# Bitter Lake

## Site Description

### Location
| | |
|---|---|
| Water designation number (WDN) | 22-0016-00 |
| Legal description | T121N-R54W-Sec. 8-10, 15-17, 20-23, 27-29, 33, 34 |
| County (ies) | Day |
| Location from nearest town | 0.5 miles south of Waubay, SD |

### Survey Dates and Netting Information
| | |
|---|---|
| Survey dates | August 25-26, 2015 (FN, GN) |
| | September 16, 2015 (EF-WAE) |
| Gill net sets (n) | 8 |
| Electrofishing-WAE (min) | 60 |

### Morphometry (Figure 1)
| | |
|---|---|
| Watershed area (acres) | 38,894 |
| Surface area (acres) | >15,000 |
| Maximum depth (ft) | ≈30 |
| Mean depth (ft) | unknown |

### Ownership and Public Access
Bitter Lake is a meandered lake owned by the State of South Dakota and the fishery is managed by SDGFP.  Three public access sites are located on Bitter Lake.  Two are maintained by SDGFP;  the first located on the east shore off Day Co. Highway 1 includes a large parking area, double-lane concrete boat ramp, and dock; while the other located on the west shore off 442nd Avenue includes a smaller gravel parking lot, concrete-plank boat ramp, and dock (Figure 1; Figure 2).  The third access, which is privately owned, is located near the Bitter Lake Lodge on the lakes northeast shore.

### Watershed and Land Use
Land use within the Waubay Lakes (HUC-10) watershed is primarily agricultural including cropland, pasture or grassland, and small wooded areas (e.g., shelterbelts).  Additionally, a portion of the City of Waubay lies within the watershed.

### Water Level Observations
No OHWM has been established by the South Dakota Water Management Board on Bitter Lake. On April 21, 2015 the elevation was 1802.2 fmsl; 0.1 ft above the fall 2014 elevation of 1802.1 fmsl.  The water level had declined to an elevation of 1801.7 fmsl on October 20, 2015.

### Fish Management Information
| | |
|---|---|
| Primary species | walleye, yellow perch |
| Other species | black bullhead, black crappie, common carp, northern pike, rock bass, spottail shiner, white bass, white sucker |
| Lake-specific regulations | walleye:  minimum length 15" |
| Management classification | warm-water permanent |
| Fish consumption advisories | Mercury:  walleye (all sizes); northern pike (> 30").  See the South Dakota fishing handbook for more details on meal and portion size recommendations. Also see Department of Health website:  http://doh.sd.gov/Fish/Default.aspx for more information. |
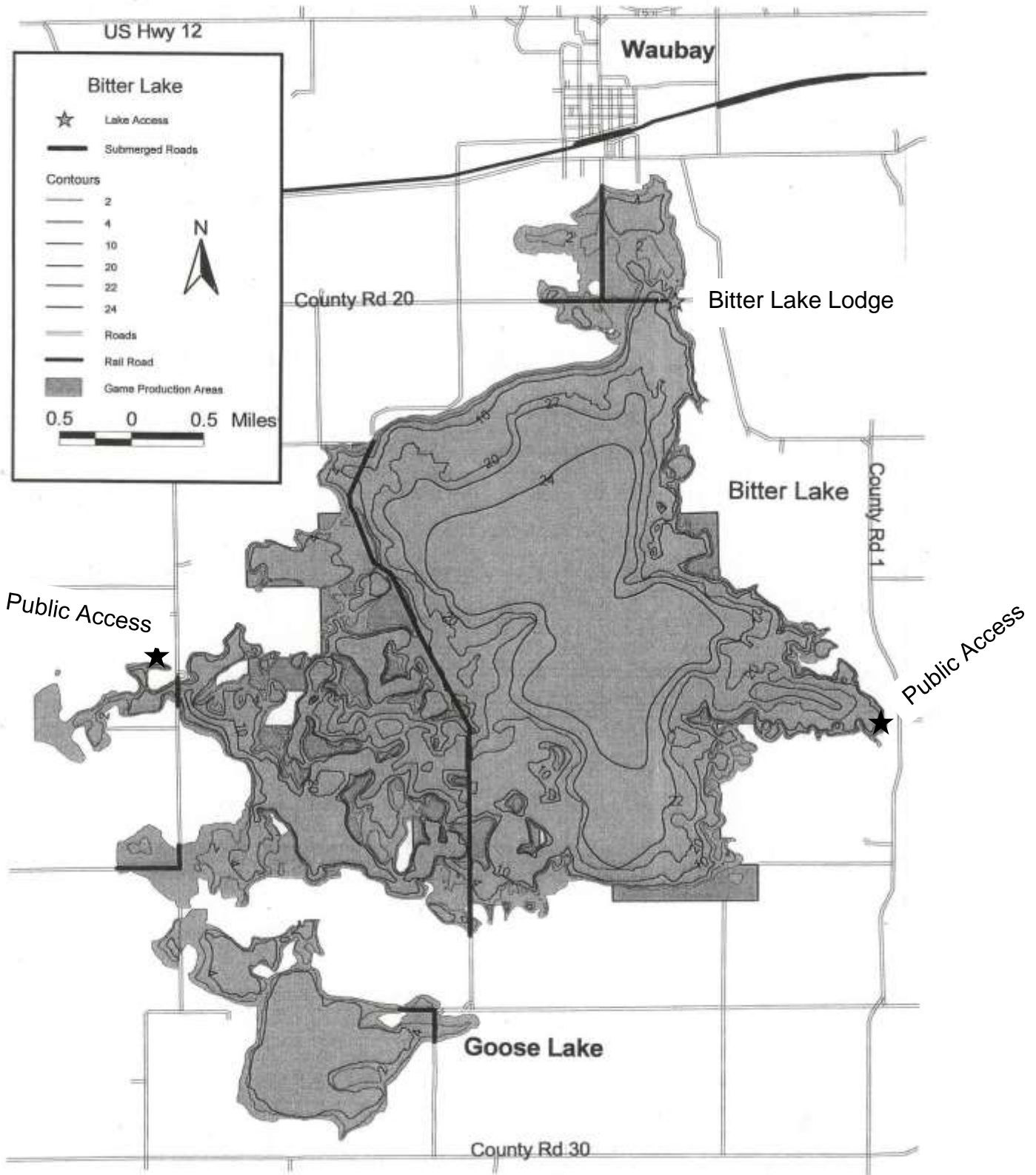
Figure 1.  Bitter Lake, Day County, South Dakota contour map.

Figure 2. Map depicting geographic location of Bitter Lake from Waubay, Day County, South Dakota. Also noted are public access and standardized net locations for Bitter Lake. BFN=frame nets; BGN=gill nets

# Management Objectives

1) Maintain a mean gill net CPUE of stock-length walleye ≥ 10, a PSD of 30-60, and a PSD-P of 5-10.

2) Maintain a mean gill net CPUE of stock-length yellow perch ≥ 30, a PSD of 30-60, and a PSD-P of 5-10

# Results and Discussion

Bitter Lake is a natural lake located south of Waubay, South Dakota in northeast South Dakota. Prior to the 1990's, Bitter Lake was a 3,000 acre alkaline slough with an approximate depth of 3 ft. High water conditions since the mid to late 1990's have increased the water depth and surface area of Bitter Lake. Currently, Bitter Lake covers in excess of 15,000 acres and is managed as a walleye and yellow perch fishery.

*Primary Species*

Walleye: The mean gill net CPUE of stock-length walleye was 41.3 (Table 1) and above the minimum objective (≥ 10 stock-length walleye/net night; Table 3). Since 2006, the mean gill net CPUE has ranged from a low of 9.1 (2008) to a high of 50.6 (2010; Table 2). Currently, relative abundance is high.

Gill net captured walleye ranged in TL from 11 to 60 cm (4.3 to 23.6 in), had a PSD of 14 and a PSD-P of 1 (Table 1; Figure 3). The PSD and PSD-P were both below the management objectives (defined as PSD of 30-60 and a PSD-P of 5-10; Table 3; Figure 3). Approximately 12% of walleye in the gill net catch were above the 381-mm (15-in) minimum length restriction (Figure 3).

Otoliths collected from a sub-sample of gill net captured walleye revealed the presence of eight year classes (2005-2006, 2009 and 2011-2015; Table 4). The naturally-produced 2011 year class was the most represented and comprised 84% of walleye in the gill net catch (Table 4; Table 6). Decline in PSD values in recent years (i.e., 2012-2015) can be attributed to growth of the strong 2011 cohort into the stock-quality length category coupled with a decrease in the number of individuals being sampled from the strong 2009 year class (Table 4; Table 5; Figure 3). In 2015, few age-0 walleye were captured by gill nets or during fall night electrofishing, which suggests that only a weak cohort was produced (Table 1; Table 4).

Historically, walleye in Bitter Lake exhibited fast growth and easily surpassed quality-length (38 cm; 15 in) by age-3 from 2006-2012 (Table 5). From 2006-2012, weighted mean TL at capture values of age-3 walleye ranged from 410 to 464 mm (16.1 to 18.3 in; Table 5). Unfortunately, limited prey fish production (e.g., yellow perch, white bass, etc.) in conjunction with the presence of the strong 2011 year class, which currently dominates the population, has resulted in slower growth. Weighted mean TL at capture values for the 2011 year class were 252, 275, and 322 mm (9.9, 10.8 and 12.7 in) at ages 1-3, respectively (Table 5). For comparison, the equally strong 2009

cohort had weighted mean TL capture values of 307, 397, and 446 mm (12.1, 15.6, and 17.6 in) at those same ages (i.e., 1-3; Table 5).  Gill net captured walleye had mean Wr values that ranged from 72 to 99 for all 10-mm length groups represented.  A decreasing trend in condition was apparent as TL increased.  Walleye from the strong 2011 cohort, which were in the stock-quality length category, had a mean Wr of 89.

      Yellow Perch:  The mean gill net CPUE of stock-length yellow perch was 8.3 (Table 1) and below the minimum objective (≥ 30 stock-length perch/net night; Table 3).  Since 2006, mean gill net CPUE values have ranged from a low of 2.6 (2007) to a high of 67.3 (2012; Table 2).  Based on the 2015 gill net CPUE, relative abundance appears to be moderate.

      Gill net captured yellow perch ranged in TL from 12 to 34 cm (4.7 to 13.4 in; Figure 4).  The PSD was 40 and the PSD-P was 21 (Table 1).  The PSD was within the management objective of 30-60 and PSD-P exceeded management objective of 5-10, (Table 1; Table 3; Figure 4).

      Otoliths were collected from a sub-sample of gill net captured yellow perch.  Age structure information suggested the presence of seven consecutive year classes (2009-2015; Table 7).  Year classes produced in 2013 and 2014 were the most abundant and collectively comprised approximately 67% of yellow perch in the gill net catch (Table 7).  Limited recruitment in recent years coupled with angling and natural mortality of older cohorts, primarily 2009 and 2011, has resulted in decreased relative abundance and decreased PSD and PSD-P (Table 3; Figure 4).

      Yellow perch in Bitter Lake display fast growth and typically approach or surpass quality-length (20 cm; 8 in) by age 2 (Table 8).  Since 2009, weighted mean TL at capture values for age-2 yellow perch have ranged from 194 to 257 mm (7.6  to 10.1 in); while the weighted mean TL at capture for age-3 fish has ranged from 239  to 292 mm (9.4  to 11.5 in; Table 8).  In 2015, the weighted mean TL at capture for age-2 and age-3 yellow perch was 194 and 245 mm (7.6 and 9.6 in), respectively (Table 8).  Condition of gill net captured yellow perch was high with mean Wr values > 103 for all length categories (e.g., stock to quality) sampled and no length related trend in Wr was observed.


*Other Species*

      Northern Pike:  The mean gill net CPUE of stock-length northern pike was 1.5 (Table 1).  The 2015 gill net CPUE was the same as the 2014 CPUE of 1.5 (Table 2) indicating moderate relative abundance.

      Northern pike captured in the gill net sample ranged in TL from 54 to 77 cm (21.3 to 30.3  in), had  a PSD of 100 and a PSD-P of 33 (Table 1; Figure 5).  No age or growth information was collected.  The mean Wr of stock-length northern pike was 78 (Table 1).

      Other:  Common carp and white bass were captured in low numbers during the 2015 fish community survey on Bitter Lake (Table 1).

**Management Recommendations**

1) Conduct fish population assessment surveys utilizing gill nets on an annual basis (next survey scheduled in summer 2016) to monitor fish relative abundance, fish population size structures, fish growth, and stocking success.

2) Conduct fall night electrofishing on an annual basis to monitor age-0 walleye relative abundance.

3) Collect otoliths from walleye and yellow perch to assess age structure and growth rates of each population.

4) Stock walleye (≈500 fry/acre) to establish additional year-classes if gill netting and/or fall night electrofishing CPUE of age-0 walleye results warrant [i.e., low gill net CPUE of sub-stock (< 25 cm; 10 in) walleye and/or fall night electrofishing CPUE of age-0 walleye < 75 fish/hour].

5) Remove the 381-mm (15 in) minimum length limit on walleye.  Growth has slowed in recent years and no longer meet criteria set forth in the South Dakota Walleye Toolbox (Lucchesi and Blackwell 2009).

Table 1.  Mean catch rate (CPUE; gill nets = catch/net night, electrofishing = catch/hour) of stock-length fish, proportional size distribution of quality- (PSD) and preferred-length (PSD-P) fish, and mean relative weight (Wr) of stock-length fish for various fish species captured in experimental gill nets and electrofishing in Bitter Lake, 2015.  Confidence intervals include 80 percent (± CI-80) or 90 percent (± CI-90).  COC= common carp; NOP= northern pike; WAE= walleye; WHB= white bass; YEP= yellow perch

| Species | Abundance | | Stock Density Indices | | | | Condition | |
|---|---|---|---|---|---|---|---|---|
| | CPUE | CI-80 | PSD | CI-90 | PSD-P | CI-90 | Wr | CI-90 |
| *Gill nets* | | | | | | | | |
| COC | 0.1 | 0.2 | 100 | --- | 100 | --- | 120 | --- |
| NOP | 1.5 | 0.6 | 100 | 0 | 33 | 26 | 78 | 4 |
| WAE | 41.3 | 2.8 | 14 | 4 | 1 | 1 | 89 | 0 |
| WHB | 0.5 | 0.5 | 100 | 0 | 100 | 0 | 108 | 2 |
| YEP | 8.3 | 3.3 | 40 | 10 | 21 | 8 | 111 | 1 |
| *Electrofishing* | | | | | | | | |
| WAE[1] | 2.0 | --- | --- | --- | --- | --- | --- | --- |

[1] Fall night electrofishing-WAE; catch rate (CPUE) represents age-0 walleye/hour


Table 2.  Historic mean catch rate (CPUE; gill nets = catch/net night, electrofishing = catch/hour) of stock-length fish for various fish species captured using experimental gill nets and electrofishing in Bitter Lake, 2006-2015.  BLB= black bullhead; BLC= black crappie; COC= common carp; NOP= northern pike; ROB= rock bass; SPS=spottail shiner; WAE= walleye; WHB= white bass; WHS=white sucker; YEP= yellow perch

| Species | CPUE | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2006[3] | 2007[3] | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
| *Frame nets* | | | | | | | | | | |
| BLB | --- | --- | --- | --- | --- | --- | --- | 0.2 | --- | --- |
| COC | --- | --- | --- | --- | --- | --- | --- | 1.4 | --- | --- |
| NOP | --- | --- | --- | --- | --- | --- | --- | 2.3 | --- | --- |
| WAE | --- | --- | --- | --- | --- | --- | --- | 5.7 | --- | --- |
| WHB | --- | --- | --- | --- | --- | --- | --- | 0.2 | --- | --- |
| YEP | --- | --- | --- | --- | --- | --- | --- | 0.2 | --- | --- |
| *Gill nets* | | | | | | | | | | |
| BLC | 0.1 | 0.0 | 0.0 | 0.0 | 0.1 | 0.5 | 0.0 | 0.0 | 0.0 | 0.0 |
| COC | 0.0 | 0.3 | 0.1 | 0.0 | 0.3 | 1.4 | 0.1 | 0.0 | 1.4 | 0.1 |
| NOP | 0.8 | 0.3 | 0.4 | 0.5 | 1.0 | 1.5 | 5.0 | 4.1 | 1.5 | 1.5 |
| ROB | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 | 0.0 | 0.0 |
| SPS [1] | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| WAE | 31.8 | 16.9 | 9.1 | 11.0 | 50.6 | 20.1 | 19.8 | 18.0 | 38.8 | 41.3 |
| WHB | 0.0 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 | 1.9 | 0.5 |
| WHS | 0.0 | 0.0 | 0.0 | 0.3 | 0.3 | 0.3 | 0.0 | 0.4 | 0.0 | 0.0 |
| YEP | 11.8 | 2.6 | 4.1 | 20.8 | 25.9 | 39.0 | 67.3 | 21.4 | 5.8 | 8.3 |
| *Electrofishing* | | | | | | | | | | |
| WAE[2] | 0.0 | 440.0 | 136.9 | 294.0 | 0.0 | 377.0 | 36.0 | 34.0 | 9.6 | 2.0 |

[1] All fish sizes.
[2] Fall night electrofishing-WAE; catch rate (CPUE) represents age-0 walleye/hour
[3] Monofilament gill net mesh size change (0.75", 1.00", 1.25", 1.50", 2.00" and 2.50")

Table 3.  Mean catch rate (CPUE; gill nets = catch/net night) of stock-length fish, proportional size distribution of quality- (PSD) and preferred-length (PSD-P) fish, and mean relative weight (Wr) of stock-length fish for selected species captured in experimental gill nets from Bitter Lake, 2006-2015.  WAE= walleye; YEP= yellow perch

| Species | 2006[1] | 2007[1] | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | Objective |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Gill nets* | | | | | | | | | | | |
| WAE | | | | | | | | | | | |
| CPUE | 32 | 17 | 9 | 11 | 51 | 20 | 20 | 18 | 39 | 41 | ≥ 10 |
| PSD | 50 | 91 | 81 | 24 | 19 | 76 | 58 | 30 | 8 | 14 | 30-60 |
| PSD-P | 8 | 10 | 8 | 2 | 3 | 4 | 4 | 6 | 3 | 1 | 5-10 |
| Wr | 96 | 90 | 92 | 94 | 102 | 93 | 86 | 83 | 91 | 89 | --- |
| YEP | | | | | | | | | | | |
| CPUE | 12 | 3 | 4 | 21 | 26 | 39 | 67 | 21 | 6 | 8 | ≥ 30 |
| PSD | 64 | 86 | 42 | 34 | 29 | 84 | 59 | 78 | 80 | 40 | 30-60 |
| PSD-P | 49 | 29 | 24 | 13 | 22 | 14 | 40 | 49 | 48 | 21 | 5-10 |
| Wr | 97 | 114 | 114 | 116 | 106 | 110 | 105 | 110 | 111 | 111 | --- |

[1] Monofilament gill net mesh size change (0.75", 1.00", 1.25", 1.50", 2.00" and 2.50")


Table 4.  Year class distribution based on the expanded age/length summary for walleye sampled in gill nets and associated stocking history (# stocked x 10,000) from Bitter Lake, 2011-2015.

| Survey Year | Year Class 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2009 | 2008 | 2007 | 2006 | 2005 | 2004 | 2003 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2015 | 7 | 18 | 15 | 10 | 297 | | 6 | | | | 1 | 1 | | |
| 2014 | --- | 12 | 18 | 13 | 280 | 2 | 12 | 1 | | 1 | 1 | | | 1 |
| 2013 | --- | --- | 3 | 3 | 102 | 3 | 33 | 3 | 1 | | 2 | | 1 | 1 |
| 2012[1] | --- | --- | --- | 8 | 107 | 15 | 73 | 4 | | | 2 | | | |
| 2011[1] | --- | --- | --- | --- | 108 | 6 | 137 | 11 | 1 | | 2 | | | 1 |
| # stocked | | | | | | | | | | | | | | |
| fry | 400 | | 750 | | | | | | 1000 | | 905 | | | |
| sm. fingerling | | | | | | | | | | | | | | |
| lg. fingerling | | | | | | | | | | | | | | |

[1] Older walleye were sampled, but are not reported in this table.

Table 5.  Weighted mean TL (mm) at capture for walleye age-0 through age-10 sampled in experimental gill nets (expanded sample size) from Bitter Lake, 2006-2015.  Note: sampling was conducted at approximately the same time during each year allowing comparisons among years to monitor growth trends.

| | Age | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 2015 | 129(7) | 228(18) | 289(15) | 315(10) | 356(297) | --- | 479(6) | --- | --- | 606(1) | 538(1) |
| 2014[1] | 120(12) | 202(18) | 255(13) | 322(280) | 417(2) | 486(12) | 575(1) | --- | 540(1) | 551(1) | --- |
| 2013[1] | 184(3) | 211(3) | 275(102) | 387(3) | 471(33) | 498(3) | 500(1) | --- | 529(2) | --- | 592(1) |
| 2012[1] | 139(8) | 252(107) | 387(15) | 446(73) | 527(4) | --- | --- | 592(2) | --- | --- | --- |
| 2011[1] | 155(108) | 312(6) | 397(137) | 464(11) | 473(1) | --- | 545(2) | --- | --- | 653(1) | 626(1) |
| 2010[1] | 185(5) | 307(326) | 406(42) | 443(16) | --- | 513(15) | --- | 561(1) | 543(3) | 635(1) | --- |
| 2009[1] | 133(123) | 287(53) | 358(15) | 458(3) | 474(13) | --- | --- | 484(1) | --- | 496(1) | 652(1) |
| 2008[1] | 130(28) | 271(19) | 357(1) | 431(50) | --- | --- | 509(4) | 510(2) | 495(1) | 598(1) | --- |
| 2007 | 170(1) | --- | 402(97) | --- | 466(3) | 497(14) | 484(6) | 504(4) | 455(1) | 599(3) | 544(6) |
| 2006 | 191(1) | 326(131) | 413(5) | 461(9) | 468(66) | --- | 490(31) | 509(5) | 584(3) | 442(4) | --- |

[1] Older walleye were sampled, but are not reported in this table.


Table 6.  Stocking history including size and number for fishes stocked into Bitter Lake, 2002-2015.  WAE= walleye

| Year | Species | Size | Number |
|---|---|---|---|
| 2005 | WAE | fry | 9,050,000 |
| 2007 | WAE | fry | 10,000,000 |
| 2013 | WAE | fry | 7,500,000 |
| 2015 | WAE | fry | 4,000,000 |


Table 7.  Year class distribution based on the age/length summary for yellow perch sampled in gill nets from Bitter Lake, 2011-2015.

| | Year Class | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Survey Year | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2009 | 2008 | 2007 |
| 2015 | 4 | 23 | 22 | 3 | 9 | 3 | 6 | | |
| 2014 | --- | | 8 | 3 | 19 | 7 | 10 | 1 | |
| 2013 | --- | --- | | 1 | 65 | 20 | 82 | 3 | |
| 2012 | --- | --- | --- | 9 | 240 | 53 | 251 | 12 | 2 |
| 2011 | --- | --- | --- | --- | 145 | 28 | 268 | 11 | 6 |

Table 8.  Weighted mean TL (mm) at capture for yellow perch captured in experimental gill nets (expanded sample size) from Bitter Lake, 2009-2015.

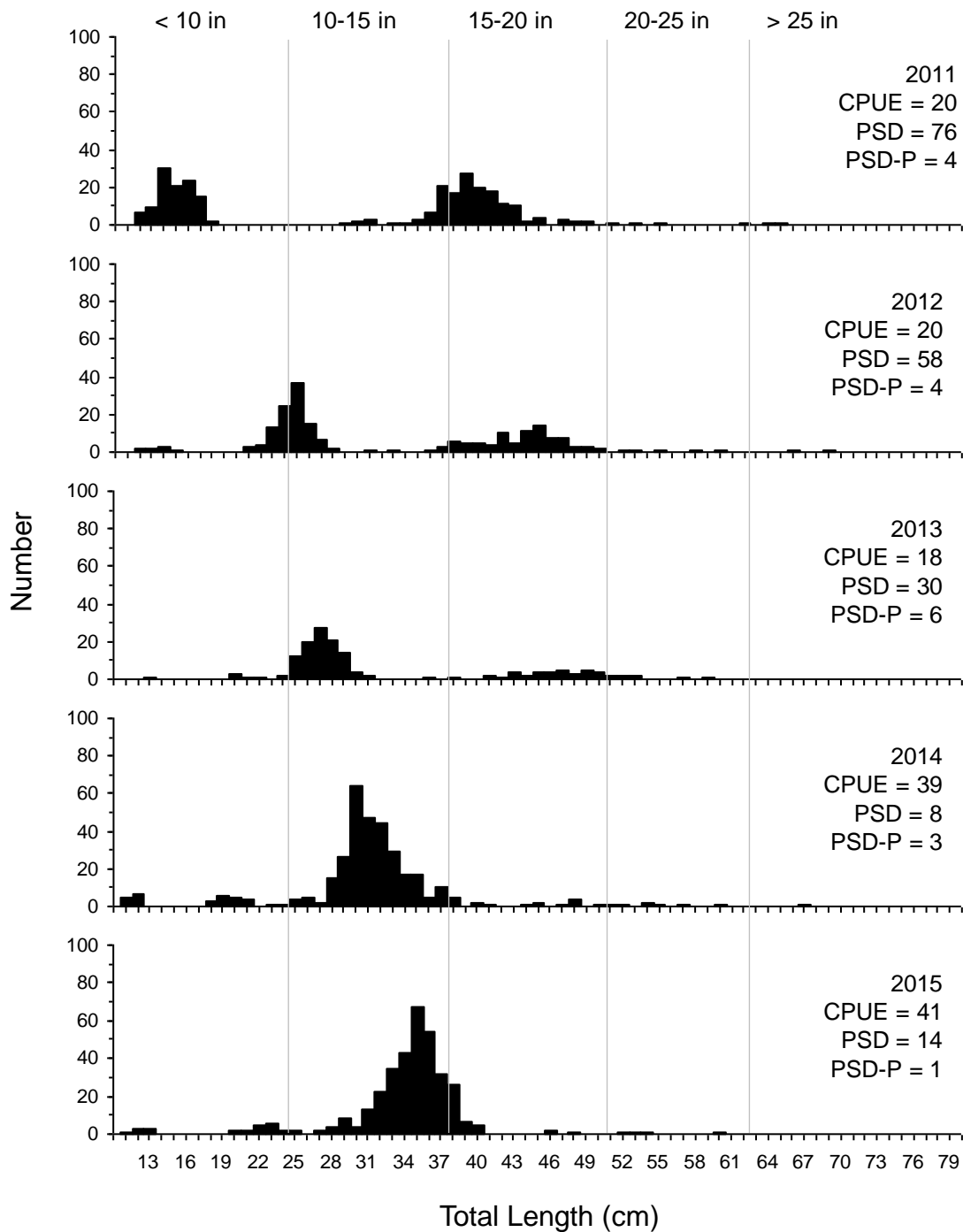| Year | Age | | | | | | |
|------|-----|-----|-----|-----|-----|-----|-----|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| 2015 | 139(4) | 140(23) | 194(22) | 245(3) | 248(9) | 303(3) | 312(6) |
| 2014 | --- | 135(8) | 195(3) | 239(19) | 263(7) | 302(10) | 313(1) |
| 2013 | --- | 147(1) | 200(65) | 267(20) | 268(82) | 289(3) | --- |
| 2012 | 126(9) | 153(240) | 226(53) | 264(251) | 303(12) | 338(2) | --- |
| 2011 | 98(145) | 172(28) | 227(268) | 292(11) | 323(6) | --- | --- |
| 2010 | --- | 172(152) | 257(48) | 286(8) | --- | --- | --- |
| 2009 | 92(36) | 172(108) | 238(55) | 264(2) | 266(2) | --- | --- |

Figure 3.  Length-frequency histogram, catch rate of stock-length fish (CPUE), proportional size distribution of quality- (PSD) and preferred-length (PSD-P) fish for walleye captured using experimental gill nets in Bitter Lake, 2011-2015.
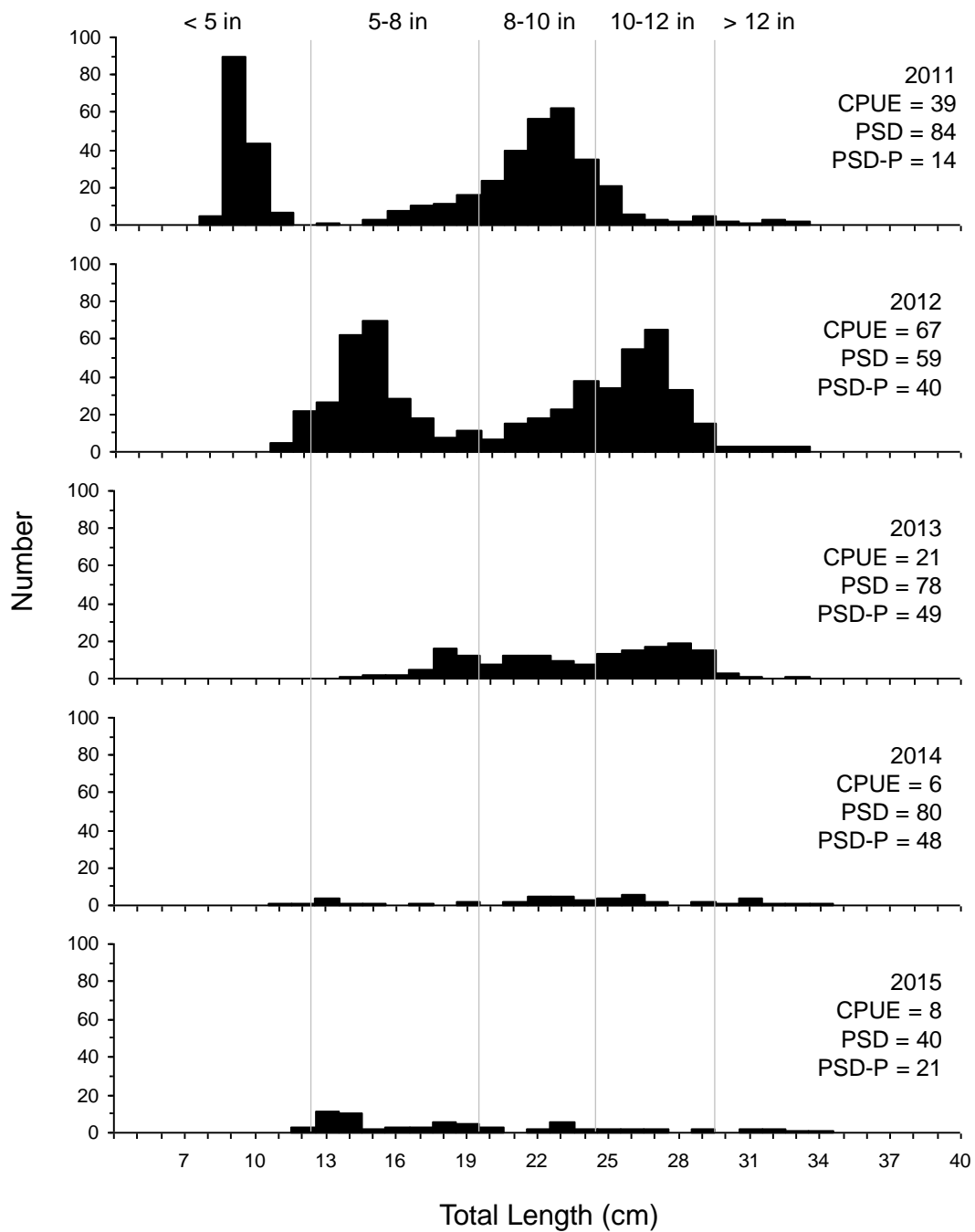
Figure 4. Length-frequency histogram, catch rate of stock-length fish (CPUE), proportional size distribution of quality- (PSD) and preferred-length (PSD-P) fish for yellow perch captured using experimental gill nets in Bitter Lake, 2011-2015.
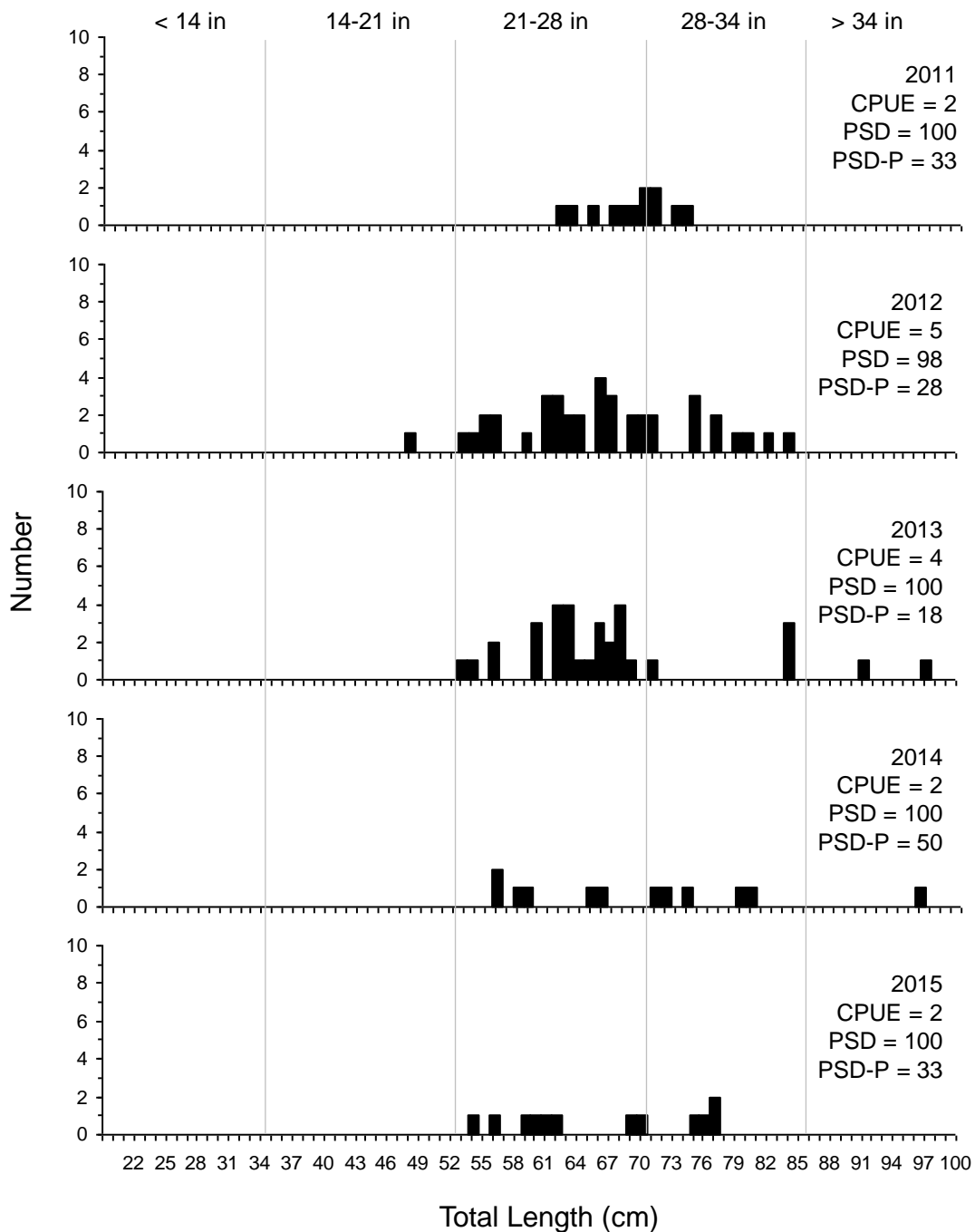
Figure 5. Length-frequency histogram, catch rate of stock-length fish (CPUE), proportional size distribution of quality- (PSD) and preferred-length (PSD-P) fish for northern pike captured using experimental gill nets in Bitter Lake, 2011-2015.