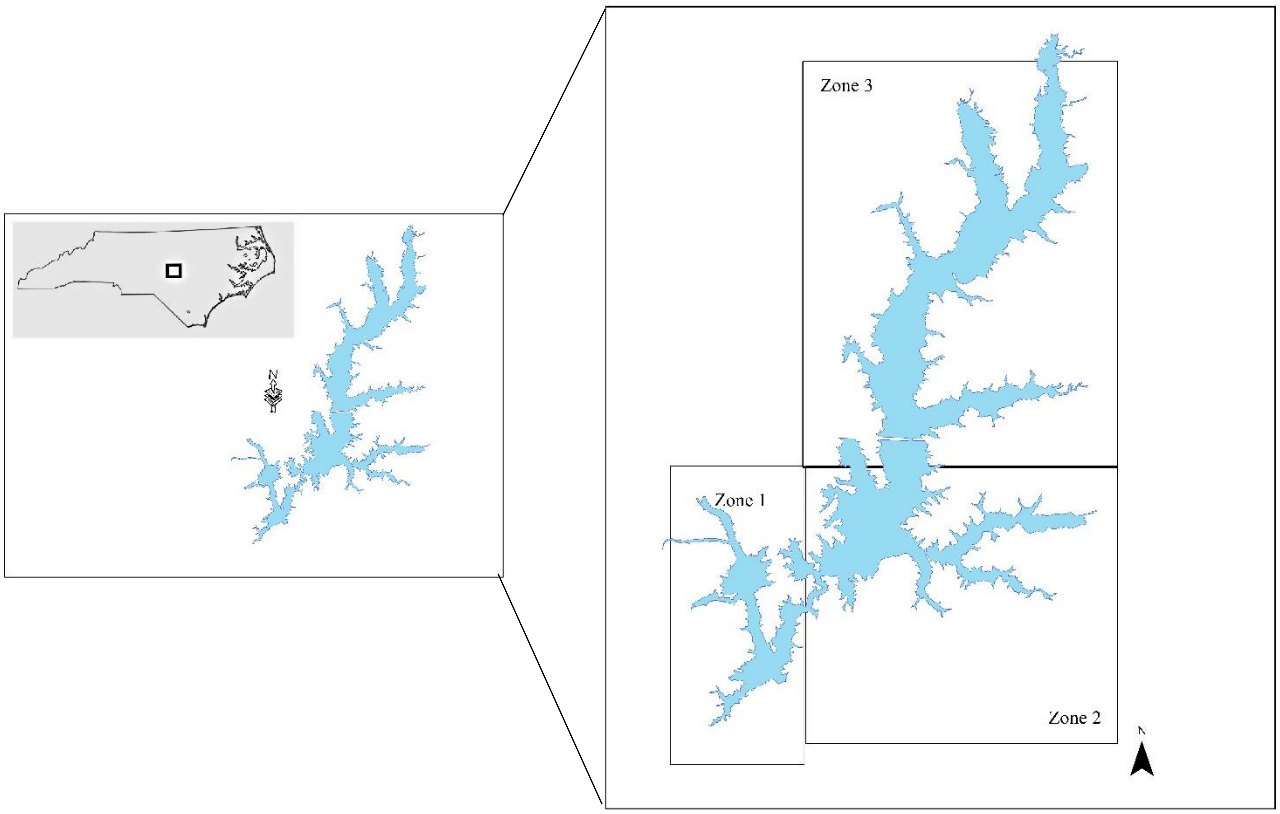


Figure 1. Map of Jordan Lake with sampling zones highlighted.

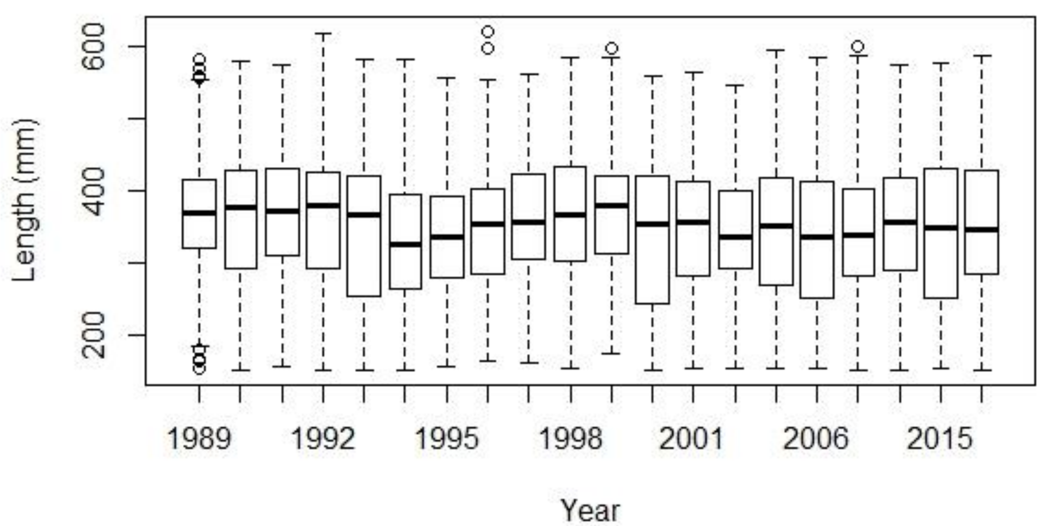


Figure 2. Boxplot of lengths of all Largemouth Bass captured during spring electrofishing surveys.

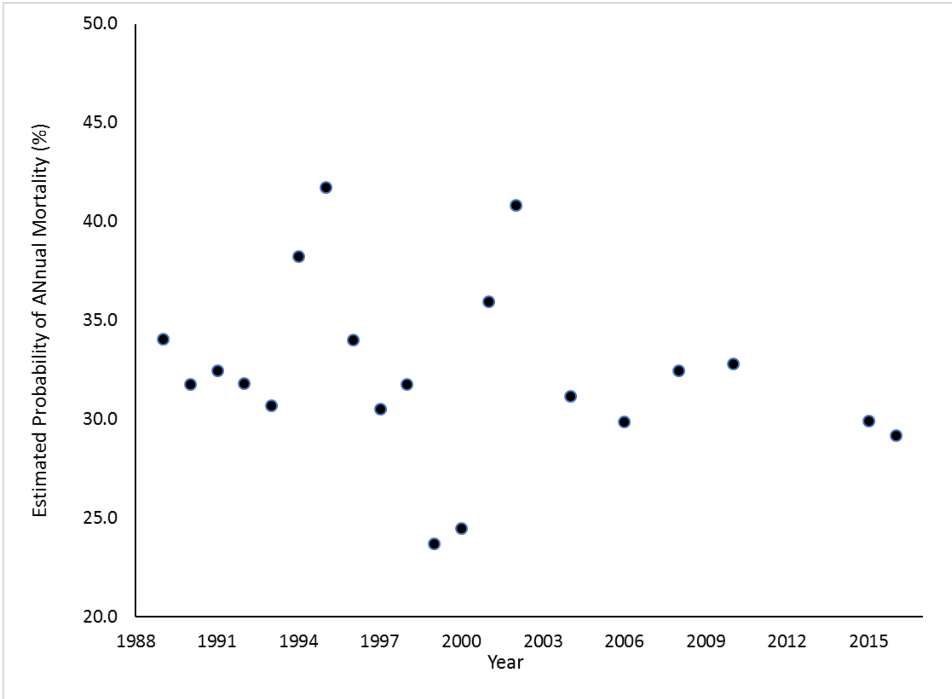


Figure 3. — Scatterplot of annual mortality estimates (*A*) for Jordan Lake Largemouth Bass.

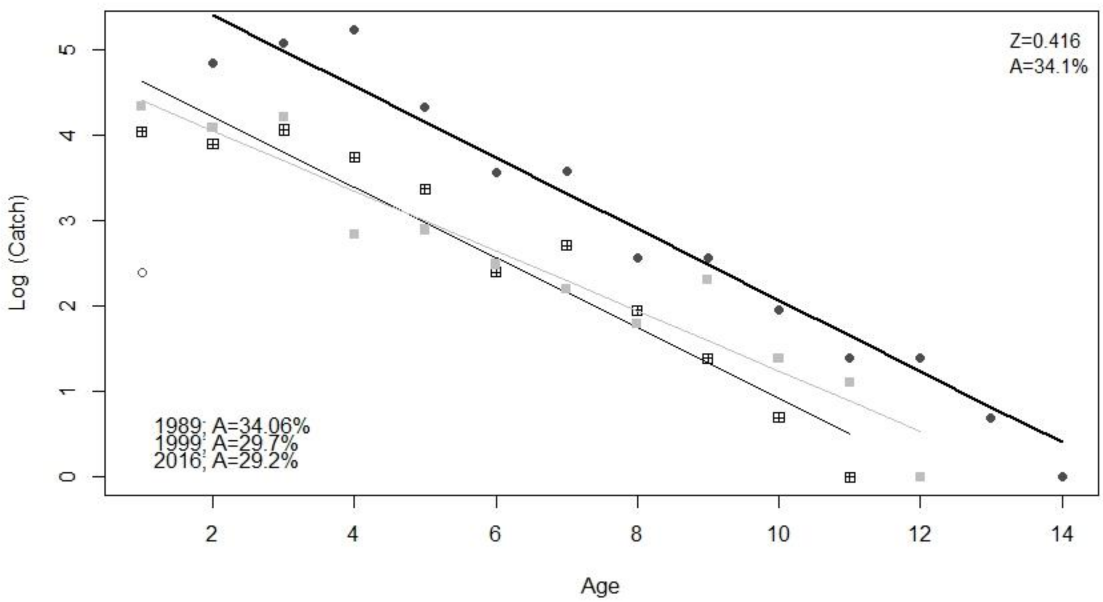


Figure 4. — Catch curve regression plots for three separate survey years through time. Black circle for 1989, hashed squares for 1999, and gray squares for 2016.

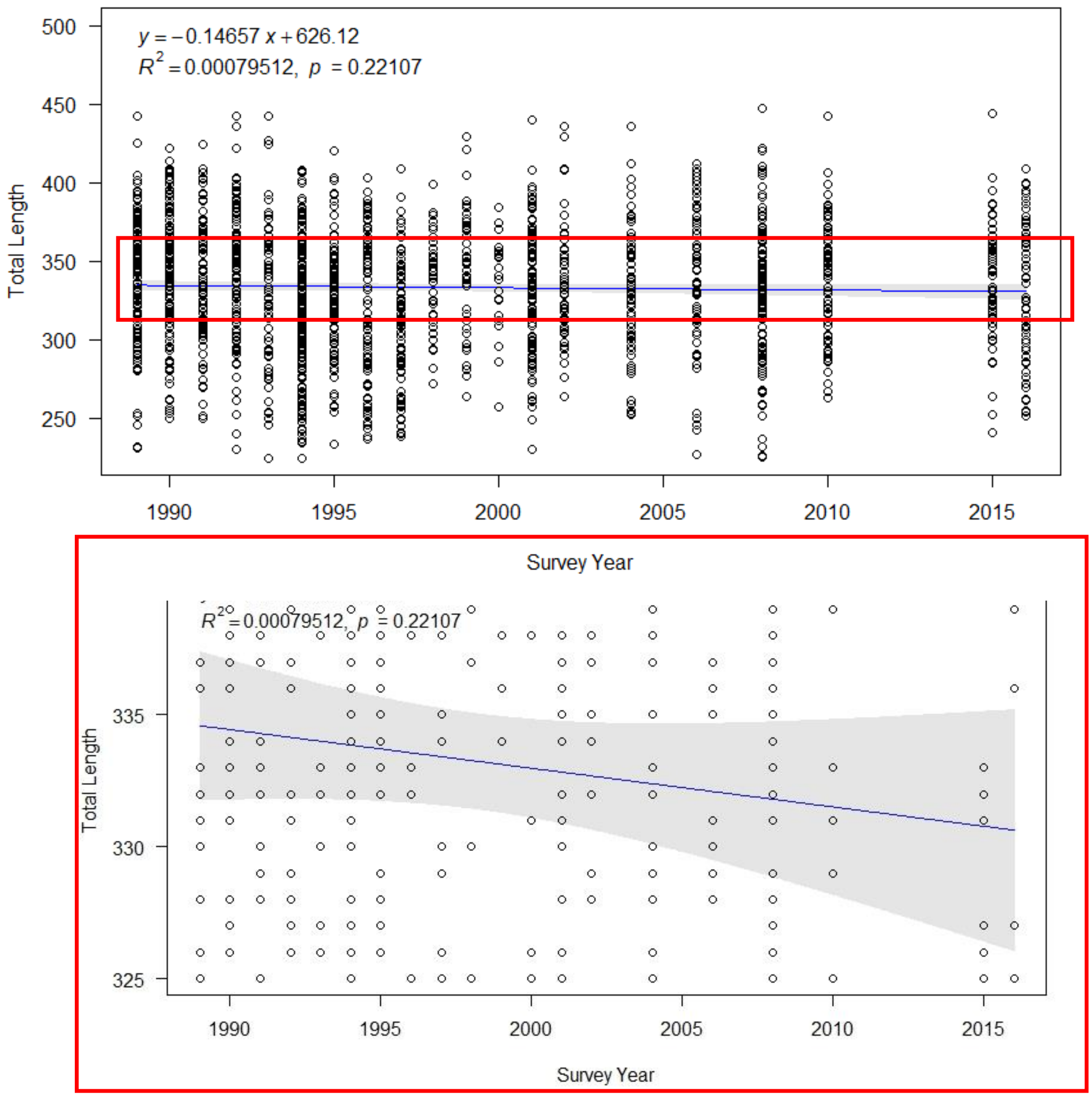
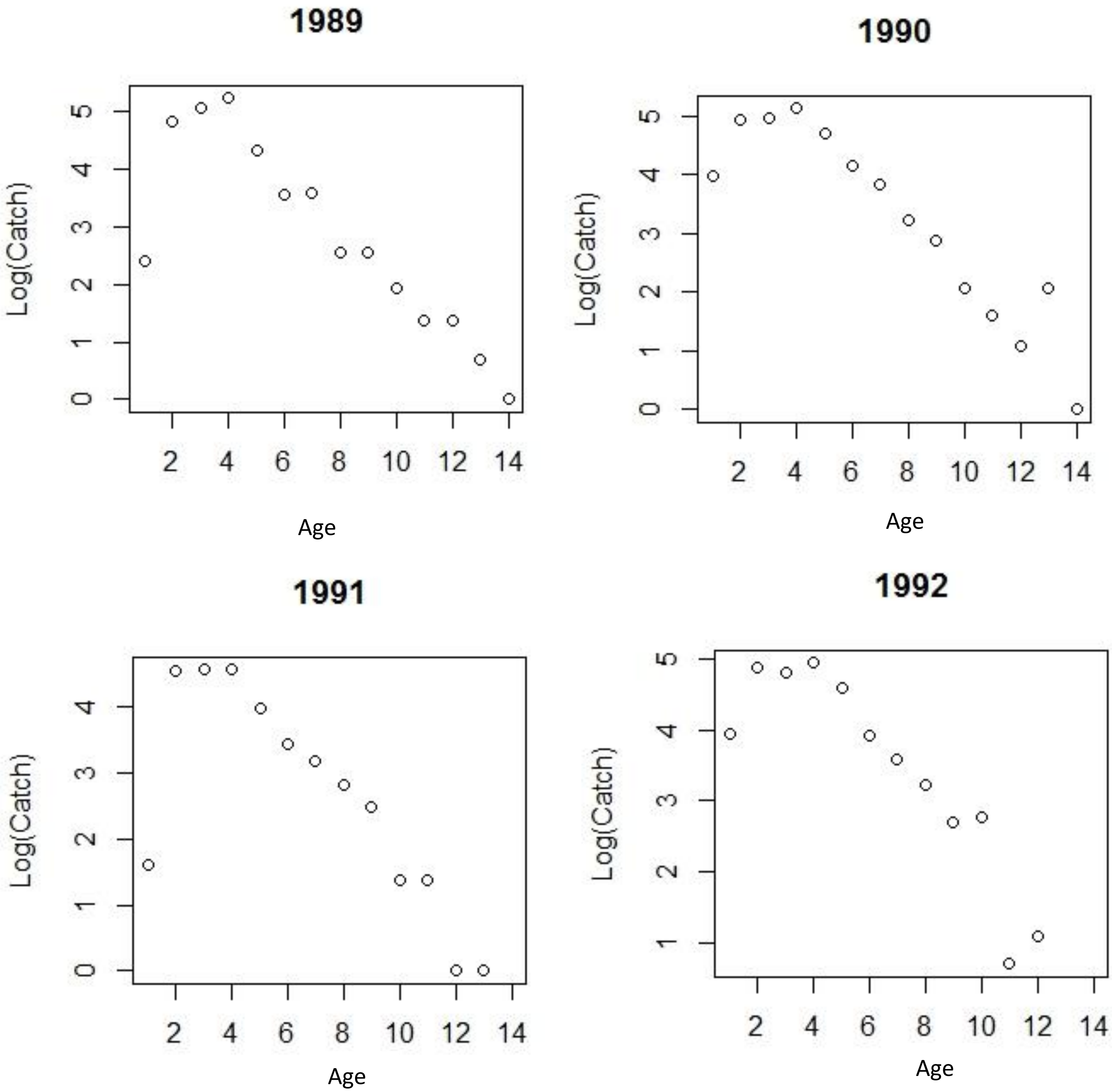
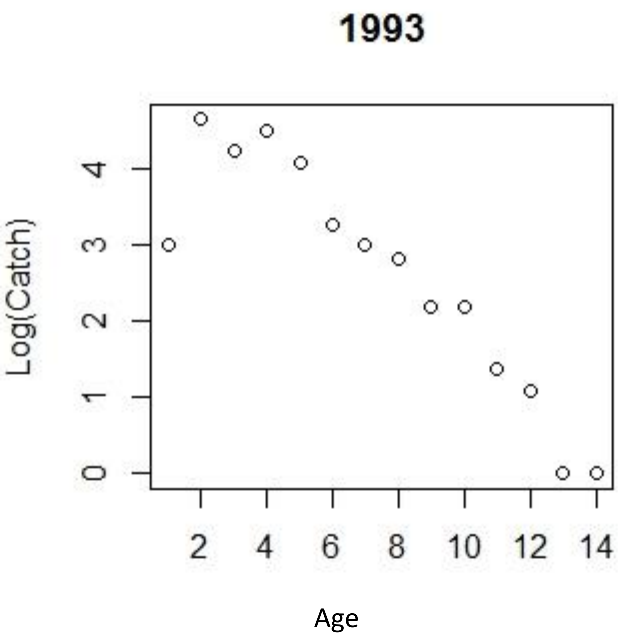
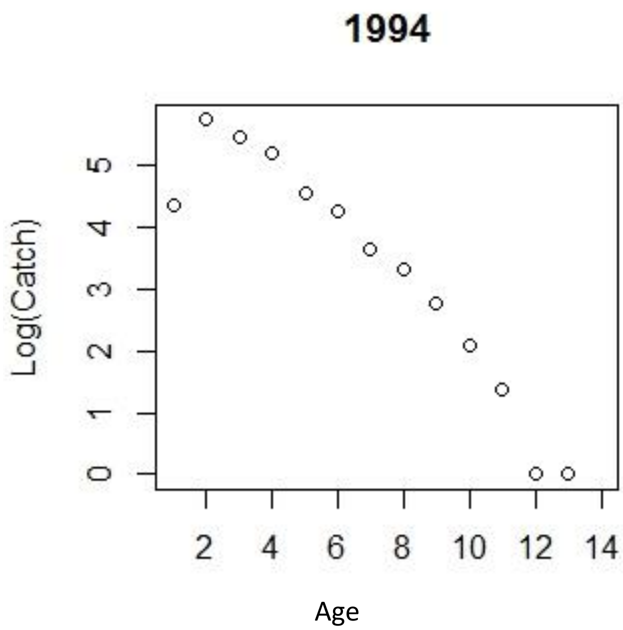


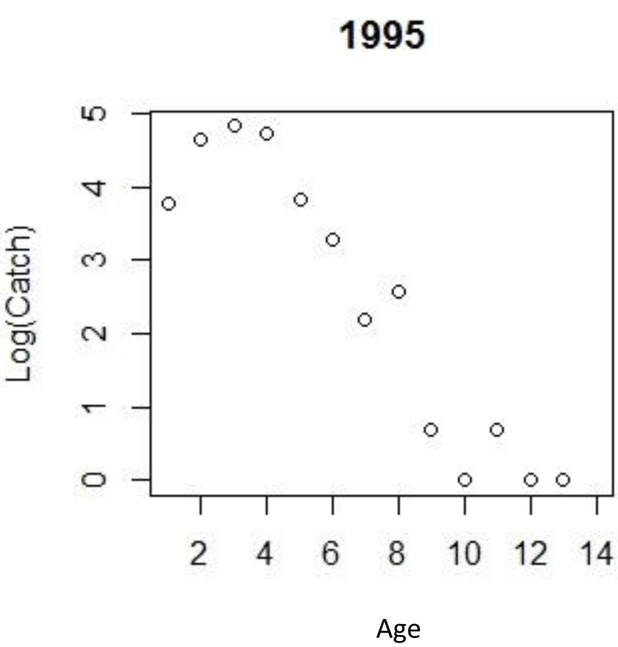
Figure 5. Simple linear regression plot of age-3 Largemouth Bass captured from Jordan Lake between 1989-2016. Area expanded to show slope.

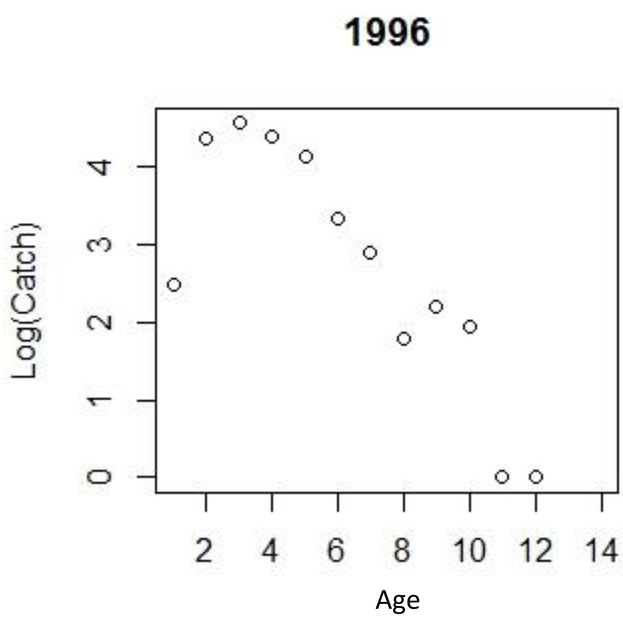
Appendix A: Log normalized catch curves for Jordan Lake Largemouth Bass from NCWRC population surveys between 1989 and 2016.

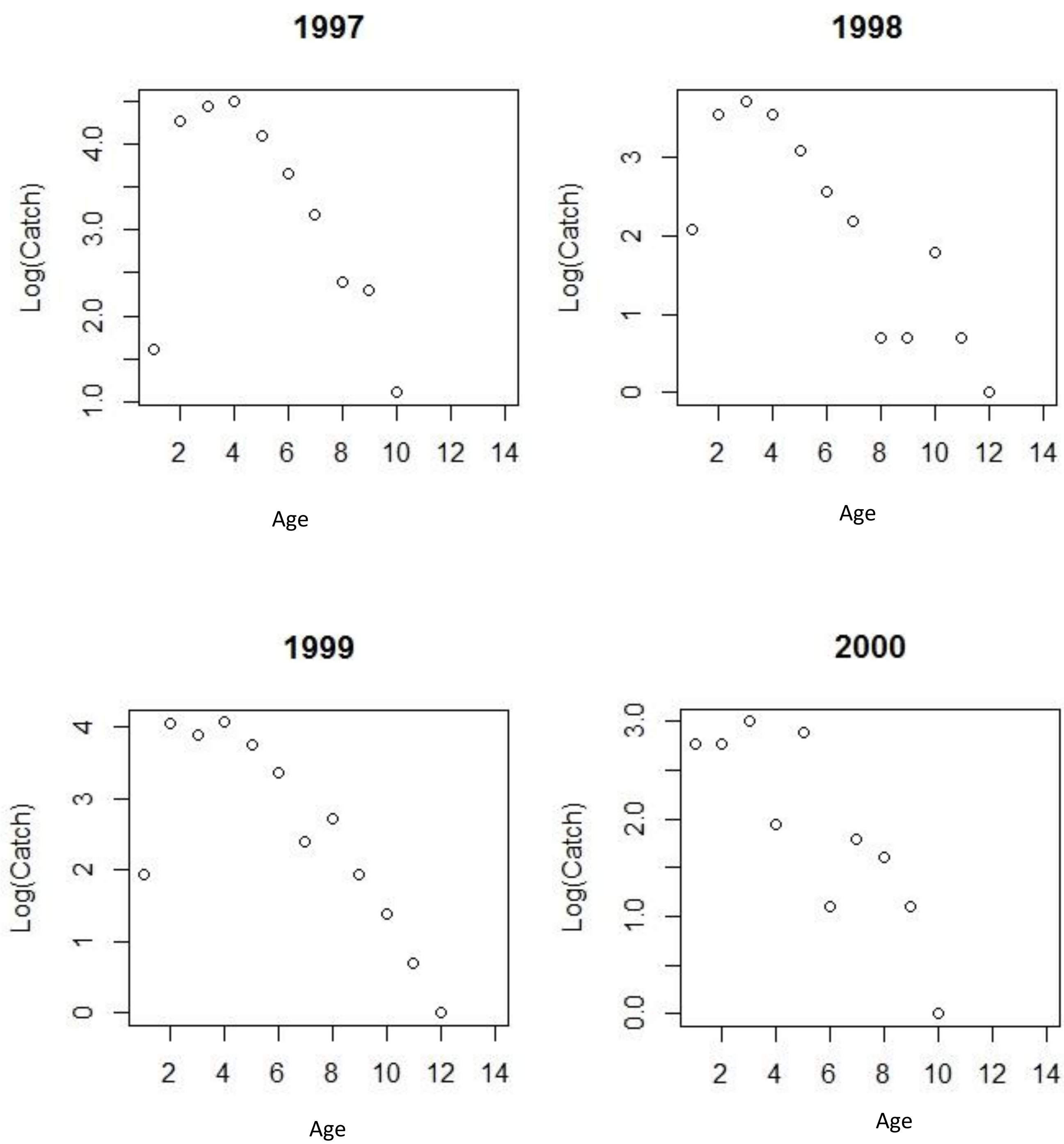


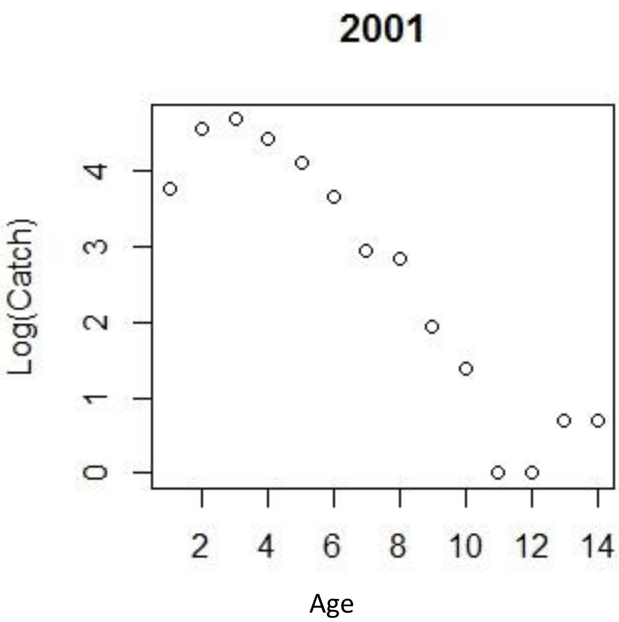

1993
Log(Catch)
0
1
2
3
4
2
4
6
8
10
12
14
Age

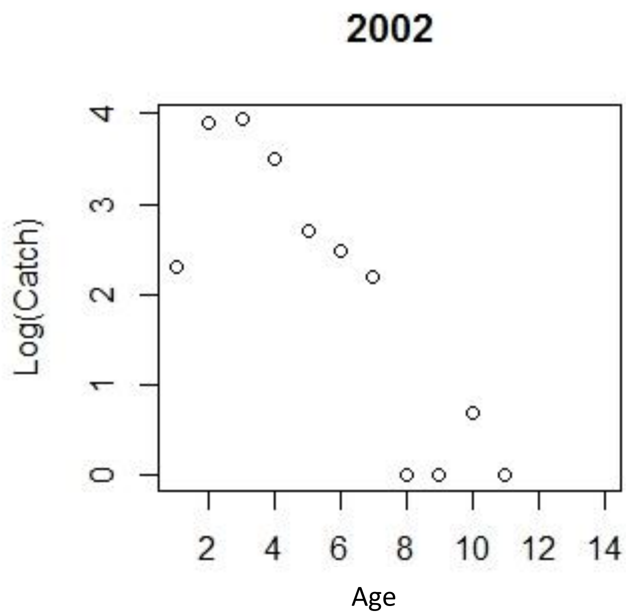

1994
Log(Catch)
0
1
2
3
4
5
2
4
6
8
10
12
14
Age


1995
Log(Catch)
0
1
2
3
4
5
2
4
6
8
10
12
14
Age


1996
Log(Catch)
0
1
2
3
4
2
4
6
8
10
12
14
Age


1997
Log(Catch)
1.0
2.0
3.0
4.0
2
4
6
8
10
12
14
Age
1998
Log(Catch)
0
1
2
3
2
4
6
8
10
12
14
Age
1999
Log(Catch)
0
1
2
3
4
2
4
6
8
10
12
14
Age
2000
Log(Catch)
0.0
1.0
2.0
3.0
2
4
6
8
10
12
14
Age


2001
Log(Catch)
0
1
2
3
4
2
4
6
8
10
12
14
Age


2002
Log(Catch)
0
1
2
3
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2
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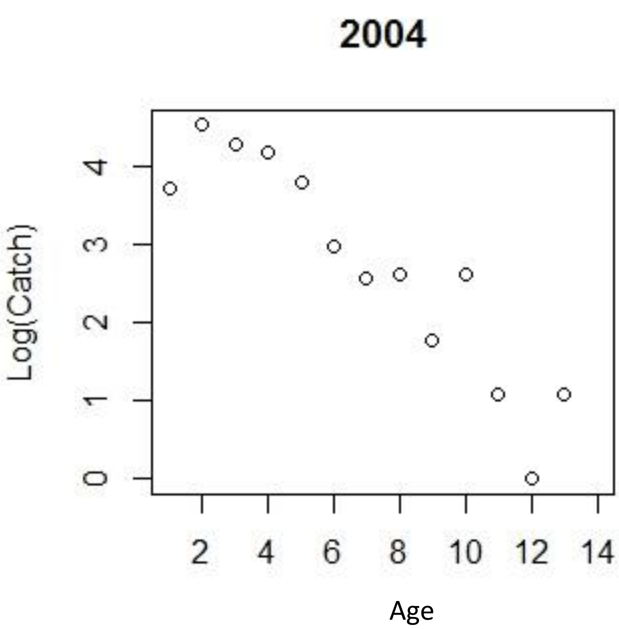
6
8
10
12
14
Age


2004
Log(Catch)
0
1
2
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2
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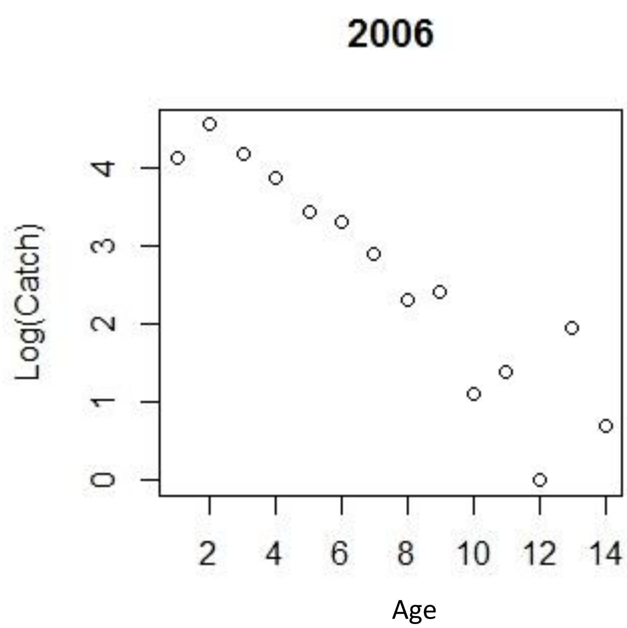
14
Age


2006
Log(Catch)
0
1
2
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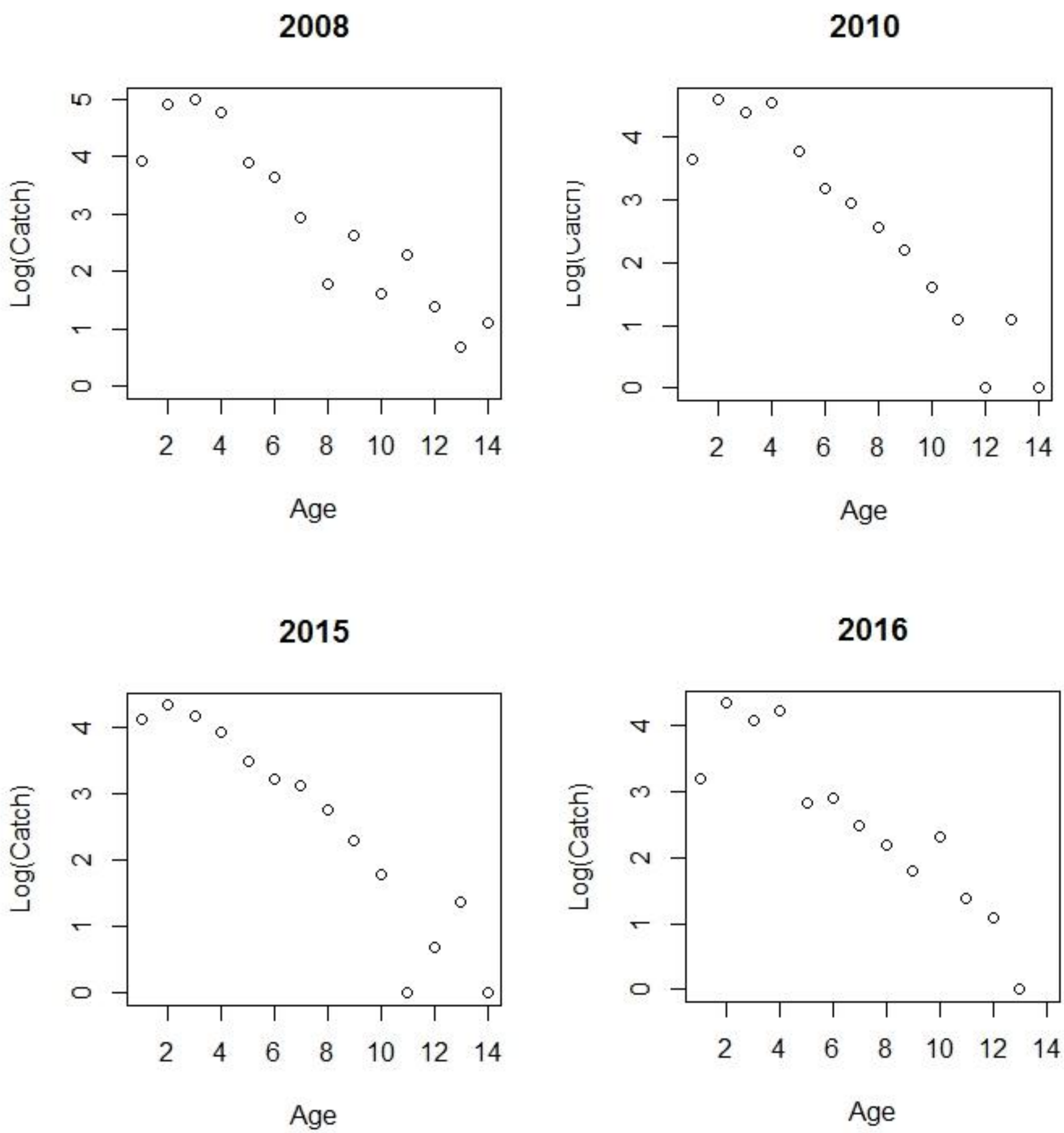
Age


2008
2010
2015
2016
Log(Catch)
Age
0
1
2
3
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5
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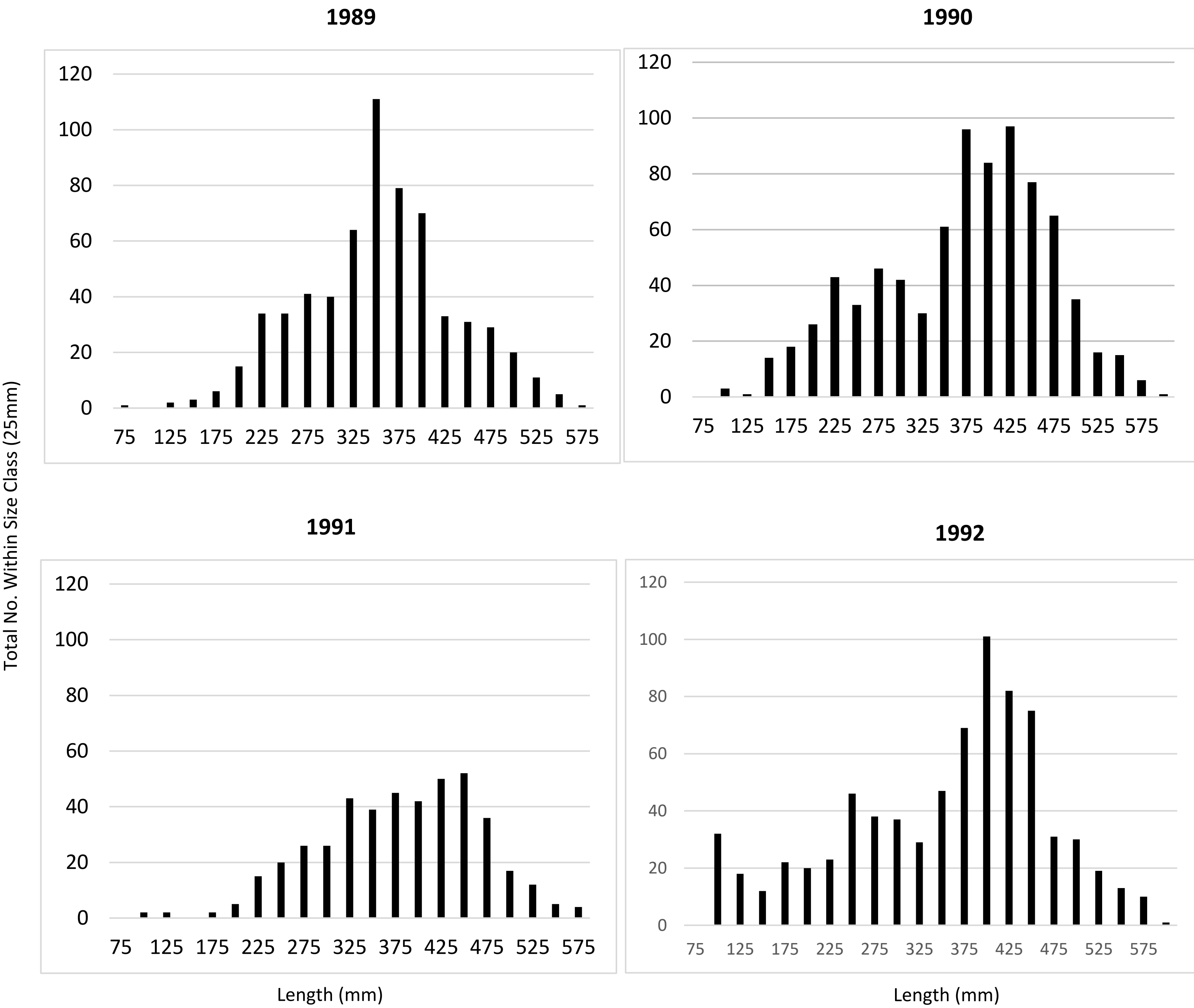
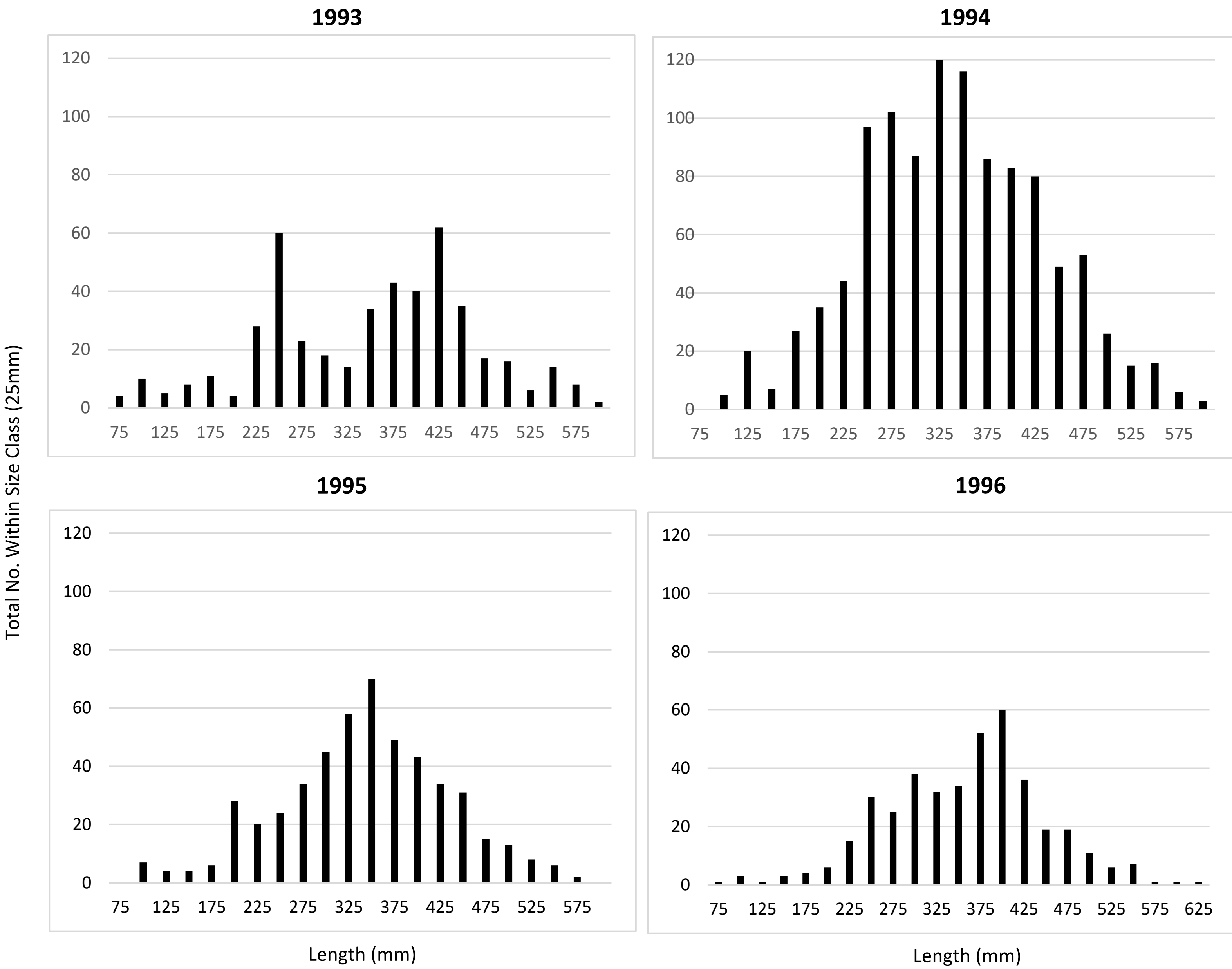
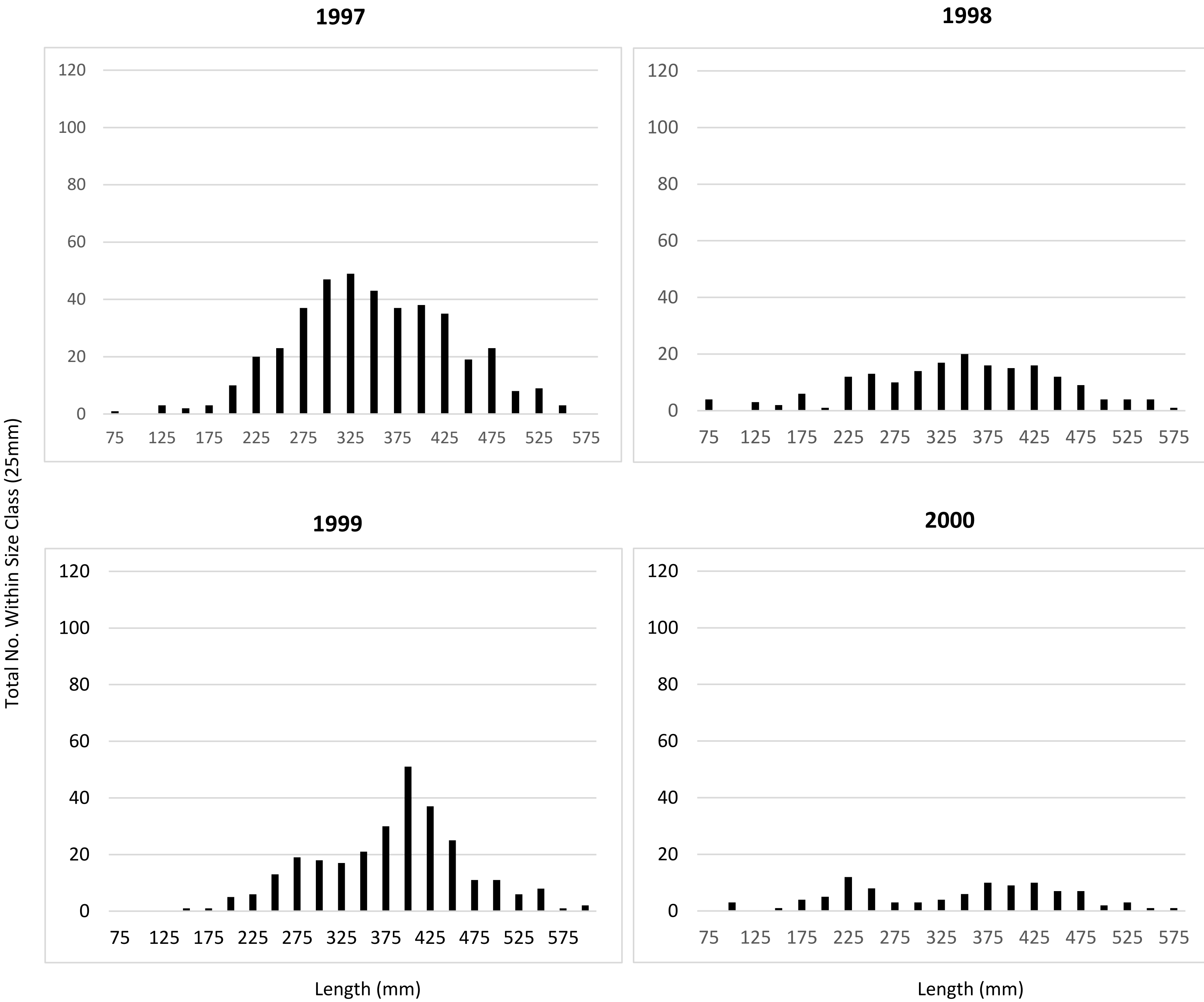
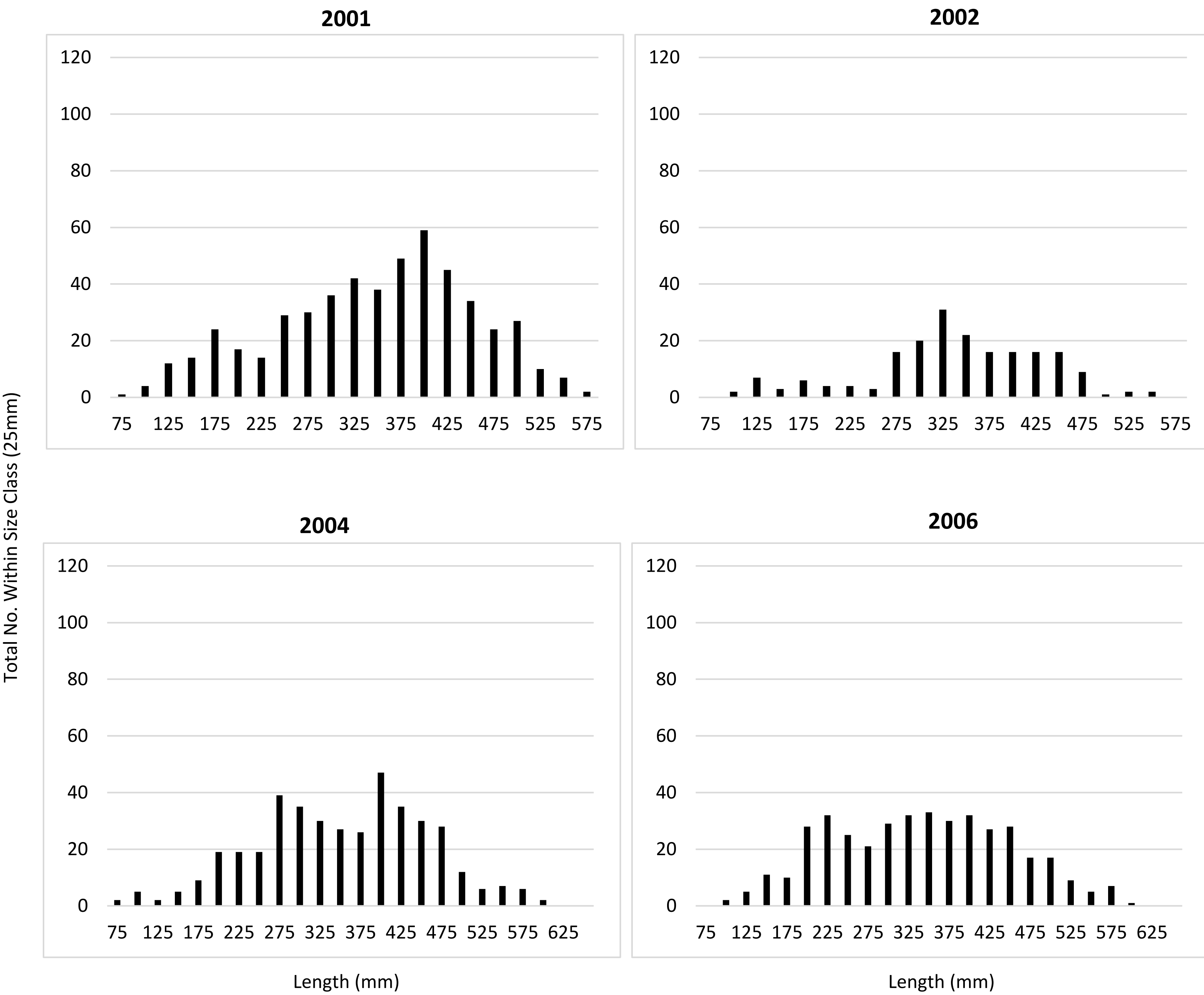
12
14

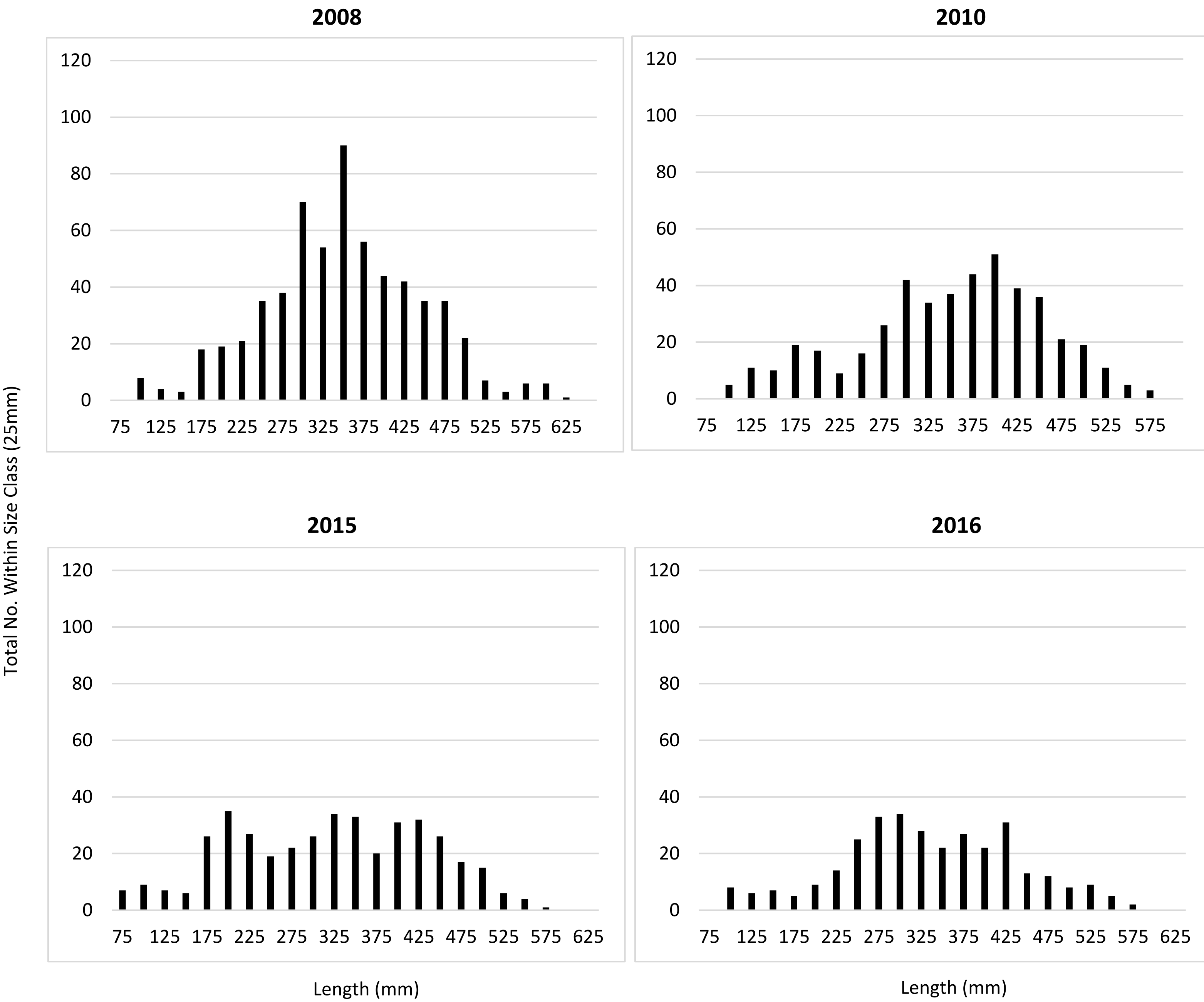
Appendix B: Length-Frequency (mm) size structure plots for Jordan Lake Largemouth Bass per survey year between 1989 and 2016.




1993
1994
1995
1996
Total No. Within Size Class (25mm)
Length (mm)
Length (mm)
0
20
40
60
80
100
120
75
125
175
225
275
325
375
425
475
525
575
625


1997
1998
1999
2000
Total No. Within Size Class (25mm)
120
100
80
60
40
20
0
75 125 175 225 275 325 375 425 475 525 575
Length (mm)
Length (mm)


2001
2002
2004
2006
Total No. Within Size Class (25mm)
Length (mm)
Length (mm)



2008
2010
2015
2016
120
100
80
60
40
20
0
75 125 175 225 275 325 375 425 475 525 575 625
75 125 175 225 275 325 375 425 475 525 575
Total No. Within Size Class (25mm)
Length (mm)