SPAWNING POPULATION CHARACTERISTICS OF ALEWIFE IN LAKE MATTAMUSKEET, 2015-2016

by

Cooper S. Butts

A Senior Honors Project Presented to the

Honors College

East Carolina University

In Partial Fulfillment of the

Requirements for

Graduation with Honors

by

Cooper S. Butts

Greenville, NC

May, 2022

Approved by:

Roger A. Rulifson, PhD

Department of Biology, Thomas Harriot College of Arts and Sciences

Abstract

Lake Mattamuskeet, a coastal lake draining to Pamlico Sound, is situated within Mattamuskeet National Wildlife Refuge in Hyde County, North Carolina. To prevent estuarine saltwater from entering the lake, water control structures have been placed in all four of the man-made outfall canals. These canals allow for the movement into and out of the lake of many aquatic species including the anadromous Alewife *Alosa pseudoharengus.* Populations of once abundant Alewife have declined to all-time lows, mainly due to habitat loss, or degradation and overfishing. The Lake Mattamuskeet Alewife population is limited by poor lake access to the spawning grounds during spring through the water control structures. There are currently two flapgate designs being used to control water passage through the Waupoppin Canal. One design is a top-hinged gate, while the other features a side-hinged gate. The objective of my study was to describe the length, weight, sex ratio, gonadosomatic index and condition factor of Alewife passing through the two gate designs in 2015 and 2016 and to determine whether one gate design was more efficient in Alewife passage. It was found that the side-hinged design allowed for a more efficient and varied passage of Alewife.

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Introduction

Lake Mattamuskeet and Water Control Structures

Lake Mattamuskeet, situated on the coastal plain in Hyde County, is the largest natural lake in North Carolina. The 40,100-acre lake is part of a 50,180-acre federal wildlife refuge known as the Mattamuskeet National Wildlife Refuge (MNWR) (Figure 1). The refuge was established in accordance with the Migratory Bird Conservation Act of 1929 "for use as an inviolate sanctuary, or for any other management purpose, for migratory birds" (Migratory Bird Conservation Act: 16 U.S.C. § 715d 1929). President Franklin D. Roosevelt officially created MNWR on December 18, 1934 by Presidential Executive Order 6924 "...as a refuge and breeding ground for birds and wild animals, and that such portion as the Secretary of Agriculture [Interior] may deem proper be reserved for use as a shooting area, to be operated under a cooperative agreement or lease .... Regarding the waters ... the Secretary of Agriculture [Interior] ... may enter into a cooperative agreement or lease ... said waters may be used for fishing purposes ..." (Presidential Executive Order 6924 1934). Overall, the refuge was created to provide habitat for wintering waterfowl, many species of fish and other wildlife. In addition to the area being a habitat for animals, it also provides recreational activities for humans. Some of these activities include hunting, fishing, photography, education and wildlife observation (USFWS, Wildlife and Habitat). The lake is connected to the Pamlico Sound by way of four man-made canals; from East to West, they are: Waupoppin Canal, Lake Landing Canal, Outfall Canal and Rose Bay Canal. The primary canal for our study was the Waupoppin Canal. The canal was dredged in 1937 to improve water flow to the Pamlico Sound (Mulligan 2020). These canals allow movement of aquatic species between lake and canal/Pamlico Sound habitats, especially migratory species like the Alewife *Alosa pseudoharengus*, which utilize lake habitats for springtime spawning. Barriers were placed on each water control structure in 2020 to prohibit large aquatic species such as adult Common Carp (Eurasian carp) *Cyprinus carpio* from entering the lake (Lamb 2020).

Water flow through the canals is controlled by the use of tide gates or flapgates, which are essentially doors mounted into low-head water control structures (WCSs). Lake Mattamuskeet is freshwater and so the purpose of these water control structures is to prevent saltwater from entering the lake. The gates open with ebb tide and close during the flood tide. When water levels within the lake are high, the flap gates allow water to flow outward into the Pamlico Sound. The gates are also engineered in a way that saltwater from the Pamlico Sound cannot enter the lake even when water levels are much higher within the Pamlico Sound (Rulifson and Wall 2006). The controlled outward flow of water is required by a historical consent decree to provide drainage for adjacent landowners. Water control structures have been found to disrupt migration of aquatic organisms and allow for increased risks of predation (Alcott et al. 2021).

Historically there have been several different designs of flapgates used to control the movement of water between Lake Mattamuskeet and the Pamlico Sound. The original flapgate design (Figure 2) was a top-hinged wooden door covering each concrete embayment of the WCS (Rulifson and Wall 2006). The top-hinged flapgate opened due to pressure from the lake water pushing the door; as pressure from lake water increased the flapgate opening increased, especially at the bottom. The wooden doors deteriorated over time allowing salt water to enter the lake. The original wooden flapgates were eventually replaced in 1989 with vertical wooden stop blocks inserted into slots within each concrete embayment of the WCSs (Rulifson and Wall, 2006). After several additional design modifications, there are only two designs in use today. One design is a stainless steel, top-hinged, full-embayment flapgate. The top-hinged gate (Figure 3) is much lighter than the original wooden gate, which was also top-hinged, and since stainless steel is being used, the gate is less susceptible to degradation. The other flapgate design is an aluminum, side-hinged gate (Figure 4). The side-hinged gate opens like a standard home door and was implemented to ascertain whether the side-opening design could better facilitate immigration and emigration of aquatic organisms to Lake Mattamuskeet. This gate design also requires little water pressure to be present to allow for opening (Mulligan 2020).

Alewife Life History

The term "river herring" is used to describe two different but similar species of fish -- the Alewife *Alosa pseudoharengus* and the Blueback Herring *Alosa aestivalis*. This study will specifically involve only Alewife, as Blueback Herring has never been considered a primary user of the lake as a spawning habitat. River herring are native to the east coast of North America, with Alewife ranging from Nova Scotia to South Carolina (Munroe 2002; Greene at al. 2009 cited in Rogers 2015). As adults both species live in the ocean but then return to the native watershed to spawn. In North Carolina, adult river herring spawn in coastal rivers and lakes from approximately March through June and return to the ocean shortly thereafter (Walsh et al. 2005). Adults inhabit coastal shelf waters until sexual maturity is reached at age 3 to 5 (Neves 1981). Juveniles live in the freshwater for 3 to 7 months after hatching, and then migrate to estuarine or marine waters (Yako et al. 2000). Alewife spawn primarily in lentic habitats such as Lake Mattamuskeet (Loesch and Lund 1977; Loesch 1987 cited in Walsh et al. 2005).

In many New England states river herring were once abundant during the spring season. Seasonal festivals were held in conjunction with inland migration of river herring, which were returning to spawn (Madin 2017). These species were very important as prey to the wildlife frequenting coastal rivers, but also important to the fishermen who harvested them. In the mid to late 1960s all of this changed. The North Atlantic population of river herring was noted to decline and then fall to an all-time low (Madin 2017). The migration of millions of fish had declined to a migration of an unknown but far smaller number of fish. Not only has this impacted the ecosystems in which the fish once supported, but it also impacted the northwestern Atlantic coastal fishing economy (Madin 2017). A further impact is occurring to river herring populations as a consequence of climate change, which is causing temperatures to warm and is adversely affecting spawning season duration (Lombardo et al. 2019).

Coastwide, these declines caused most US coastal states to enact strict commercial and recreational harvest limits for these species; more recently, moratoria were implemented in both North Carolina and the other coastal states (NCDMF 2007, 2013). Other states including Maine, New Hampshire, Massachusetts, New York and South Carolina have Sustainable Fishery Management Plans (SFMPs) that allow for some harvest of river herring under Amendment 2 to the Fishery Management Plan (FMP) (ASMFC 2012). Several attempts were made to list both species as federally endangered (ASMFC 2012). The expectation that the coastwide population size would increase was not realized after enduring endless years of the same problem. To this day, river herring have not recovered in some Atlantic coastal states. Population decline has been attributed to multiple causes, especially habitat loss and overfishing (ASMFC 2012). Much of the restoration effort for both species has been in spawning and nursery habitat restoration, and in reduction in ocean bycatch (ASMFC 2012). Hare et al. (2021) stated that human development and water contamination may have also played a large part in population decline, but that dam removal and an increase in stream connectivity is important for river herring restoration.

Goal and Objectives of the Study

The overall goal of the Mattamuskeet study was to determine whether the flapgate design allows an easier passage for Alewife. Mulligan (2020) analyzed the passage of all fish taxa, including Alewife, through both flapgate designs. However, the Alewife data were not examined in detail in the Mulligan (2020) study. The objective of my study was to reexamine the length, weight and sex ratio of Alewife passing through the two gate designs to determine whether one design was more efficient in providing Alewife passage. These aspects and other population demographics were analyzed to determine population characteristics of the Alewife using Lake Mattamuskeet as a spawning habitat. I hypothesized that the side-hinged gate would allow for more complete Alewife passage compared to the top-hinged flapgate because the side-hinged flapgate requires less water pressure to open, and the opening is vertical throughout the water column compared to the top-hinged flapgate, which opens at the bottom resulting in a horizontal stream of water at depth. These two aspects offer the migrants a choice of vertical positioning and a slow and stable flow of water compared to the top-hinged gate, thereby allowing for a greater size and age range of Alewife to use Lake Mattamuskeet for spawning. It is also worth stating that the discharge velocities through the top-hinged gate are higher than those of the side-hinged gates due to the smaller opening, and that may preclude or impair entry by smaller Alewife.

Methods

Area of Sampling

All samples were collected in spring of 2015 and 2016 from Lake Mattamuskeet located in Hyde County, North Carolina. Historically, Alewife studies have focused on two of the four canals that connect Lake Mattamuskeet to other bodies of water -- Lake Landing Canal and Waupoppin Canal. During this study, all samples were collected from the Waupoppin Canal by Allison Stewart Mulligan (Mulligan 2020). The samples were previously used in her dissertation and the resultant data were examined in detail for this study.

Field Collection

Alewife were collected using “custom-built, dual sided aluminum fish traps” (Mulligan 2020). The traps were designed so that both immigrating and emigrating groups of fish could be collected and held separately to determine direction of movement. Details of the trap design were presented in Mulligan (2020). Briefly, the traps were designed to fully enclose the entire embayment and were made of 1.9-cm (¾-inch) metal mesh material, which was small enough to retain adult fish but large enough to minimize water pressure from buildup of debris.
One trap was in the side-opening gate embayment (2015 and 2016) (Figure 5), and the second trap was in a top-hinged gate embayment (2016 only) (Figure 6). The traps were identical in dimension: 203 cm (80 inches) wide to span the entire embayment opening, 203 cm tall, and 102 cm (40 inches) deep. One side of each trap (102 cm) had a funnel to catch upstream-moving

fishes (immigrating), and the other side (102 cm wide) had a funnel to catch downstream-moving fishes (emigrating). This design kept both catches separate to document what was entering and exiting the lake through the embayments housing the two flapgate designs. Each catch was removed from the trap through a trap door in each compartment. The traps were placed upstream from each water control embayment to ensure they did not impede movement of the flapgate. The traps were lowered and raised using a winch and boom system modelled after the earlier fish passage studies (Wall and Rulifson 1999, Godwin and Rulifson 2004, Rulifson et al. 2004). The 2015 collection year was completed to determine the effectiveness of the custom traps and to determine the baseline status of the spawning population at the time the study was initiated (Mulligan 2020). In 2016, both gate designs were tested at the same time (one trap in a side-hinged gate and one in a top-hinged gate).

Traps were fished for a 48-hour period but worked up every 10 hours. Total length (TL, mm), fork length (FL, mm), weight (g) and sex were recorded for each fish captured. All collected Alewife were then frozen until they were examined in the laboratory.

Water quality measurements were taken to obtain water quality trends during the Alewife spawning run. All measurements of dissolved oxygen (mg/L), water temperature (ºC), salinity (ppt) and conductivity (uS) were collected using an YSI 2030 water quality meter (Mulligan 2020). These values were collected on both the lakeside and sound side of the WCS. The water velocity (1 fps= 0.3048 m/s) through each gate type was also recorded using a Marsh-McBirney water velocity meter (Mulligan 2020). Water velocities were taken at the bottom center of each gate type (Mulligan 2020).

Laboratory Workup

After specimens were thawed, the otoliths and gonads of adult (older than age 3) Alewife were removed. Otoliths were placed under a dissecting microscope for photographing to determine fish age (Figure 7). Two personnel aged each otolith. If there was a discrepancy, the personnel would re-age the fish without having access to the previous assignment of age. A final age would then be decided for each fish but if a final age could not be decided, the fish was excluded from further analysis.

Gonads were removed (Figure 8), weighed (g) and used for calculating the Gonadosomatic Index (GSI). The GSI value is calculated by dividing the gonad weight by the total body weight of that individual, then multiplying by 100 to present the value as a percentage of the total fish weight.

Condition factor (Fulton's K) was calculated using TL and FL for both somatic body weight and total body weight. The condition factor value was calculated by:

$$K = (W/L^3) \times 100{,}000.$$

Four condition factor values were calculated in order to compare the results of this study with other studies. However, since we were interested in the total length of fish relative to water velocity and gate type, and we identified various stages of gonadal development in both sexes of immigrating and emigrating fishes, we used the Fulton's (K) calculated using TL and somatic body weight in discussing the results.

Since the number of fish with records of both FL and TL was similar, TL was chosen to compare fish length to water velocities through the embayments. The conversion from TL to FL was calculated as:

Females: $FL_F = -6.700548 + 0.89862\ TL_F$;

$n = 167$, $R^2 = 0.96$, F ratio = 3785.75, and P>F = <0.0001.

Males: $FL_M = -6.538175 + 0.8968288TL_M$;

$n = 142$, $R^2 = 0.94$, F ratio = 2170.41, and P>F = <0.0001.

All data were stored in a Microsoft Excel file. This excel file was then imported into the JMP Pro 15.1 software to allow for data analysis and graphical presentation.

Results

2015 Study

Design Differences in Water Flow -- The two gate designs were significantly different in water velocity and in operation. In 2015, the side-hinged gate allowed for a significantly lower average water velocity (0.12 m/s or 0.40 fps) each sampling week compared to the top-hinged gate value of 0.29 m/s or 0.94 fps (df = 5, t = -3.253, p = 0.012) (Mulligan 2020).

Environmental Conditions -- Measurements of water temperature, dissolved oxygen, salinity, and conductivity were measured on both the lake side and sound side of the WCS (n = 50). Water temperatures averaged 19.5 ºC, ranging from 10.2 to 23.8 ºC. The greatest numbers of Alewife were captured at 19.3 ºC during the first week of the 2015 sampling period. Dissolved oxygen averaged 11.14 mg/L, with a minimum of 3.47 mg/L and a maximum of 18.81 mg/L. Salinity averaged 0.6 ppt, with a minimum of 0.3 ppt and a maximum of 0.7 ppt. Conductivity averaged 1094 uS, with a minimum of 573 uS and a maximum of 1349 uS (Mulligan 2020). All environmental conditions were calculated from a combination of both upstream and downstream collected values. For both years there were no significant differences between matched pairs of upstream and downstream measurements of each environmental variable (logistic fit, chi-square test).

Timing of Spawning Run -- Results of samples taken from March 22 to May 7, 2015, indicated that the peak spawning run in the Waupoppin Canal occurred between March 22 and March 29 (Mulligan 2020). However, it was clearly evident that sampling did not start prior to the spawning run, so fish captured in samples from the first week were not included in the data analysis. The Alewife diurnal movements through the water control structure were similar for daylight hours (45%; 0700-1900 hours) compared to nighttime hours (55%; 1900-0700 hours (Figure 9).

Direction of Movement – During the 2015 six-week period, 86 Alewife were collected. More adults (47, or 54.7%) were caught immigrating into the lake and 39 (45.3%) were emigrating. Mulligan (2020) estimated (number ± SD) that approximately 186 ± 18 individuals passed through the Waupoppin Canal embayment containing the side opening gate during the sampling period; these numbers were not extrapolated to the other embayments since Alewife behavior through the top-opening gate design was not documented. The immigration catch per unit effort (CPUE) was 0.19 fish per hour based on 247.5 sample hours.

Age and Sex Ratio -- Of the 86 Alewife, four fish were juveniles and therefore excluded from analyses. Data from the remaining 82 individuals were used to determine population demographics. The 2015 sex ratio (F:M) for the study period was 1.28:1 or 46 (56.1%) females and 36 (43.9%) males. Females ranged in age from 4 to 9 years with a mean age of 5.5 years. Male ages ranged from 4 to 8 years with a mean age of 5.2 years. The modal age of both males (18; 50.0%) and females (22; 47.8% was 5 years. Frequencies of the remaining male age classes were age 4 (7; 19.4%), age 6 (8; 22.2%), age 7 (1; 2.8%), and one male age 8 (2.8%). The age of one male was undetermined (2.8%). Age classes of the remaining females were 13.0% (6) age 4, 17.4% (8) age 6, 17.4% (8) age 7, one (2.2%) age 8, and one (2.2%) female classified as age 9.

Weight and Length -- In 2015, female Alewife were generally larger than males of the same age. Adult females in 2015 ranged from 242 to 297 TL with a mean of 265 ± 14 mm, and males ranged from 176 to 275 mm TL with a mean of 249 ± 11 mm (Table 1). For weight, females averaged 149.95 ± 33.50 g (range 102.87 - 237.97 g) and mean male weight of 125.93 ± 28.46 g (range 73.80 - 235.04 g; Table 1). Mean lengths and eights by age and sex are shown in Table 2.

GSI -- In 2015, the female Alewife gonadosomatic indices were larger than those for males (Table 1, Table 2). The female GSI ranged from 0.19 to 14.33 with a mean of 3.9 ± 4.1; the larger standard deviation indicated that GSI measurements were from both pre-spawn and post-spawn fish. The male samples varied in GSI from 0.41 to 5.75 with the average being 1.8 ± 1.7. The mean at age for both sexes did not increase consistently over the age ranges likely due to the variable spawning stages observed in the sampled fish (Table 2); the same phenomenon was observed in 2016 (Table 3). The 2015 mean GSI of the immigrating population was observed to be higher than the mean GSI of the emigrating population regardless of sex. Immigrating males had a mean GSI of 2.5 ± 1.9 (range 0.41 - 5.75) whereas emigrating males had a mean GSI of 1.1 ± 1.0 (range 0.24 - 4.30). Immigrating females had a mean GSI of 7.2 ± 5.6 (range 0.28 - 14.33) whereas emigrating females had a mean GSI of 2.4 ± 2.1 (range 0.19 - 9.24) (Table 4). The smaller standard deviations indicated that most adults of both sexes had spawned within lake habitats prior to emigrating.

Condition Factor -- The population varied in condition factor (K, calculated as somatic TL and somatic weight) from 0.60 to 1.32. Values for female Alewife varied from 0.60 to 1.32 with an average of 0.77 ± 0.12. Male fish varied in condition factor from 0.66 to 1.18 with an average of 0.83 ± 0.11 (Table 1). The mean condition factor of the immigrating population was observed to be higher than that of the emigrating population depending on sex. Immigrating males had a mean condition factor of 0.83 ± 0.10 (range 0.64 - 0.99) whereas that of emigrating males was slightly lower at 0.82 ± 0.13 (range 0.66 - 1.18). Immigrating females had a mean condition factor of 0.82 ± 0.10 (range 0.66 - 0.96) while that of emigrating females was lower at 0.75 ± 0.12 (range 0.60 - 1.32) (Table 4). Average Fulton K values calculated using FL and total body weight (including gonads) are presented in Table 4.

Mortality Rate -- Total mortality rates (Z) of female and male Alewife in 2015 were 0.36 and 0.47 respectively estimated from a catch-curve analysis (Figure 10).

2016 Study

Design Differences in Water Flow -- The two gate designs were significantly different in water velocity and in operation. Results for 2016 showed that the side-hinged gate had a significantly lower average water velocity (0.05 m/s or 0.16 fps) each sampling week compared to the top-hinged gate value of 0.09 m/s or 0.28 fps (df = 9, t = -2.409, p = 0.019) (Mulligan 2020).

Environmental Conditions -- Measurements of water temperature (ºC), dissolved oxygen (mg/L), salinity (ppt), and conductivity (uS) were measured on both the lake side and sound side of the WCS (n = 58). Water temperatures averaged 16 ºC, ranging from 9.0 to 25.5 ºC. The greatest number of Alewife were captured at 13.0 ºC during the second week of the 2016 sampling period. Dissolved oxygen averaged 11.13 mg/L, with a minimum of 6.58 mg/L and a maximum of 19.5 mg/L. Salinity averaged 0.37 ppt, with a minimum of 0.2 ppt and a maximum of 0.4 ppt. Conductivity averaged 657 uS, with a minimum of 399 uS and a maximum of 877 uS (Mulligan 2020).

Timing of Spawning Run – Results of samples taken from February 25 to May 1, 2016 indicated that the peak spawning run in the Waupoppin Canal occurred between February 28 and March 6, 2016 (Mulligan 2020). The diurnal rhythms of Alewife movements through the water control structure were similar for daylight hours (42%; 0700 - 1900 hours) compared to nighttime hours (58%; 1900 - 0700 hours) (Figure 9).

Direction of Movement – During the ten-week period, 266 Alewife were collected. More adults (191 or 71.8%) were caught immigrating into the lake and 75 (28.2%) were emigrating. Mulligan (2020) estimated (number ± SD) that approximately 2,380 ± 261 individuals immigrated through all Waupoppin Canal embayments during the sampling period. The immigration catch per unit effort (CPUE) was 0.225 fish per hour based on 855 sample hours.

Age and Sex Ratio -- Of the total 266 Alewife, eight fish were determined to be juveniles and therefore excluded from analysis. The data from the remaining 258 individuals were used to determine population demographics. The 2016 sex ratio (F:M) for the study period was 1.09:1, or 134 (51.9%) females, 123 (47.7%) males and one (0.4%) individual that was undetermined. Females ranged from 3 to 8 years of age with 5.2 years being the average age. Males ranged from 3 to 8 years with a mean age of 5.3 years. The modal age of both males (46; 37.4%) and females (60; 44.8%) was 5 years. Frequencies of the remaining male age classes were age 3 (1; 0.8%), age 4 (30; 24.4%), age 6 (26; 21.1%), age 7 (11; 8.9%), and five males age 8 (4.1%). The age of four males was undetermined (3.3%). Age classes of the remaining female individuals were 24.6% (33) age 4, 15.7% (21) age 6, 8.2% (11) age 7, 3.7% (5) age 8, 1.5% (2) females classified as age 3 and 1.5% (2) females whose ages could not be determined.

Weight and Length -- In 2016, female Alewife were generally larger than males of the same age (Table 3). Females in 2016 ranged from 235 to 293 mm with a mean TL of 258 ± 12 mm, and males ranged from 212 to 280 mm TL with a mean of 247 ± 12 mm. Females varied in weight from 111.20 to 281.97 g with a mean weight of 173.62 ± 33.20 g. Male Alewife varied in weight from 89.53 to 224.2 g with a mean weight of 150.54 ± 27.20 g.

GSI -- In 2016, the female Alewife gonadosomatic indices were larger than those for males (Table 1). The female GSI ranged from 0.68 to 16.74 with a mean of 8.3 ± 4.3. The male samples varied in GSI from 0.22 to 8.05 with the average being 4.4 ± 2.1. Again in 2016, the mean GSI of the immigrating population was higher than the mean GSI of the emigrating population regardless of sex indicating that spawning had occurred in the lake. Immigrating males had a mean GSI of 5.3 ± 1.2 (range 0.22 - 7.65) whereas emigrating males had a mean GSI of 1.4 ± 1.5 (range 0.26 - 8.05). Immigrating females had a mean GSI of 10.5 ± 2.9 (range 1.51 - 16.74) whereas emigrating females had a mean GSI of 3.1 ± 2.1 (range 0.68 - 10.72) (Table 4).

Condition Factor -- The population varied in condition factor (K) from 0.64 to 1.14. The female Alewife varied in condition factor from 0.64 to 1.14 with an average of 0.92 ± 0.11. The male fish varied in condition factor from 0.65 to 1.09 with an average of 0.94 ± 0.10 (Table 1). The mean condition factor of the immigrating population was observed to be higher than the mean condition factor of the emigrating population. Immigrating males had a mean condition factor of 0.98 ± 0.07 (range 0.68 - 1.09) whereas emigrating males had a mean condition factor of 0.84 ± 0.09 (range 0.65 - 1.07). Immigrating females had a mean condition factor of 0.96 ± 0.07 (range 0.69 - 1.10) whereas emigrating females had a mean condition factor of 0.80 ± 0.09 (range 0.64 - 1.14) (Table 4).

Mortality Rate -- Total mortality rates (Z) of female and male Alewife in 2016 were 0.35 and 0.33 respectively estimated from a catch-curve analysis (Figure 10).

Population Demographics by Movement Status and Gate Type

Weight and Total Length -- In 2015 there was high variation in weight and total length for Alewife moving through the side-hinged gate regardless of sex. Body weight and total length were log-transformed, and the resultant correlations of the linear equations (Figure 11) were r^2 = 0.451 for females and 0.433 for males. One male Alewife with a high weight was considered an outlier and was not included in the analysis.

In 2016 there was high variation in weight and total length regardless of sex but variation was different based on status of movement and type of gate design. The highest log weight and log total length coefficient of determination (r^2) value was 0.816 for immigrating males passing through the top-hinged gate (Figure 12). All other r^2 values were 0.751 for females passing through the top-hinged gate, 0.439 for males passing through the side-hinged gate and 0.372 for females passing through the side-hinged gate (Figure 12).

In 2016, the average female throughout the entire population was larger than the average male (Table 1). It was also noted that female Alewife were on average larger than males of the same age (Table 3).

Age and Sex -- It was noted that high numbers of Alewife passed through the side-hinged gate while emigrating back to the Pamlico Sound (Figure 13). It was also noted that most age classes of both sexes passed through the side-hinged gate at high numbers while immigrating to Lake Mattamuskeet (Figure 13). All (100%) of age 3 Alewives passed through the side-hinged gate in 2016 (Figure 13).

Time of Spawning-- It was noted that a large number of Alewife were captured while immigrating into the lake at the end of February and the beginning of March in 2016 (Calendar weeks 8 - 10) (Table 5, Figure 14) and continued to enter the lake throughout March of 2016 to spawn (Figure 14). In 2016, fish began to leave the lake in mid-March. The number of fish captured emigrating in April exceeded the number of fish immigrating.

GSI -- The mean GSI of all female Alewife was noted to be larger than that of all males in both sampling years (Table 1). In 2015 and 2016, the mean GSI of female Alewife was noted to generally be larger than males of the same age (Table 2, Table 3).

The mean GSI indicated the time of spawning as reflected in the decrease in GSI after spawning had occurred. The mean GSI of all immigrating fish was much higher than the GSI of all emigrating fish in both sampling years (Figure 15, Figure 16). At the end of the spawn, some emigrating fish were noted to have a higher GSI than the immigrating fish, but the values of the GSI closely match to those of post-spawn Alewife.

In 2016, it was noted that immigrating fish with a low average GSI tended to pass through the side-hinged gate (Figure 16). It was also noted that most emigrating Alewife passed through the side-hinged gate instead of the top-hinged gate.

Condition Factor -- The average condition factor generally decreased over time for each sex (Figure 17). Alewife with lower average condition factors generally passed through the side-hinged gate rather than the top-hinged flapgate embayment (Figure 17). Male Alewife were noted to have a higher mean condition factor than females in both sampling years (Table 1). The average condition factor of Alewife sampled in 2015 varied for males and females of the same age (Table 2). In 2016, the mean condition factor of male Alewife was generally higher than females of the same age (Table 3).

Discussion

One portion of Mulligan's (2020) study evaluated the passage of *Alosa pseudoharengus* to determine efficiency of fish passage through two different flapgate designs within the Waupoppin Canal Water Control Structure, Lake Mattamuskeet, North Carolina. According to Silva et al. (2017), knowledge in fish passage science has grown, but the concepts of fish passage discussed for larger watersheds are not practical for low-head costal applications such as the WCS of Lake Mattamuskeet. Historically the lake has been a river herring habitat for spawning due to suitable conditions such as lentic water. The lake is connected to other bodies of water including the Pamlico Sound. In order to maintain the freshwater ecosystem, the canals of Lake Mattamuskeet contain water control structures with flapgates of a top-hinged design, which results in strong water pressure from the lake required to open the flapgate; this design results in high velocities of water released at the bottom of the embayments. Even so, these WCSs do allow fish species and other aquatic fauna to pass into and out of the lake when flapgates are open.

Population Demographics

Almost all population characteristics of the Alewife population including time of spawning, age structure, length ranges, weight ranges and sex ratios were found to be similar to the historical values found by Tyus (1974), Wall (2003) and Godwin (2004). Water quality was also measured throughout the entire study and all measurements including water temperature, dissolved oxygen, salinity and conductivity were found to be similar to the historical values during the Alewife spawning run.

Water temperature values during the Alewife peak spawning weeks of 2003, 1970 and 1971, were reported to be 18.4 ºC, 12.9 ºC and 13.1 ºC respectively. However, the 2015 water temperature values were higher than the previous studies conducted by Godwin (2004) and Tyus (1974); this may have been due to the fact that sampling was initiated too late to catch the start of the Alewife spawning run. Alewife in North Carolina tend to spawn when water temperatures are between 12.9 ºC and 16 ºC (Tyus 1974; Winslow 1989) compared to Alewife spawning in Canada at the northern end of the range, usually when water temperatures range from 5 ºC to 10 ºC (Mullen et al., 1986; Nau et al., 2017; Norden, 1967 as cited in Breau 2020).

Dissolved oxygen values in 2003 were rarely below 4.0 mg/L and usually remained above 7.0 mg/L (Godwin 2004) similar to those observed in 2015 for lake waters, also rarely dropping below 4.0 mg/L and averaged 11.14 mg/L. Davis and Cheek (1967) stated that dissolved oxygen values during Alewife spawning in North Carolina ranged from 2.4 to 10 mg/L. Water salinities were slightly less in 2015 compared to 2003; the maximum recorded salinity level in 2003 was 1.0 ppt whereas the maximum recorded salinity value in 2015 was 0.7 ppt. Slight shifts in lake salinity is common and the result of precipitation, evaporation, and leakage of flapgates at water control structures.

A historical study by Godwin (2004) in the Waupoppin Canal found that the peak spawning run took place between March 23 and March 29 in 2003, a result similar to that of our 2015 sampling. Tyus (1974) reported Alewife peak spawning at Lake Landing Canal to the west between the dates of April 5 - 12, 1970, and April 2 - 9, 1971. Smith and Rulifson (2015) reported that the first peak of Alewife spawning in the Tar River to the west was March 29, 2004, and April 22, 2005. Alewife spawning in Canada tend to begin their upstream migration in late April through mid-June (Mullen et al., 1986; Nau et al., 2017; Norden, 1967 as cited in Breau 2020). This shows that there is not only a spawning temperature difference in different water systems, but that spawning occurs later at increased latitude. Results of these North Carolina studies suggest that Alewife are now spawning earlier in the year compared to the 1970s and even those observations from the early 2000s. Lombardo et al. (2019) states that these shifts are the result of climate change.

The CPUE value calculated for 2015 (0.19) was lower than the estimate of 1.113 from Waupoppin Canal in 2003 (Godwin 2004). The 2015 calculated estimate more closely resembled the CPUE estimates from 1997 (CPUE = 0.033) and 1998 (CPUE = 0.036) by Wall (2003) when sampling took place at Lake Landing Canal. However, the 2015 estimates did not include the start of the Alewife spawning run and so this may account for the difference in estimates. Also, different sampling techniques were used in each study and could have affected the calculated CPUE values.

Differences between the Two Gate Designs

Both flapgate designs experience periodic open and closure events during normal springtime conditions. Spring is usually characterized by many periods of precipitation in Eastern North Carolina resulting in lake level fluctuation. As the water level within the lake rises above the water level outside of the WCS, the gates open to discharge water into the Pamlico Sound. On the flipside, if the water level of the Pamlico Sound rises above the level within Lake Mattamuskeet, the flapgates will close. This results in the lake maintaining a water level that is below the flood stage (Wall and Rulifson 1999). Wind direction and higher wind velocities also cause seiches in the lake forcing flapgates to open and release water even while water levels are low (Rulifson and Wall 2006). These periodic open and closure events of spring allow Alewife to enter and exit Lake Mattamuskeet during the spawning run.

The side-opening gate is much like a standard home door creating a large vertical opening compared to the top-hinged gate, which creates a much smaller and horizontal opening as it swings upward. This likely explains the differences in water velocity. A larger surface area will allow for a lower water velocity as seen with the side-hinged gate. Bunt et al. (2001) found that both weak and increased water flow can attract fish to pass through different structures. This means that the fish are choosing the gate type design that is allowing for their specific ease of passage.

Shifts in Population Demographics by Status and Gate Type

The low r^2 values show that the total weight of a particular fish could not be accurately predicted by the total length of the fish. The outlying samples are due to the fact that pre-spawn, spawning and post-spawning fish were present in each movement status and sex category. Fewer outliers were noted within the 2016 data. It is also worth noting that the sample size in 2016 (n = 258) was approximately 3 times the size of the 2015 (n = 86) sample. It is possible that some changes in population characteristics were due to the differences in the number of Alewife captured in each year. Breau (2020) calculated similar correlation values ($r^2 = 0.79$) of total length and weight relationships for Alewife inhabiting four river systems in Canada.

The variables including log weight, log total length and sex were compared for fish that passed through each gate design. The r^2 values associated with the side-hinged gate were noted to be much lower than the value associated with the top-hinged flapgate (Figure 11, Figure 12). These values support the hypothesis that a greater size range of Alewife was able to pass though the side-hinged flapgate. It was also found that gate design passage was not dependent on sex but dependent on weight. Many fish passing through the side-hinged gate were plotted below the line of best fit, due to having lower than predicted weights. Many Alewife passing through the top-hinged gate were noted to be on or above the line of best fit. Therefore, these fish weighed more than predicted by the length of the fish. It was concluded that fish weighing more at a given length are able to more easily utilize the top-hinged gate than fish weighing less than the predicted weight.

The mean total length of male Alewife increased between 2015 and 2016, while the mean total length of females decreased. The mean total lengths of female Alewife aged as 3 (156 mm), 4 (171 mm) or 5 (182 mm) years that populate Lake Michigan (Prause 2020) were observed to be much lower than the mean total lengths of Alewife collected in Lake Mattamuskeet (Table 2, Table 3). The mean weight of both male and female Alewife increased substantially between 2015 and 2016. The mean GSI and condition factor of each sex also increased between the sampling years of 2015 and 2016 (Table 1).

The natural mortality rate of Alewife has been assumed to be approximately 0.5 (NCDMF 2007) but the catch-curve calculated mortality rates were observed to be lower than the literature value. This means that mortality likely did not have an effect on the low number of Alewife emigrating from the lake even though the mortality of Alewife and their gametes are an important source of nutrient (phosphorus) deposition to the ecosystem of Lake Mattamuskeet (Twining et al. 2016). It is also possible that the use of otolith ageing techniques was not completely accurate thus causing fish to be classified into older age classes, which in turn would lead to lower total mortality estimates.

Alewife emigration with respect to Lake Mattamuskeet was found to be almost solely through the side-hinged gate. Of all Alewife caught in 2016, only 1 (6%) of 5-year-old females and 1 (17%) of 7-year-old males emigrating from the lake were observed to pass through the top-hinged gate (Figure 13). An average of 65.5% of immigrating females and 59.2% of immigrating males passed through the side-hinged flapgate (Figure 13).

Historically, Alewife use Lake Mattamuskeet to spawn from late February to mid-April. In both 2015 and 2016, it was found that the peak spawning run occurred from late February to late March (Figure 14). Throughout the sampling periods, the mean GSI of fish was noted to drop. This is mainly due to the fish releasing eggs or sperm depending on the sex of the fish. This loss of weight causes the GSI of each fish to decrease. Most emigrating fish were observed to utilize the side-hinged gate. The average GSI of emigrating fish was noted to be very low, so this led me to believe that post-spawn fish chose passage through the side-hinged gate due to it being easier, as it creates a larger and more detectable opening. This was also true of immigrating Alewife, as the mean GSI values tended to be lower throughout the month of March with passage through the side-hinged gate (Figure 15, Figure 16).

The average condition factor of fish was also calculated and used to compare the fish by gate type passage (Figure 17). In both years, the mean condition factor was noted to decrease from the peak spawning until the fish emigrated from the lake. This is likely due to the fact that Alewife were focused on spawning while inside of Lake Mattamuskeet and they did not maintain their somatic weight by consuming food. This same observation has been made in studies based on other alosine populations, as fat deposits were observed to be highest prior to the fish entering estuarine waters but then decreased during the freshwater spawning run (Murauskas and Rulifson 2011; Rulifson and Batsavage 2014). Throughout February and March of 2016, the mean condition factor was not observed to affect gate type passage as the mean condition factors of Alewife passing through each gate type were very similar. Upon exiting the lake in late March and April, the fish with lower average condition factor values were observed to once again pass through the side-hinged flapgate. Condition factor values of other anadromous species (Salmonid fish) range from poor condition (0.80) to good condition (1.60) (Barnham and Baxter 2003, Spares et al. 2014). Condition factors of Alewife were calculated using total length, fork length, somatic body weight and total body weight. Most condition factor values calculated for Alewife in Lake Mattamuskeet were within the condition factor range and therefore the population was in average condition. Stewart et al. (2021) reported that mean condition factor values in Canada (Male = 1.4 ± 0.11, Female = 1.39 ± 0.14) calculated from fork length and total body weight closely resemble the values calculated for Lake Mattamuskeet in the same way (Table 1).

Conclusions

Overall, it was concluded that the evidence supported the hypothesis that the side-hinged flapgate design allows for a more varied age and size range of Alewife passage. A greater variety of length and weight ratios of Alewife were observed to pass through the side-hinged flapgate throughout the year of 2016. When the data were sorted by age and sex, it was found that an average percentage greater than 50% of both sexes passed through the side-hinged gate. Almost all emigrating fish were observed to utilize the side-hinged gate and it was believed that this was due to a decreased water velocity along with the large and easily detectable opening. Many of the emigrating fish were likely weak due to the stress of spawning and these fish chose to pass through the gate design that was easier to navigate. In conclusion, the side-hinged flapgate design allowed for a greater age and size range of Alewife passage indicating that this gate design allowed for easier fish passage due to factors such as lower water velocity and total water column exposure.

Acknowledgements

I thank Dr. Allison Stewart Mulligan and Dr. Roger A. Rulifson for providing the datasets and perspectives on the study. The U.S. Fish and Wildlife Service, Mattamuskeet National Wildlife Refuge, provided project funding. Students taking the Fall 2015 and Fall 2016 Fisheries Techniques course at East Carolina University assisted in sample workup, water quality, and data entry during FishTech Weekends. The East Carolina University Coastal Resources Management PhD program provided supplemental funds.

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Figures

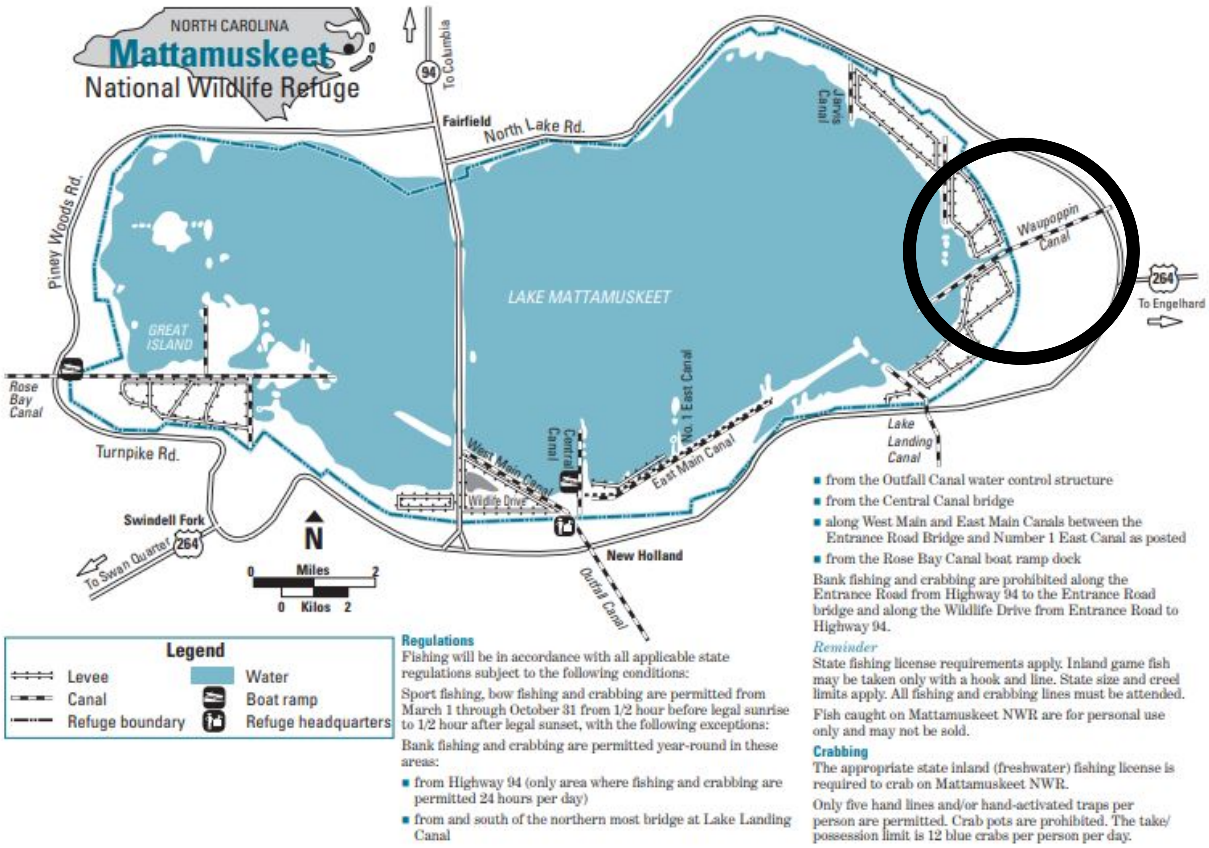

Figure 1. Map of Lake Mattamuskeet, all four man-made canals and surrounding highway systems (USFWS, About the Refuge). Circle indicates location of the 2015-2016 study.

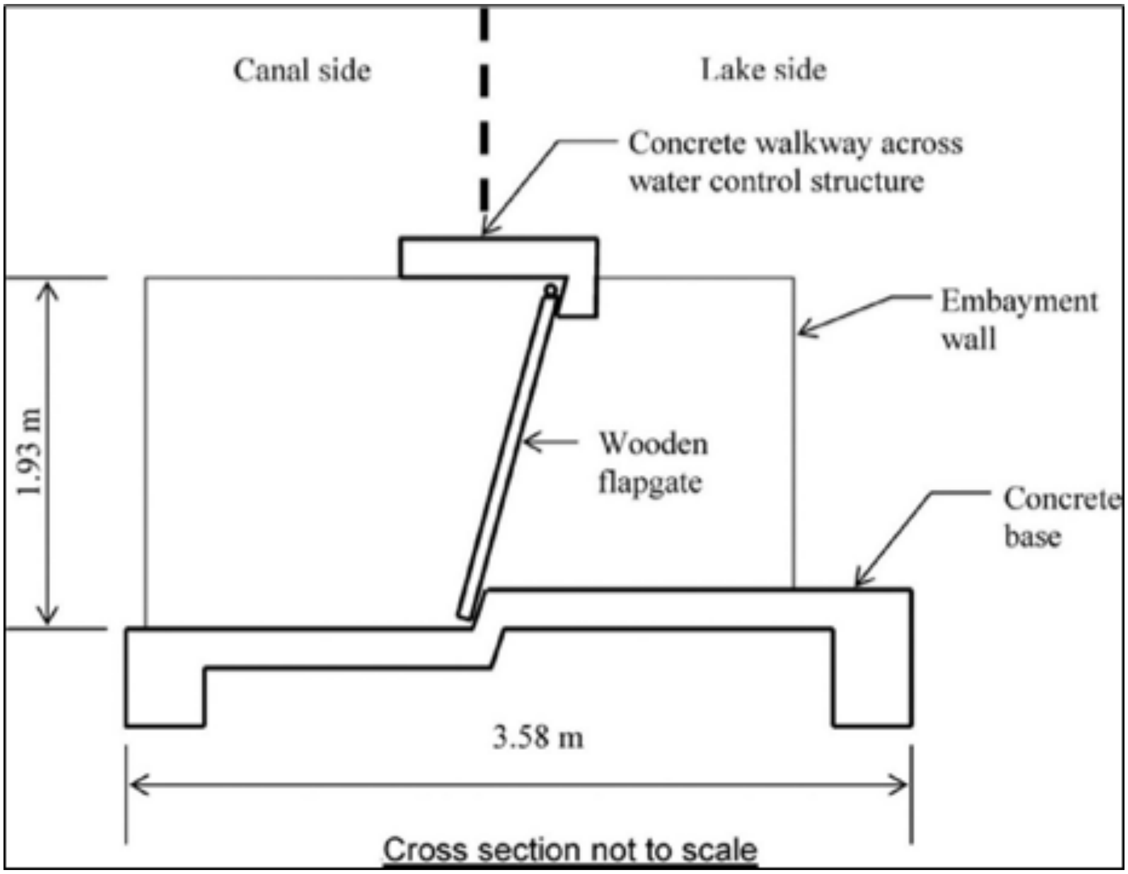

Figure 2. Redrawn image of the original wooden flapgate structure. Originally drawn by U.S. Fish and Wildlife Service, regional engineer, Atlanta, 1950, Lake Mattamuskeet, North Carolina (Rulifson and Wall 2006).

Figure 3. Photograph of a current stainless steel, top-hinged flapgate at Waupoppin Canal, Lake Mattamuskeet, North Carolina (Godwin 2004).

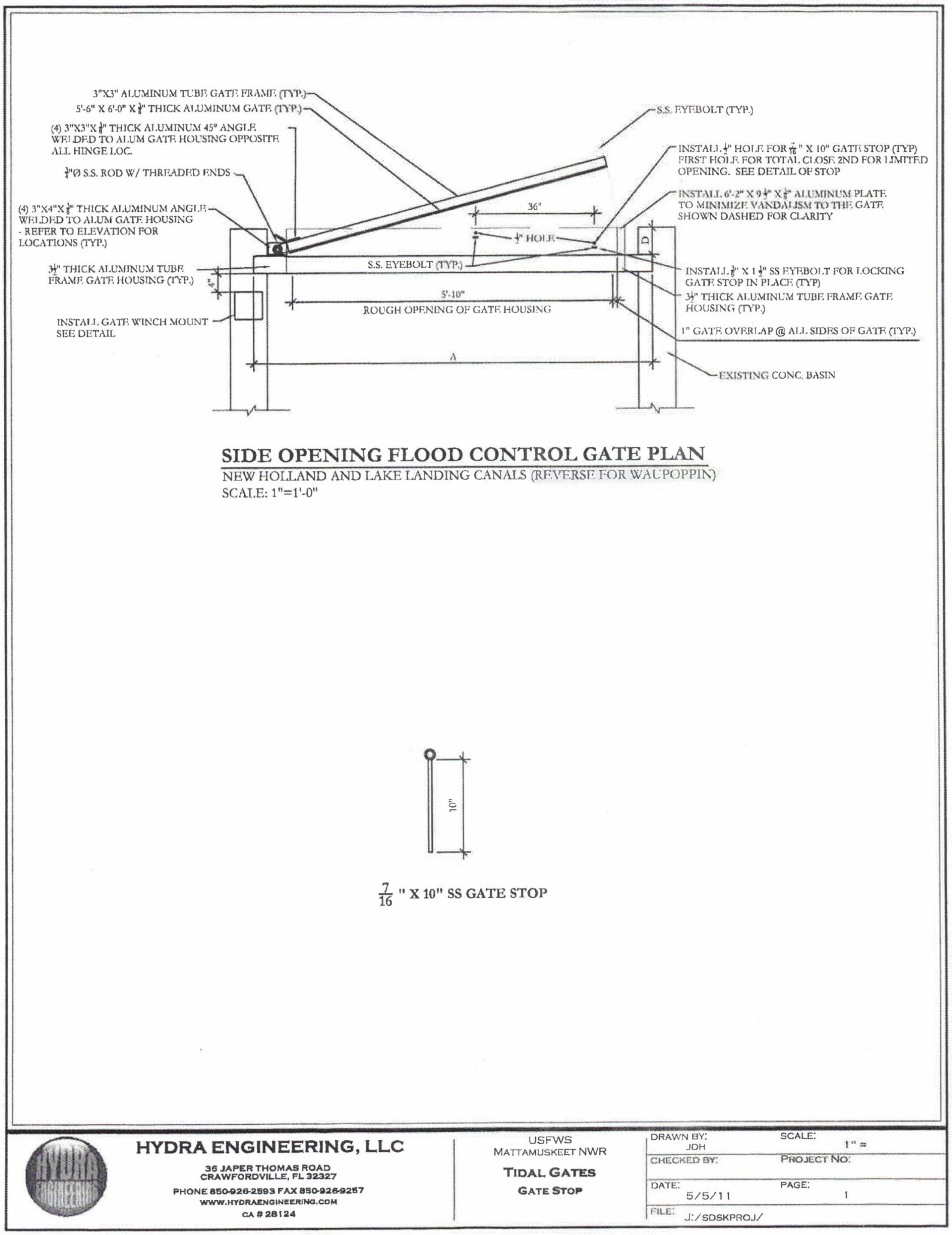

Figure 4. Sketch of the aluminum, side-hinged flapgate at Waupoppin Canal, Lake Mattamuskeet, North Carolina (JDH 2011).

Figure 5. Photograph of Dr. Allison Stewart Mulligan alongside the winch system and the custom-built fish trap which was used in the side-hinged gates during the 2015 and 2016 field sampling campaigns at Waupoppin Canal, Lake Mattamuskeet, North Carolina (Mulligan 2020).

Figure 6. Photograph of the winch system and the custom-built fish trap which was used in the top-hinged gates during the 2016 field sampling campaign at Waupoppin Canal, Lake Mattamuskeet, North Carolina (Mulligan 2020).

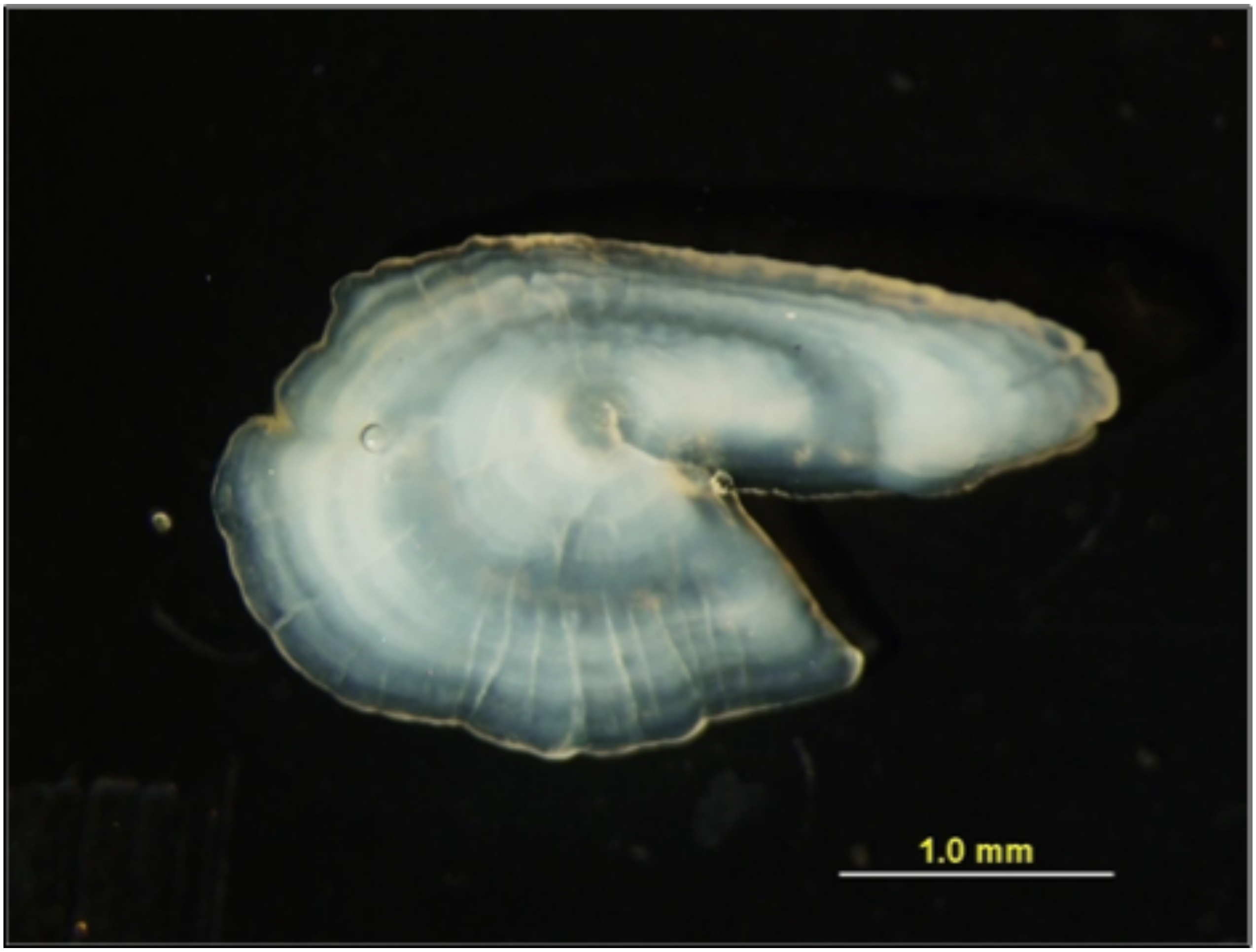

Figure 7. An example of an Alewife otolith image, which was taken for the purpose of aging each fish (Mulligan 2020).

Figure 8. An adult female Alewife after her gonads were removed for the purpose of weighing them (Mulligan 2020).

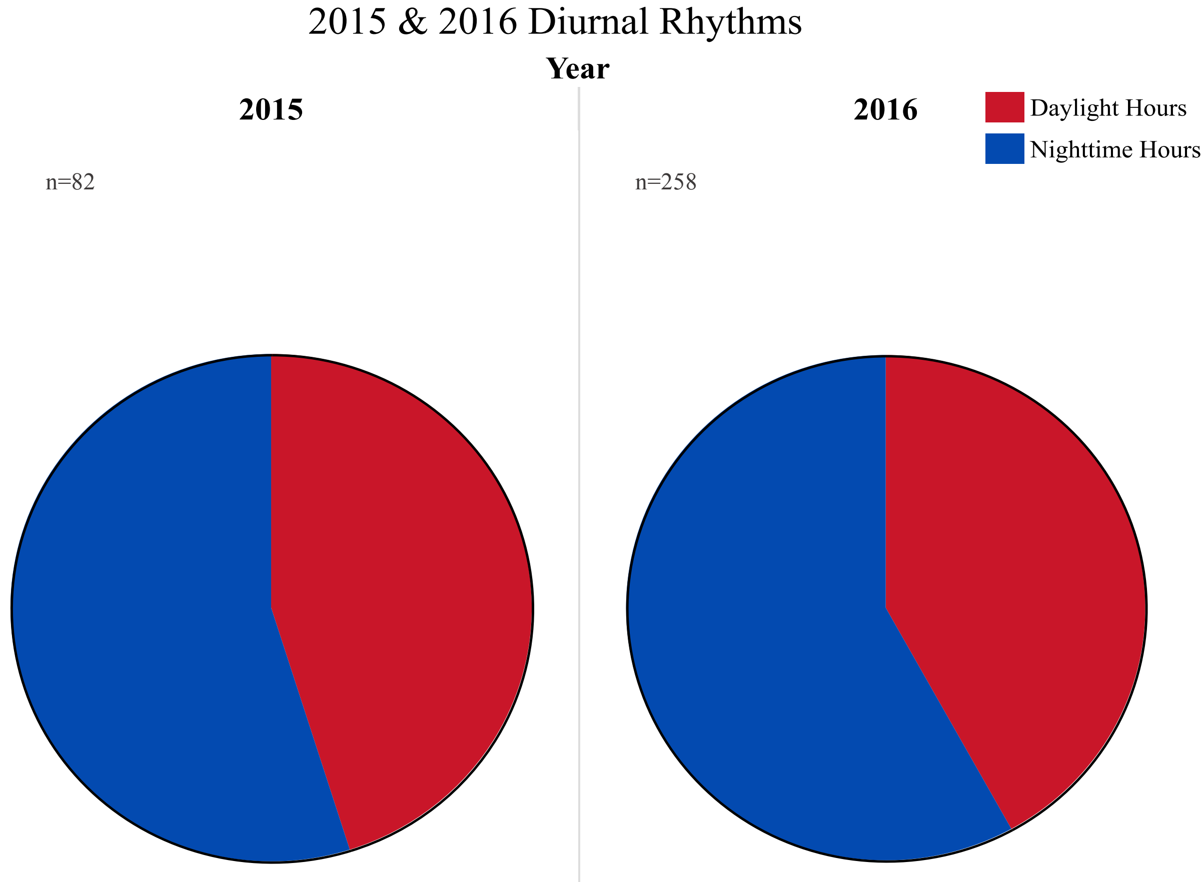

Figure 9. The diurnal rhythms of Alewife captured during the 2015 and 2016 sampling periods from the Waupoppin Canal Water Control Structure, Lake Mattamuskeet, North Carolina.

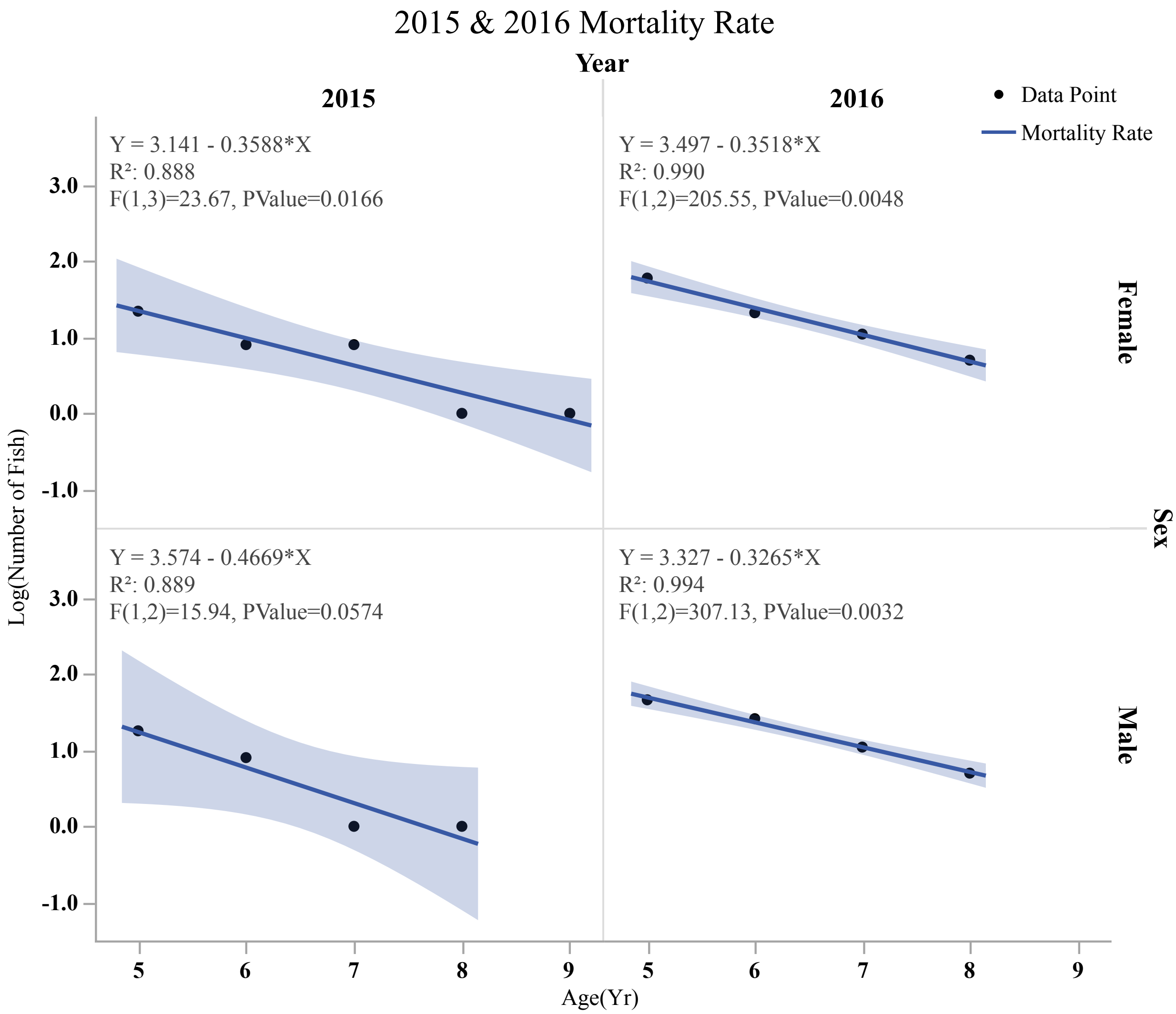

Figure 10. Estimated mortality (Z) of Alewife collected during the 2015 and 2016 sampling periods from the Waupoppin Canal Water Control Structure, Lake Mattamuskeet, North Carolina. The large F values indicate that there is large variation between each age class of Alewife.

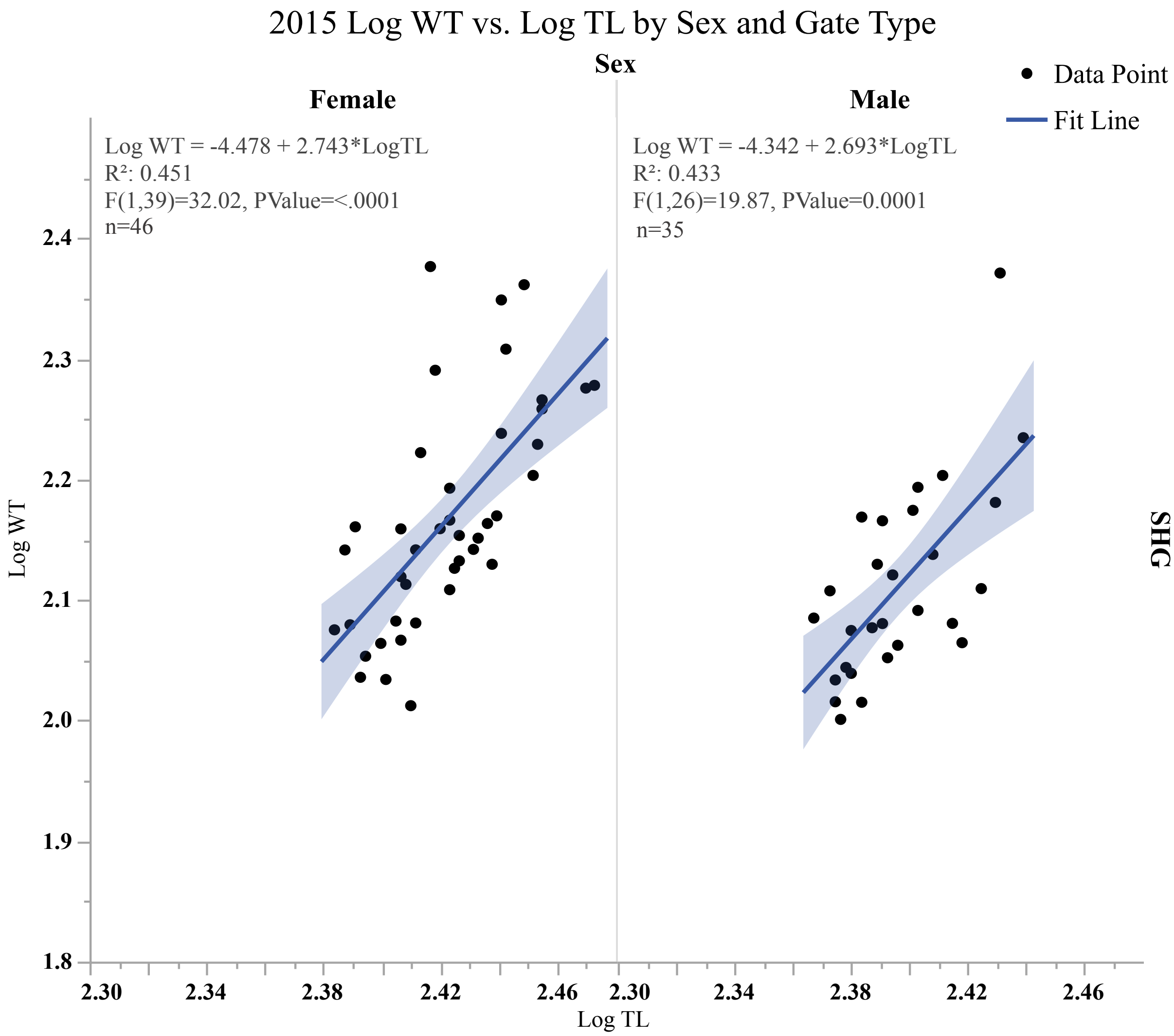

Figure 11. Log transformed somatic weight (g) and total length (mm) relationships based on sex and gate type of Alewife collected during the 2015 sampling period from the Waupoppin Canal Water Control Structure, Lake Mattamuskeet, North Carolina.

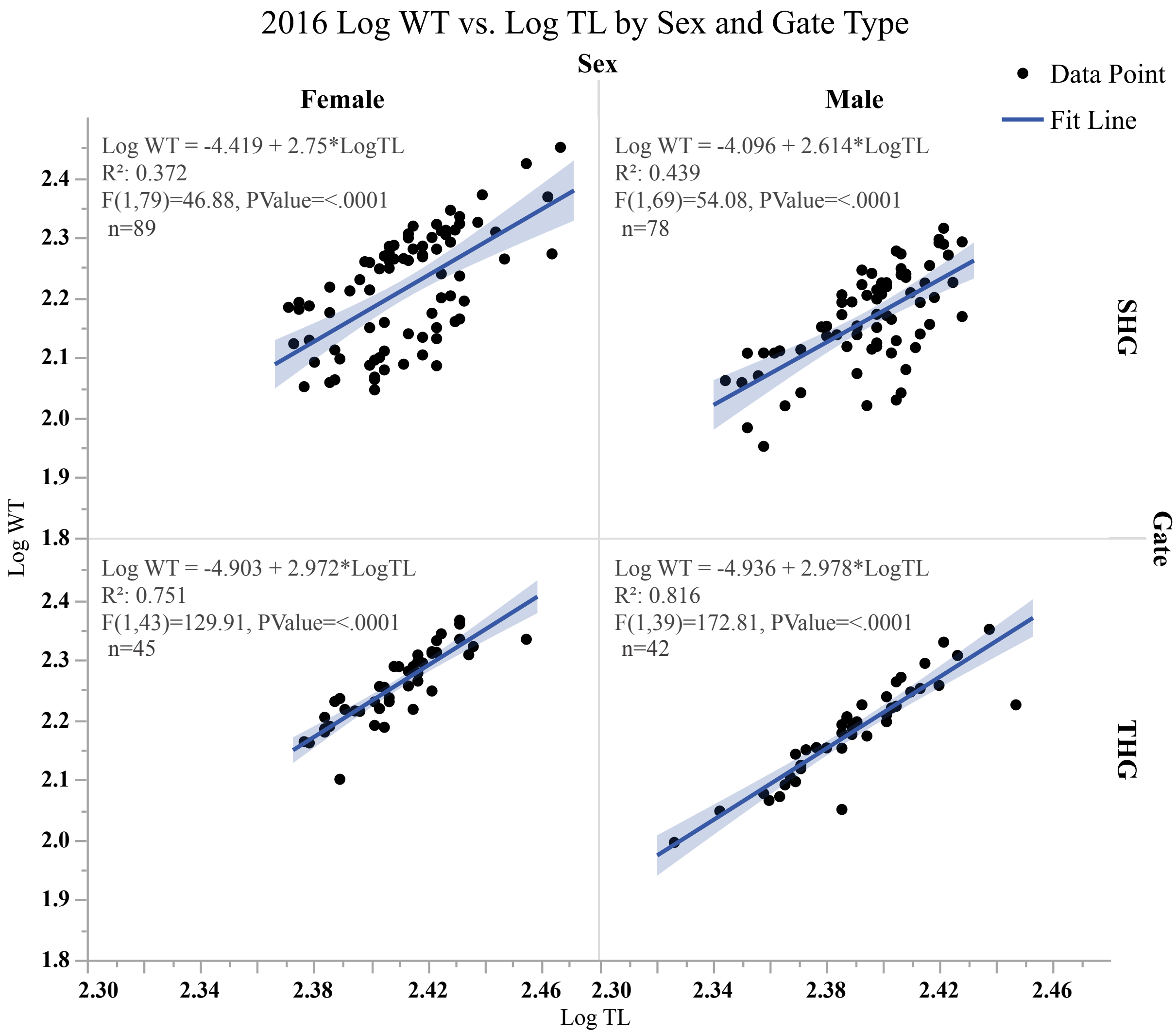

Figure 12. Log transformed weight and length ratios based on sex and gate type of Alewife collected during the 2016 sampling period from the Waupoppin Canal Water Control Structure, Lake Mattamuskeet, North Carolina. Not the large variability of Alewife passing through the side-hinged gate (SHG) compared to the top-hinged gate (THG).

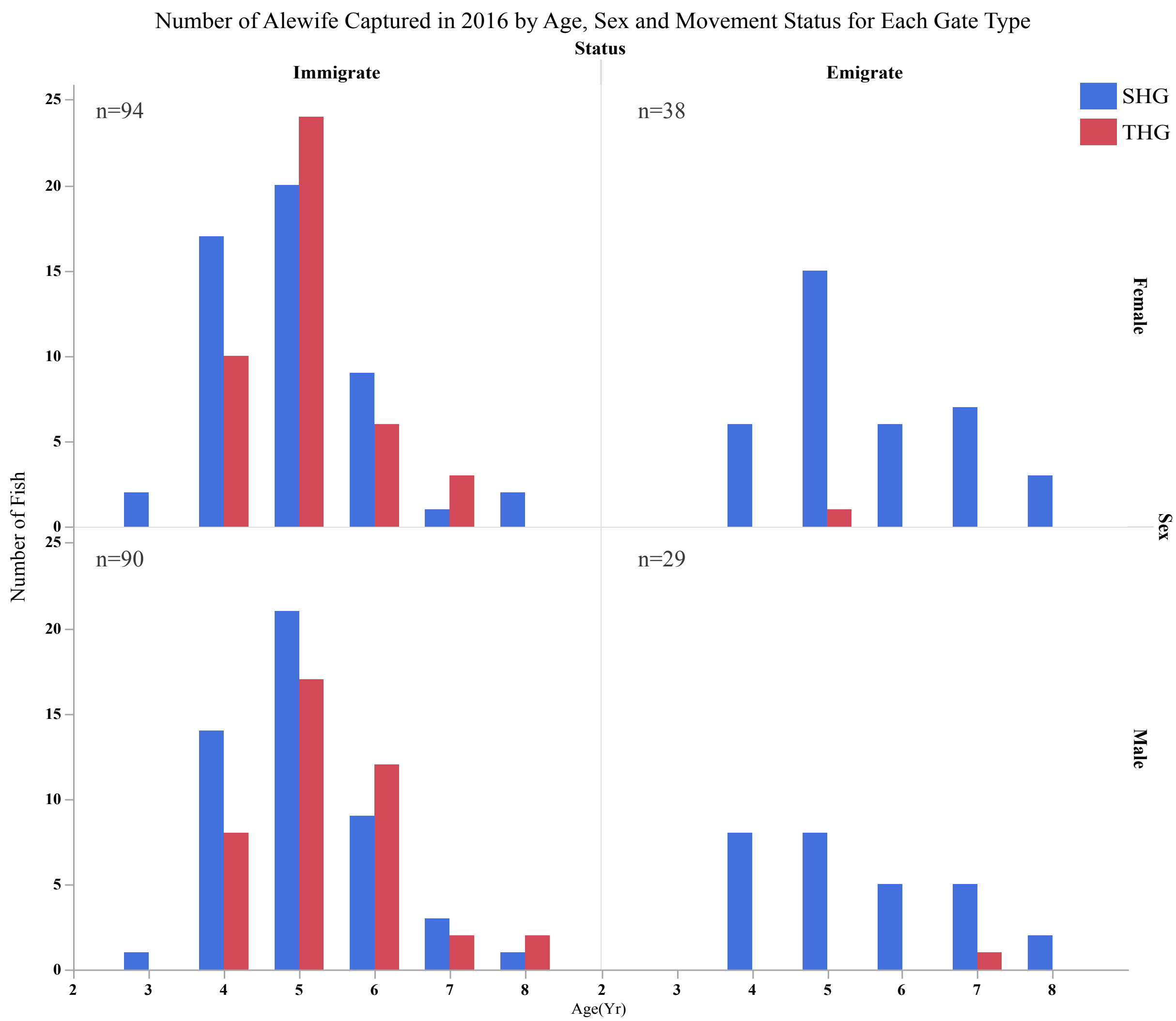

Figure 13. The number of Alewife that passed through each gate design depending on the movement direction, age and sex of the samples collected during the 2016 sampling period from the Waupoppin Canal Water Control Structure, Lake Mattamuskeet, North Carolina.

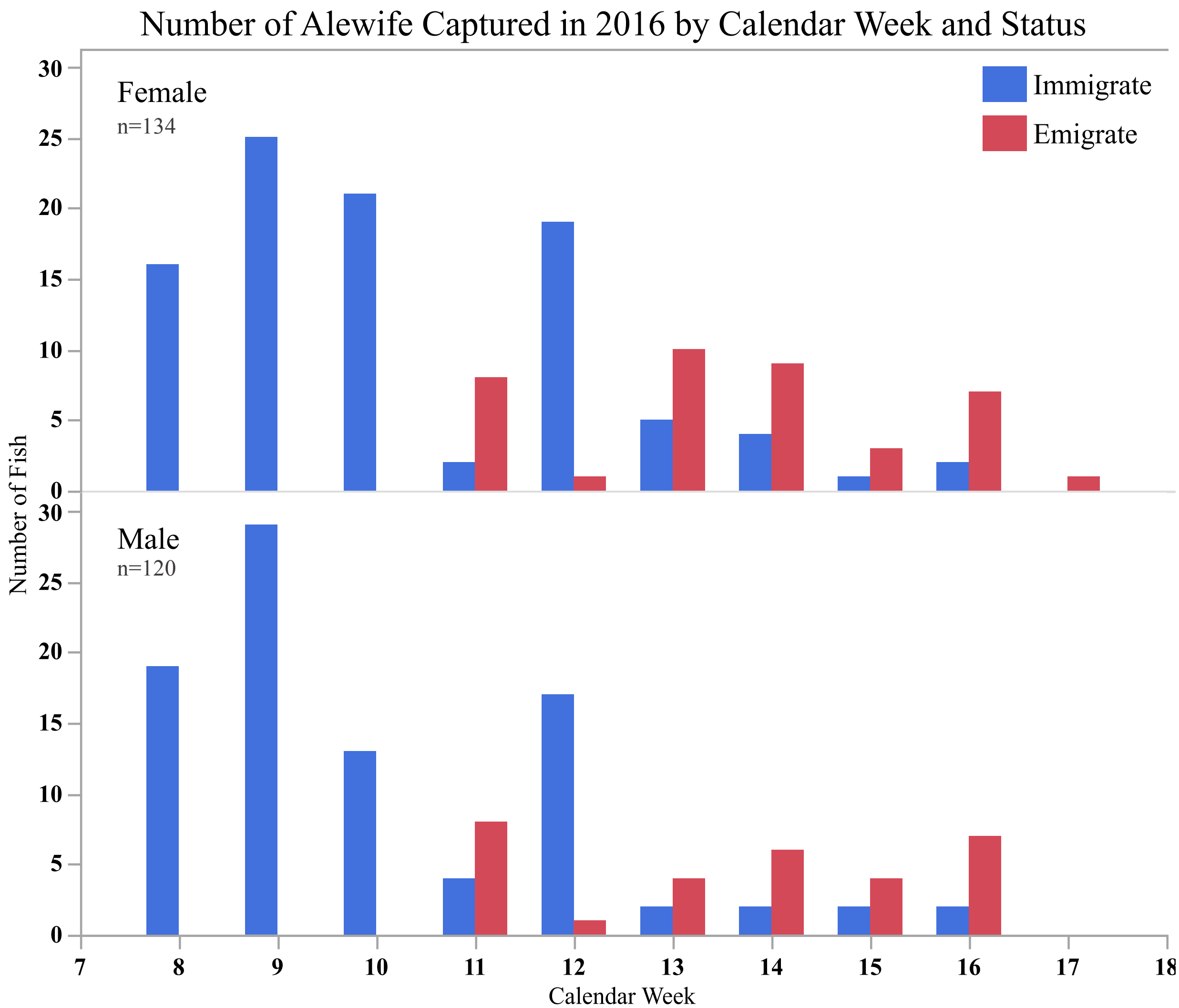

Figure 14. The number of Alewife captured by calendar week, sex and movement status during the 2016 sampling period from the Waupoppin Canal Water Control Structure, Lake Mattamuskeet, North Carolina. Calendar week 8= February; week 18= May.

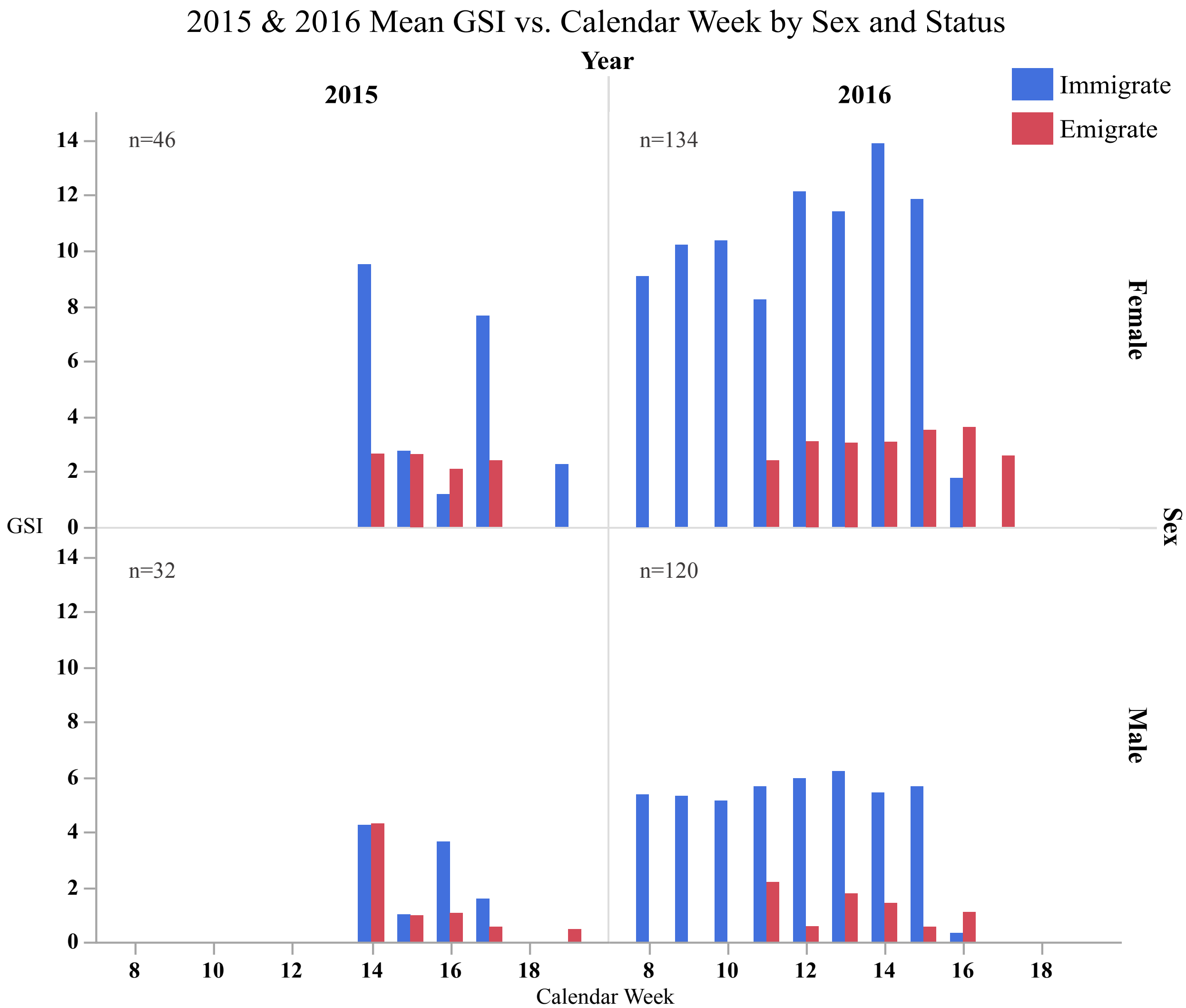

Figure 15. The mean GSI of Alewife captured by calendar week, sex and movement status during the 2015 and 2016 sampling periods from the Waupoppin Canal Water Control Structure, Lake Mattamuskeet, North Carolina. Calendar week 8= February; week 18= May.

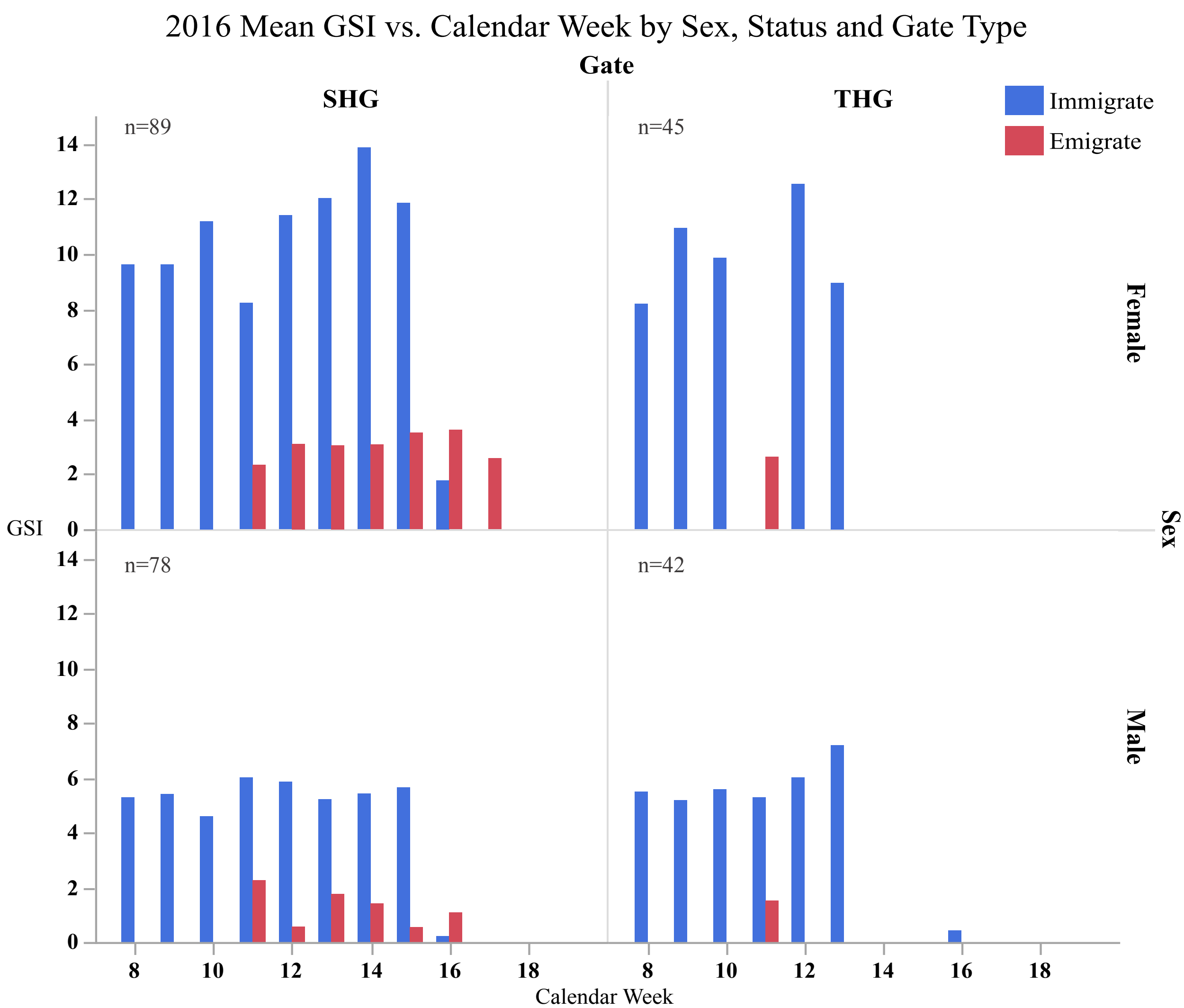

Figure 16. The mean GSI of Alewife captured by calendar week, sex, movement status and gate type during the 2016 sampling period from the Waupoppin Canal Water Control Structure, Lake Mattamuskeet, North Carolina. Calendar week 8= February; week 18= May.

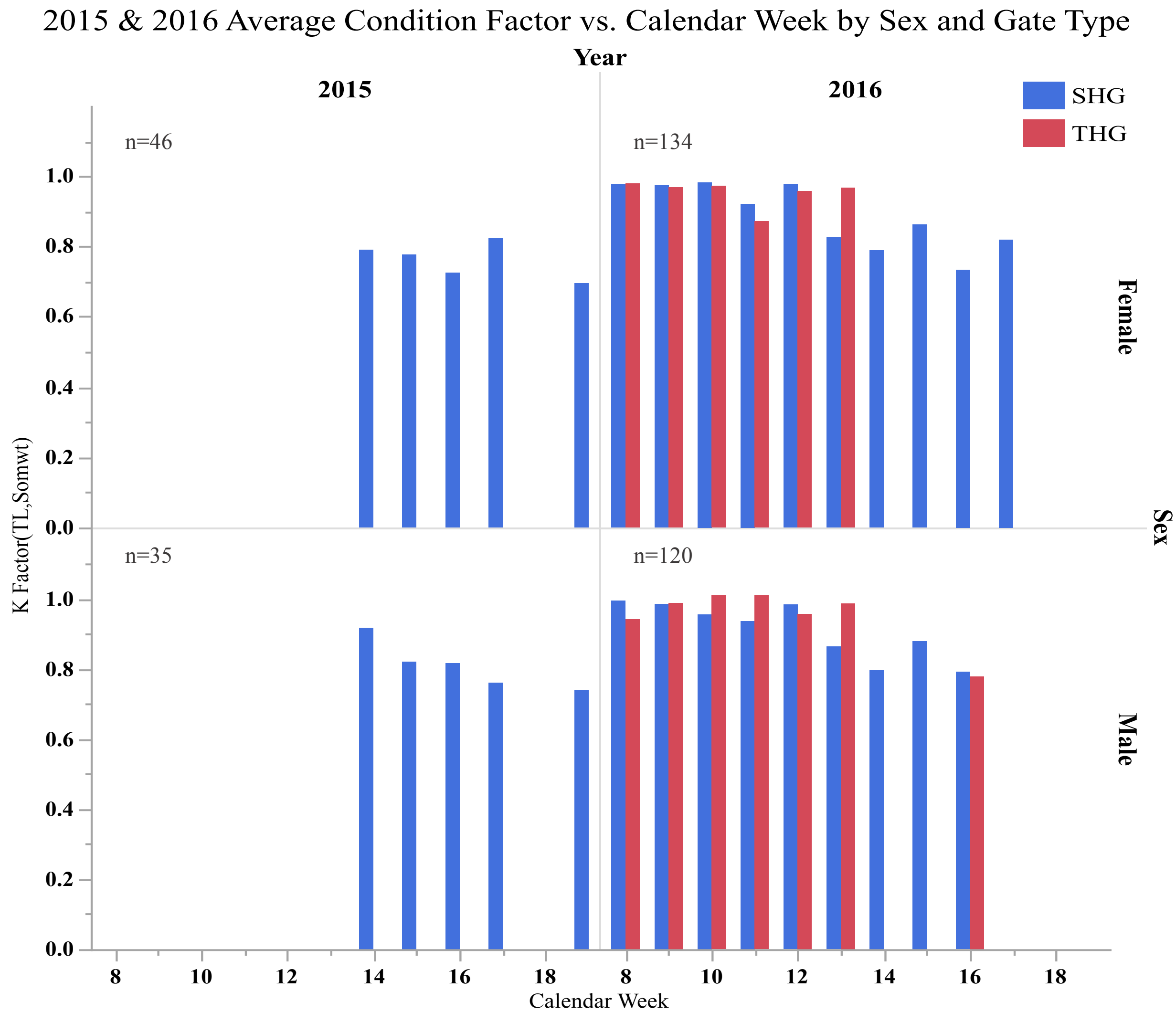

Figure 17. The mean condition factor by calendar week, sex and gate type of Alewife passage during the 2015 and 2016 sampling periods from the Waupoppin Canal Water Control Structure, Lake Mattamuskeet, North Carolina. Calendar week 8= February; week 18= May.

Tables

Table 1. Mean± SD total length, weight, GSI and condition factor by sex of Alewife collected during the 2015 and 2016 sampling periods from the Waupoppin Canal Water Control Structure, Lake Mattamuskeet, North Carolina.

Year	Sex	Number of Alewife (n)	Mean Total Length (mm)	Mean Weight (g)	Mean GSI	Mean Condition Factor (TL, Somwt)	Mean Condition Factor (FL, Somwt)	Mean Condition Factor (TL, Bodywt)	Mean Condition Factor (FL, Bodywt)
2015	Male	36	249± 11	125.93± 28.46	1.8± 1.7	0.83± 0.11	1.24± 0.16	0.84± 0.12	1.26± 0.17
	Female	46	265± 14	149.95± 33.50	3.9± 4.1	0.77± 0.12	1.15± 0.18	0.80± 0.14	1.20± 0.21
2016	Male	120	247± 12	150.54± 27.20	4.4± 2.1	0.94± 0.10	1.43± 0.15	0.99± 0.12	1.50± 0.18
	Female	134	258± 12	173.62± 33.20	8.3± 4.3	0.92± 0.11	1.38± 0.16	1.00± 0.15	1.52± 0.22

Table 2. Mean± SD total length, weight, GSI and condition factor of each sex and age of Alewife collected during the 2015 sampling period from the Waupoppin Canal Water Control Structure, Lake Mattamuskeet, North Carolina.

Sex	Age	Number of Alewife (n)	Mean TL (mm)	Mean Weight (g)	Mean GSI	Mean Condition Factor (TL, Somwt)	Mean Condition Factor (FL, Somwt)	Mean Condition Factor (TL, Bodywt)	Mean Condition Factor (FL, Bodywt)
Male	4	7	254± 11	126.59± 19.76	1.4± 1.5	0.77± 0.07	1.14± 0.09	0.79± 0.09	1.16± 0.11
	5	18	247± 23	127.76± 32.86	1.7± 1.7	0.85± 0.12	1.29± 0.16	0.87± 0.12	1.32± 0.17
	6	8	245± 8	128.88± 26.61	2.6± 1.9	0.88± 0.09	1.31± 0.10	0.90± 0.11	1.35± 0.13
	7	1	262± 0	116.02± 0	0.4± 0	0.64± 0	0.95± 0	0.65± 0	0.95± 0
	8	1	266± 0	128.65± 0	2.9± 0	0.66± 0	0.99± 0	0.68± 0	1.02± 0
	9	0	-	-	-	-	-	-	-
Female	4	6	261± 5	154.74± 42.01	1.9± 1.8	0.87± 0.26	1.31± 0.29	0.88± 0.26	1.32± 0.40
	5	22	263± 16	141.10± 26.37	3.3± 2.9	0.75± 0.08	1.12± 0.11	0.78± 0.10	1.16± 0.14
	6	8	267± 18	149.13± 33.10	4.2± 4.9	0.77± 0.06	1.14± 0.09	0.81± 0.10	1.20± 0.14
	7	8	172± 8	166.03± 36.53	6.0± 5.6	0.76± 0.12	1.15± 0.17	0.81± 0.17	1.23± 0.26
	8	1	258± 0	120.47± 0	1.1± 0	0.69± 0	0.98± 0	0.70± 0	0.99± 0
	9	1	276± 0	223.26± 0	14.3± 0	0.91± 0	1.37± 0	1.06± 0	1.60± 0

Table 3. Mean± SD total length, weight, GSI and condition factor of each sex and age of Alewife collected during the 2016 sampling period from the Waupoppin Canal Water Control Structure, Lake Mattamuskeet, North Carolina.

Sex	Age	Number of Alewife (n)	Mean TL (mm)	Mean Weight (g)	Mean GSI	Mean Condition Factor (TL, Somwt)	Mean Condition Factor (FL, Somwt)	Mean Condition Factor (TL, Bodywt)	Mean Condition Factor (FL, Bodywt)
Male	3	1	250± 0	148.60± 0	4.9± 0	0.91± 0	1.40± 0	0.95± 0	1.48± 0
	4	30	247± 15	149.73± 29.13	4.6± 2.2	0.94± 0.12	1.45± 0.18	0.98± 0.14	1.53± 0.21
	5	46	246± 13	148.98± 27.71	4.4± 2.0	0.95± 0.08	1.44± 0.12	0.99± 0.10	1.51± 0.15
	6	26	250± 10	156.76± 22.78	4.8± 2.1	0.95± 0.07	1.45± 0.11	1.00± 0.09	1.52± 0.13
	7	11	247± 12	140.46± 30.15	2.6± 2.2	0.92± 0.15	1.35± 0.24	0.95± 0.17	1.38± 0.27
	8	5	254± 10	158.59± 33.67	4.1± 2.6	0.92± 0.13	1.41± 0.18	0.97± 0.16	1.47± 0.22
Female	3	2	250± 18	174.28± 26.52	10.9± 0.7	1.00± 0.07	1.53± 0.12	1.12± 0.07	1.72± 0.12
	4	33	254± 11	171.98± 30.70	9.2± 3.5	0.93± 0.09	1.41± 0.14	1.03± 0.12	1.55± 0.18
	5	60	259± 12	179.19± 34.84	8.7± 4.3	0.93± 0.10	1.40± 0.15	1.03± 0.14	1.55± 0.20
	6	21	256± 11	166.11± 32.71	8.2± 4.7	0.90± 0.12	1.36± 0.18	0.99± 0.16	1.49± 0.24
	7	11	264± 14	168.90± 27.72	5.4± 3.9	0.87± 0.11	1.32± 0.17	0.92± 0.14	1.40± 0.22
	8	5	262± 7	143.74± 32.01	3.0± 3.4	0.76± 0.10	1.15± 0.16	0.79± 0.13	1.19± 0.21

Table 4. Mean± SD GSI and mean condition factor of each sex and movement status of Alewife collected during the 2015 and 2016 sampling periods from the Waupoppin Canal Water Control Structure, Lake Mattamuskeet, North Carolina.

Year	Sex	Movement Status	Number of Alewife (n)	Mean GSI	Mean Condition Factor (TL, Somwt)	Mean Condition Factor (FL, Somwt)	Mean Condition Factor (TL, Bodywt)	Mean Condition Factor (FL, Bodywt)
2015	Male	Immigrate	18	2.5± 1.9	0.83± 0.10	1.24± 0.13	0.86± 0.11	1.28± 0.15
		Emigrate	18	1.1± 1.0	0.82± 0.13	1.23± 0.19	0.83± 0.14	1.24± 0.19
	Female	Immigrate	14	7.2± 5.6	0.82± 0.10	1.22± 0.14	0.89± 0.15	1.33± 0.22
		Emigrate	32	2.4± 2.1	0.75± 0.12	1.12± 0.18	0.77± 0.12	1.14± 0.18
2016	Male	Immigrate	90	5.3± 1.2	0.98± 0.07	1.49± 0.10	1.03± 0.08	1.57± 0.12
		Emigrate	30	1.4± 1.5	0.84± 0.09	1.26± 0.14	0.85± 0.10	1.28± 0.15
	Female	Immigrate	95	10.5± 2.9	0.96± 0.07	1.46± 0.10	1.08± 0.08	1.63± 0.12
		Emigrate	39	3.1± 2.1	0.80± 0.09	1.19± 0.12	0.82± 0.10	1.23± 0.12

Table 5. Calendar week of each year and month of Alewife collected during the 2015 and 2016 sampling periods from the Waupoppin Canal Water Control Structure, Lake Mattamuskeet, North Carolina.

Year	Month	Calendar Week
2015	March	14
	April	14
		15
		16
		17
		18
	May	18
		19
2016	February	8
		9
	March	9
		10
		11
		12
		13
	April	13
		14
		15
		16
		17

Appendix

Date	Time	Calendar Week	Hours	Period	Fish Identification	Gate	Status	FL(mm)	TL(mm)	Wt(g)	Age(Yr)	Gonad wt(g)	Sex	GSI	K Factor (TL,Somwt)
20150405	830	14	13.5	Night	15WAUPAW01	SHG	Immigrate	217	246	146.44	6	5.55	M	3.79	0.95
20150405	830	14	13.5	Night	15WAUPAW02	SHG	Immigrate	241	276	223.26	9	32	F	14.33	0.91
20150405	830	14	13.5	Night	15WAUPAW03	SHG	Immigrate	213	242	147.48	6	6.71	M	4.55	0.99
20150405	830	14	13.5	Night	15WAUPAW04	SHG	Immigrate	215	246	144.76	5	12.29	F	8.49	0.89
20150507	830	19	13.75	Night	15WAUPAW05	SHG	Emigrate	207	238	100.21	4	0.45	M	0.45	0.74
20150507	830	19	13.75	Night	15WAUPAW06	SHG	Immigrate	236	271	141.66	5	3.22	F	2.27	0.70
20150417	1730	16	8	Day	15WAUPAW07	SHG	Immigrate	215	245	134.76	5	7.75	M	5.75	0.86
20150411	1800	15	9	Day	15WAUPAW08	SHG	Immigrate	233		146.68	6	4.02	F	2.74	
20150405	830	14	13.5	Night	15WAUPAW09	SHG	Emigrate	231	265	128.38	7	2.62	F	2.04	0.68
20150405	830	14	13.5	Night	15WAUPAW10	SHG	Emigrate	260	297	189.66	5	8.17	F	4.31	0.69
20150405	830	14	13.5	Night	15WAUPAW11	SHG	Emigrate	247	283	159.69	7	3.55	F	2.22	0.69
20150405	830	14	13.5	Night	15WAUPAW12	SHG	Emigrate	244	276	173.04	6	4.58	F	2.65	0.80
20150405	830	14	13.5	Night	15WAUPAW13	SHG	Emigrate	233	267	135.65	4	2.68	F	1.98	0.70
20150405	830	14	13.5	Night	15WAUPAW14	SHG	Immigrate	221	252	108.15	5	2.13	F	1.97	0.66
20150411	1800	15	9	Day	15WAUPAW15	SHG	Emigrate	233	265	155.84	5	3.38	F	2.17	0.82
20150411	1800	15	9	Day	15WAUPAW16	SHG	Emigrate	223	254	120.91	4	2.09	F	1.73	0.73
20150411	1800	15	9	Day	15WAUPAW17	SHG	Emigrate	205	240	109.42	5	0.99	M	0.9	0.78
20150417	700	16	11	Night	15WAUPAW18	SHG	Emigrate	233	266	128.65	8	3.76	M	2.92	0.66
20150417	700	16	11	Night	15WAUPAW19	SHG	Emigrate	222	255	144.19	5	1.23	F	0.85	0.86
20150417	700	16	11	Night	15WAUPAW20	SHG	Emigrate	227	258	159.68	6	2.58	M	1.62	0.91
20150417	700	16	11	Night	15WAUPAW21	SHG	Emigrate	236	270	138.65	7	3.52	F	2.54	0.69
20150417	700	16	11	Night	15WAUPAW22	SHG	Emigrate	233	267	142.39	5	5.67	F	3.98	0.72
20150417	1730	16	8	Day	15WAUPAW23	SHG	Emigrate	241	273	145.68	5	5.43	F	3.73	0.69
20150417	1730	16	8	Day	15WAUPAW24	SHG	Emigrate			151.14	4	8	F	5.29	
20150417	1730	16	8	Day	15WAUPAW25	SHG	Emigrate	251	285	181.31	6	5.46	F	3.01	0.76
20150404	715	14	12.25	Night	15WAUPAW26	SHG	Immigrate	230	262	195.21	7	22.94	F	11.75	0.96
20150404	715	14	12.25	Night	15WAUPAW27	SHG	Emigrate	205	236	128.1	5	5.51	M	4.3	0.93
20150404	1700	14	8	Day	15WAUPAW28	SHG	Immigrate	223	252	149.39	4	7.11	M	4.76	0.89
20150404	1700	14	8	Day	15WAUPAW29	SHG	Immigrate	214	244	138.5	5	8.77	F	6.33	0.89
20150404	1700	14	8	Day	15WAUPAW30	SHG	Immigrate	242	277	203.24	6	28.61	F	14.08	0.82
20150404	1700	14	8	Day	15WAUPAW31	SHG	Immigrate	214	248	132.06	5	5.16	M	3.91	0.83

20150411	700	15	12	Night	15WAUPAW32	SHG	Immigrate	220	253	123.39	5	1.22	M	0.99	0.75
20150418	700	16	12	Night	15WAUPAW36	SHG	Immigrate	207	239	110.67	5	0.64	M	0.58	0.81
20150423	1830	17	7.5	Day	15WAUPAW37	SHG	Emigrate	221		119.12	5	2.86	F	2.4	
20150410	1830	15	9.5	Day	15WAUPAW38	SHG	Immigrate	208	237	108.05	6	1.09	M	1.01	0.80
20150410	1830	15	9.5	Day	15WAUPAW39	SHG	Immigrate	207		111.71	4	1.27	M	1.14	
20150410	1830	15	9.5	Day	15WAUPAW40	SHG	Immigrate	214	244	119.38	5	1.4	M	1.17	0.81
20150410	1830	15	9.5	Day	15WAUPAW41	SHG	Emigrate	247	284	169.46	5	1.87	F	1.1	0.73
20150410	1830	15	9.5	Day	15WAUPAW42	SHG	Emigrate	233	256	137.32	4	2.03	M	1.48	0.81
20150410	1830	15	9.5	Day	15WAUPAW43	SHG	Emigrate	258	295	188.66	5	2.68	F	1.42	0.72
20150410	1830	15	9.5	Day	15WAUPAW44	SHG	Emigrate	238	270	235.04	5	2.27	M	0.97	1.18
20150410	1830	15	9.5	Day	15WAUPAW45	SHG	Emigrate	227	261	237.97	4	2.75	F	1.16	1.32
20150410	1830	15	9.5	Day	15WAUPAW46	SHG	Emigrate	215	247	108.6	5	4.61	F	4.24	0.69
20150410	1830	15	9.5	Day	15WAUPAW47	SHG	Emigrate	230	263	144.24	4	1.04	F	0.72	0.79
20150410	1830	15	9.5	Day	15WAUPAW48	SHG	Emigrate	216	248	113.06	5	2.46	F	2.18	0.73
20150416	1930	16	11.25	Day	15WAUPAW49	SHG	Emigrate	252	285	184.5	5	3.42	F	1.85	0.78
20150418	700	16	12	Night	15WAUPAW50	SHG	Emigrate			92.74	5	0.7	M	0.75	
20150418	700	16	12	Night	15WAUPAW51	SHG	Emigrate			109.26	5	1.12	M	1.03	
20150418	700	16	12	Night	15WAUPAW52	SHG	Emigrate	242	275	171.62	5	0.64	M	0.37	0.82
20150418	700	16	12	Night	15WAUPAW53	SHG	Emigrate	206	242	103.54	6	0.4	M	0.39	0.73
20150418	700	16	12	Night	15WAUPAW54	SHG	Emigrate			73.8		0.18	M	0.24	
20150418	700	16	12	Night	15WAUPAW55	SHG	Emigrate			115.03	6	0.68	F	0.59	
20150418	700	16	12	Night	15WAUPAW56	SHG	Emigrate	240	274	134.76	6	0.85	F	0.63	0.65
20150418	700	16	12	Night	15WAUPAW57	SHG	Emigrate	215	257	102.87	5	0.29	F	0.28	0.60
20150418	700	16	12	Night	15WAUPAW58	SHG	Emigrate	225	258	138.53	4	0.27	F	0.19	0.81
20150423	1830	17	7.5	Day	15WAUPAW59	SHG	Immigrate	222	251	115.87	5	0.57	F	0.49	0.73
20150423	1830	17	7.5	Day	15WAUPAW60	SHG	Immigrate	223	259	166.79	5	18.51	F	11.1	0.85
20150423	1830	17	7.5	Day	15WAUPAW61	SHG	Immigrate	247	281	229.86	7	31.04	F	13.5	0.90
20150423	1830	17	7.5	Day	15WAUPAW62	SHG	Immigrate	205	237	103.64	5	0.93	M	0.9	0.77
20150423	1830	17	7.5	Day	15WAUPAW63	SHG	Immigrate	213	245	120.06	6	0.34	F	0.28	0.81
20150411	700	15	12	Night	15WAUPAW64	SHG	Emigrate	236	269	151.66	4	0.59	M	0.39	0.78
20150411	700	15	12	Night	15WAUPAW65	SHG	Emigrate	242	275	147.82	7	1.91	F	1.29	0.70
20150411	700	15	12	Night	15WAUPAW66	SHG	Emigrate	225	256	129.69	5	2.32	F	1.79	0.76
20150411	700	15	12	Night	15WAUPAW67	SHG	Emigrate	218	249	115.45	4	0.87	M	0.75	0.74

20150411	700	15	12	Night	15WAUPAW68	SHG	Emigrate	225	255	131.6	5	11.42	F	8.68	0.72
20150411	700	15	12	Night	15WAUPAW69	SHG	Emigrate	133	165	160.74	5	2.02	M	1.26	3.53
20150411	700	15	12	Night	15WAUPAW70	SHG	Emigrate	213	242	118.91	6	10.99	F	9.24	0.76
20150410	800	15	13	Night	15WAUPAW71	SHG	Immigrate			106.86	5	0.75	M	0.7	
20150416	1930	16	11.25	Day	15WAUPAW72	SHG	Immigrate	209	240	118.76	6	4.59	M	3.86	0.83
20150416	1930	16	11.25	Day	15WAUPAW73	SHG	Immigrate	223	255	116.58	5	1.37	F	1.18	0.69
20150416	1930	16	11.25	Day	15WAUPAW74	SHG	Immigrate	203	233	121.61	5	5.33	M	4.38	0.92
20150424	700	17	11.5	Night	15WAUPAW75	SHG	Immigrate	235		194.86	7	25	F	12.83	
20150424	700	17	11.5	Night	15WAUPAW76	SHG	Emigrate	212	246	120.34	5	0.66	M	0.55	0.80
20150424	1800	17	7	Day	15WAUPAW77	SHG	Immigrate	230	262	116.02	7	0.48	M	0.41	0.64
20150424	1800	17	7	Day	15WAUPAW78	SHG	Immigrate	222	253	156.11	6	7.83	M	5.02	0.92
20150424	1800	17	7	Day	15WAUPAW79	SHG	Immigrate			91	6	0.5	M	0.55	
20150424	1800	17	7	Day	15WAUPAW80	SHG	Immigrate	227	260	120.38	4	1.13	M	0.94	0.68
20150410	800	15	13	Night	15WAUPAW81	SHG	Emigrate	234	265	146.61	5	1.04	F	0.71	0.78
20150410	800	15	13	Night	15WAUPAW82	SHG	Emigrate			140.23	5	1.24	M	0.88	
20150410	800	15	13	Night	15WAUPAW83	SHG	Emigrate	215	247	112.73	5	1.16	M	1.03	0.74
20150410	800	15	13	Night	15WAUPAW84	SHG	Emigrate	230	258	120.47	8	1.29	F	1.07	0.69
20150410	800	15	13	Night	15WAUPAW85	SHG	Emigrate	235	266	133.73	7	2.72	F	2.03	0.70
20160318	2330	11	6.75	Night	16WAUPAW01	SHG	Emigrate	220	250	141.27	6	1.38	M	0.98	0.90
20160318	2330	11	6.75	Night	16WAUPAW02	SHG	Emigrate	232	266	173.58	5	5.25	F	3.02	0.89
20160318	2330	11	6.75	Night	16WAUPAW03	SHG	Emigrate	217	250	133.11	6	1.54	M	1.16	0.84
20160318	2330	11	6.75	Night	16WAUPAW04	SHG	Emigrate	221	252	147.92	5	0.86	M	0.58	0.92
20160319	830	11	8.75	Night	16WAUPAW06	SHG	Emigrate	230	262	158.49	5	1.89	M	1.19	0.87
20160319	830	11	8.75	Night	16WAUPAW07	SHG	Emigrate	255	290	233.18	7	6.47	F	2.77	0.93
20160319	830	11	8.75	Night	16WAUPAW08	SHG	Emigrate	237	270	172.1	5	2.44	F	1.42	0.86
20160319	830	11	8.75	Night	16WAUPAW09	SHG	Emigrate	233	263	198.07	4	15.94	M	8.05	1.00
20160407	1900	14	9.25	Day	16WAUPAW100	SHG	Emigrate	214	245	125.21	5	1.82	F	1.45	0.84
20160407	1900	14	9.25	Day	16WAUPAW102	SHG	Emigrate	224	258	122.71	5	2.76	F	2.25	0.70
20160407	1900	14	9.25	Day	16WAUPAW103	SHG	Emigrate	218	253	125.82	5	4.57	F	3.63	0.75
20160407	1900	14	9.25	Day	16WAUPAW104	SHG	Emigrate	215	249	130.01	4	3.56	M	2.74	0.82
20160325	1730	12	8.25	Day	16WAUPAW105	SHG	Immigrate	225		160.94	5	8.5	F	5.28	
20160325	1730	12	8.25	Day	16WAUPAW106	SHG	Immigrate	205	237	155.52	3	16.16	F	10.39	1.05
20160325	1730	12	8.25	Day	16WAUPAW107	SHG	Immigrate	217		180.59	4	12.17	M	6.74	

20160325	1730	12	8.25	Day	16WAUPAW108	SHG	Immigrate	208	237	151.48	4	16.19	F	10.69	1.02
20160401	1700	13	6	Day	16WAUPAW109	SHG	Immigrate	221	255	177.36	5	16.53	F	9.32	0.97
20160319	2130	11	3.75	Night	16WAUPAW11	THG	Emigrate	213	245	126.1	5	2.8	F	2.22	0.84
20160401	1700	13	6	Day	16WAUPAW110	SHG	Immigrate	220	252	167.74	6	8.74	M	5.21	0.99
20160401	1700	13	6	Day	16WAUPAW111	SHG	Immigrate	222		172.04	5	18.27	F	10.62	
20160401	1700	13	6	Day	16WAUPAW112	SHG	Emigrate	254	291	187.36	5	3.01	F	1.61	0.75
20160401	1700	13	6	Day	16WAUPAW113	SHG	Emigrate	199	232	104.61	4	2.3	M	2.2	0.82
20160401	1700	13	6	Day	16WAUPAW114	SHG	Emigrate	207	236	132.73	4	14.23	F	10.72	0.90
20160407	830	14	13.5	Night	16WAUPAW115	SHG	Emigrate	225	268	147.32	5	1.91	M	1.3	0.76
20160407	830	14	13.5	Night	16WAUPAW116	SHG	Emigrate	230	265	135.32	6	2.85	F	2.11	0.71
20160407	830	14	13.5	Night	16WAUPAW117	SHG	Emigrate	223	255	109.9	4	1.53	M	1.39	0.65
20160407	830	14	13.5	Night	16WAUPAW118	SHG	Emigrate	194	225	96.15	5	1.44	M	1.5	0.83
20160407	830	14	13.5	Night	16WAUPAW119	SHG	Emigrate	224	259	137.87	6	1.63	F	1.18	0.78
20160319	2130	11	3.75	Night	16WAUPAW12	THG	Emigrate	246	285	215.77		6.51	F	3.02	0.90
20160407	830	14	13.5	Night	16WAUPAW120	SHG	Emigrate	225	259	137.78	5	1.75	M	1.27	0.78
20160325	730	12	13.25	Night	16WAUPAW121	THG	Immigrate	228	261	189.46	6	25.97	F	13.71	0.92
20160325	730	12	13.25	Night	16WAUPAW122	THG	Immigrate	231	264	204.51	5	29.67	F	14.51	0.95
20160325	730	12	13.25	Night	16WAUPAW123	THG	Immigrate	210	242	151.16	5	18.14	F	12	0.94
20160325	730	12	13.25	Night	16WAUPAW124	THG	Immigrate	215	245	153.7	6	10.51	M	6.84	0.97
20160325	730	12	13.25	Night	16WAUPAW125	THG	Immigrate	230	264	205.75	5	13.24	F	6.43	1.05
20160325	730	12	13.25	Night	16WAUPAW126	THG	Immigrate	210	242	159.98	6	17.77	F	11.11	1.00
20160325	730	12	13.25	Night	16WAUPAW127	THG	Immigrate	204	235	133.05	6	6.73	M	5.06	0.97
20160324	945	12	13.75	Night	16WAUPAW128	THG	Immigrate	228	263	180.79	6	13.83	M	7.65	0.92
20160324	945	12	13.75	Night	16WAUPAW129	THG	Immigrate	192	220	111.62	5	5.93	M	5.31	0.99
20160319	830	11	8.75	Night	16WAUPAW13	SHG	Immigrate	196	225	128	4	6.74	M	5.27	1.06
20160324	945	12	13.75	Night	16WAUPAW130	THG	Immigrate	217	246	164.82	5	18.44	F	11.19	0.98
20160324	945	12	13.75	Night	16WAUPAW131	THG	Immigrate	219	252	161.34	6	9.04	M	5.6	0.95
20160324	945	12	13.75	Night	16WAUPAW132	THG	Immigrate	204	235	131.34	6	8.59	M	6.54	0.95
20160324	945	12	13.75	Night	16WAUPAW133	THG	Immigrate	226	259	180.39	5	27.27	F	15.12	0.88
20160324	945	12	13.75	Night	16WAUPAW134	THG	Immigrate	223	257	176.29	6	10.16	M	5.76	0.98
20160324	945	12	13.75	Night	16WAUPAW135	THG	Immigrate	224	256	194.4	5	27.18	F	13.98	1.00
20160324	945	12	13.75	Night	16WAUPAW136	THG	Immigrate	223	253	165.78	5	9.01	M	5.43	0.97
20160324	945	12	13.75	Night	16WAUPAW137	THG	Immigrate	237	273	209.86	5	35.13	F	16.74	0.86

20160324	945	12	13.75	Night	16WAUPAW138	THG	Immigrate	224	255	169.86	4	16.12	F	9.49	0.93
20160311	1830	10	10.5	Day	16WAUPAW139	THG	Immigrate	225	257	194.27	4	22.93	F	11.8	1.01
20160319	830	11	8.75	Night	16WAUPAW14	SHG	Immigrate	219	256	193.63	5	25.41	F	13.12	1.00
20160311	1830	10	10.5	Day	16WAUPAW140	THG	Immigrate	215	247	167.81	6	10.59	M	6.31	1.04
20160311	1830	10	10.5	Day	16WAUPAW141	THG	Immigrate	220	252	155.08	4	16.23	F	10.47	0.87
20160311	1830	10	10.5	Day	16WAUPAW142	THG	Immigrate	184	212	98.96	4	5.09	M	5.14	0.99
20160311	1830	10	10.5	Day	16WAUPAW143	THG	Immigrate	220	253	165.37	6	23.92	F	14.46	0.87
20160311	1800	10	10.5	Day	16WAUPAW144	SHG	Immigrate	216	245	155.81	6	6.92	M	4.44	1.01
20160311	1800	10	10.5	Day	16WAUPAW145	SHG	Immigrate	218	251	181.23	5	17.12	F	9.45	1.04
20160311	1800	10	10.5	Day	16WAUPAW146	SHG	Immigrate	236	269	205.34	5	19.64	F	9.56	0.95
20160311	1800	10	10.5	Day	16WAUPAW147	SHG	Immigrate	214	246	142.09	4	7.16	M	5.04	0.91
20160311	1800	10	10.5	Day	16WAUPAW148	SHG	Immigrate	195	224	114.33	5	5.1	M	4.46	0.97
20160311	1800	10	10.5	Day	16WAUPAW149	SHG	Immigrate	218	250	181.82	4	21.92	F	12.06	1.02
20160319	830	11	8.75	Night	16WAUPAW15	SHG	Immigrate	206	247	176.08	4	11.89	M	6.75	1.09
20160226	2000	8	11	Day	16WAUPAW150	THG	Immigrate	213	254	153.95	5	13.77	F	8.94	0.86
20160226	2000	8	11	Day	16WAUPAW151	THG	Immigrate	233	266	220.34	4	13.11	F	5.95	1.10
20160302	845	9	11.75	Night	16WAUPAW152	SHG	Immigrate	207		151.08	4	10.4	M	6.88	
20160302	1730	9	8.25	Day	16WAUPAW153	SHG	Immigrate	229	262	186.52	4	23.59	F	12.65	0.91
20160302	1730	9	8.25	Day	16WAUPAW154	SHG	Immigrate	214	243	149.55	4	18.04	F	12.06	0.92
20160302	1730	9	8.25	Day	16WAUPAW155	SHG	Immigrate	216		161.23	5	15.56	F	9.65	
20160302	1900	9	9.75	Day	16WAUPAW156	THG	Immigrate	230	260	191.42	6	22.24	F	11.62	0.96
20160302	1900	9	9.75	Day	16WAUPAW157	THG	Immigrate	219	252	173.1	7	8.16	M	4.71	1.03
20160302	1900	9	9.75	Day	16WAUPAW158	THG	Immigrate	242	274	224.2	5	14.5	M	6.47	1.02
20160302	1900	9	9.75	Day	16WAUPAW159	THG	Immigrate	200	231	117.99	5	4.73	M	4.01	0.92
20160319	1800	11	8.5	Day	16WAUPAW16	SHG	Emigrate	211	253	145.79	6	1.6	M	1.1	0.89
20160302	1900	9	9.75	Day	16WAUPAW160	THG	Immigrate	236	270	232.16	5	24.51	F	10.56	1.05
20160302	915	9	12.25	Night	16WAUPAW161	THG	Immigrate	227	262	197.09	6	23.02	F	11.68	0.97
20160302	915	9	12.25	Night	16WAUPAW162	THG	Immigrate	227	260	196.74	5	14.27	M	7.25	1.04
20160302	915	9	12.25	Night	16WAUPAW163	THG	Immigrate	215	246	157.22	5	8.47	M	5.39	1.00
20160302	915	9	12.25	Night	16WAUPAW164	THG	Immigrate	226	259	190.87	5	22.26	F	11.66	0.97
20160302	915	9	12.25	Night	16WAUPAW165	THG	Immigrate	200	229	116.29	5	6.27	M	5.39	0.92
20160302	915	9	12.25	Night	16WAUPAW166	THG	Immigrate	204	236	141.21	5	5.31	M	3.76	1.03
20160302	915	9	12.25	Night	16WAUPAW167	THG	Immigrate	235	270	215.82	5	24.93	F	11.55	0.97

20160303	1745	9	7	Day	16WAUPAW168	THG	Immigrate	231	265	205.21	5	25.99	F	12.67	0.96
20160303	1745	9	7	Day	16WAUPAW169	THG	Immigrate	230	261	198.18	4	16.52	F	8.34	1.02
20160319	1800	11	8.5	Day	16WAUPAW17	SHG	Emigrate	225	259	155.5		4.29	M	2.76	0.87
20160303	1745	9	7	Day	16WAUPAW170	THG	Immigrate	201	232	123.45	5	5	M	4.05	0.95
20160303	1745	9	7	Day	16WAUPAW171	THG	Immigrate	212	245	149.77	6	8.92	M	5.96	0.96
20160303	1745	9	7	Day	16WAUPAW172	THG	Immigrate	211	243	142.07	5	6.43	M	4.53	0.95
20160303	1700	9	7	Day	16WAUPAW173	SHG	Immigrate	228		190.11	4	13.35	F	7.02	
20160303	1700	9	7	Day	16WAUPAW174	SHG	Immigrate	200	230	128.06	4	4.54	M	3.55	1.02
20160303	1700	9	7	Day	16WAUPAW175	SHG	Immigrate	225	255	182.5	5	14.13	F	7.74	1.02
20160303	1700	9	7	Day	16WAUPAW176	SHG	Immigrate	216	249	169.72	5	17.64	F	10.39	0.99
20160303	1700	9	7	Day	16WAUPAW177	SHG	Immigrate	206	239	134.53	4	6.54	F	4.86	0.94
20160226	2030	8	10.5	Day	16WAUPAW178	SHG	Immigrate	216	250	163.24	5	9.39	M	5.75	0.98
20160226	2030	8	10.5	Day	16WAUPAW179	SHG	Immigrate	225		184.63	5	11.8	M	6.39	
20160319	1800	11	8.5	Day	16WAUPAW18	SHG	Emigrate	229	265	141.16	7	2.19	F	1.55	0.75
20160226	2030	8	10.5	Day	16WAUPAW180	SHG	Immigrate	225		186.75	4	17.42	F	9.33	
20160226	2030	8	10.5	Day	16WAUPAW181	SHG	Immigrate	228	262	193.03	3	22.06	F	11.43	0.95
20160226	2030	8	10.5	Day	16WAUPAW182	SHG	Immigrate	233	268	196	8	17.92	F	9.14	0.93
20160226	2030	8	10.5	Day	16WAUPAW183	SHG	Immigrate	230	264	194.39	6	8.31	M	4.27	1.01
20160226	2030	8	10.5	Day	16WAUPAW184	SHG	Immigrate	231	267	205.11	5	28.6	F	13.94	0.93
20160226	2030	8	10.5	Day	16WAUPAW185	SHG	Immigrate	223	258	183.99	6	16.83	F	9.15	0.97
20160226	2030	8	10.5	Day	16WAUPAW186	SHG	Immigrate	212	243	155.56	5	7.52	M	4.83	1.03
20160226	2030	8	10.5	Day	16WAUPAW187	SHG	Immigrate	220	251	166.06	4	11.64	M	7.01	0.98
20160303	1700	9	7	Day	16WAUPAW188	SHG	Immigrate	225	259	199.22	6	23.42	F	11.76	1.01
20160303	1700	9	7	Day	16WAUPAW189	SHG	Immigrate	233	268	196.19	4	12.08	M	6.16	0.96
20160303	1700	9	7	Day	16WAUPAW190	SHG	Immigrate	224	256	183.72	5	17.35	F	9.44	0.99
20160303	1700	9	7	Day	16WAUPAW191	SHG	Immigrate	220	255	177.04	5	12.65	M	7.15	0.99
20160303	1700	9	7	Day	16WAUPAW192	SHG	Immigrate	219	250		5	7.46	M		
20160303	1700	9	7	Day	16WAUPAW193	SHG	Immigrate	236	266	204.56	5	15.85	F	7.75	1.00
20160303	1700	9	7	Day	16WAUPAW194	SHG	Immigrate	230	265	186.49	5	9.81	M	5.26	0.95
20160303	1700	9	7	Day	16WAUPAW195	SHG	Immigrate	225	255	187.35	5	9.23	M	4.93	1.07
20160303	1700	9	7	Day	16WAUPAW196	SHG	Immigrate	230	265	190.79	4	19.98	F	10.47	0.92
20160303	1700	9	7	Day	16WAUPAW197	SHG	Immigrate	197	227	117.38	5	4.32	M	3.68	0.97
20160303	1700	9	7	Day	16WAUPAW198	SHG	Immigrate	223	255	173	5	7.88	M	4.55	1.00

20160310	830	10	12	Night	16WAUPAW199	SHG	Immigrate	247	285	264.87	5	36.48	F	13.77	0.99
20160319	1800	11	8.5	Day	16WAUPAW20	SHG	Immigrate	200	240	123.64	6	4.11	F	3.32	0.86
20160310	830	10	12	Night	16WAUPAW200	SHG	Immigrate	209	240	136.7	4	7.17	M	5.25	0.94
20160310	830	10	12	Night	16WAUPAW201	SHG	Immigrate	217	247	162.55	4	19.04	F	11.71	0.95
20160310	830	10	12	Night	16WAUPAW202	SHG	Immigrate	216	250	148.6	3	7.27	M	4.89	0.90
20160310	800	10	11.5	Night	16WAUPAW203	THG	Immigrate	220	255	172.39	4	17.01	F	9.87	0.94
20160310	800	10	11.5	Night	16WAUPAW204	THG	Immigrate	212	242	153.05	5	10.44	F	6.82	1.01
20160310	800	10	11.5	Night	16WAUPAW205	THG	Immigrate	227	261	183.81	4	14.14	F	7.69	0.95
20160310	800	10	11.5	Night	16WAUPAW206	THG	Immigrate	212	244	159.17	4	10.51	M	6.6	1.02
20160310	800	10	11.5	Night	16WAUPAW207	THG	Immigrate	218	252	169.7	4	16.08	F	9.48	0.96
20160310	800	10	11.5	Night	16WAUPAW208	THG	Immigrate	211	245	171.92	4	19.43	F	11.3	1.04
20160310	800	10	11.5	Night	16WAUPAW209	THG	Immigrate	224	260	194.31	5	16.56	F	8.52	1.01
20160319	2145	11	3.75	Day	16WAUPAW21	SHG	Emigrate	235	278	203.74	7	4.91	F	2.54	0.93
20160310	800	10	11.5	Night	16WAUPAW210	THG	Immigrate	236	265	214.62	5	26.05	F	12.14	1.01
20160311	745	10	13.25	Night	16WAUPAW211	THG	Immigrate	214	245	149.91	5	7.51	M	5.01	0.97
20160311	745	10	13.25	Night	16WAUPAW212	THG	Immigrate	208	238	142.41	5	6.35	M	4.46	1.01
20160311	745	10	13.25	Night	16WAUPAW213	THG	Immigrate	215	248	163.91	5	12.92	F	7.88	0.99
20160311	745	10	13.25	Night	16WAUPAW214	THG	Immigrate	224	254	179.42	5	18.02	F	10.04	0.98
20160311	745	10	13.25	Night	16WAUPAW215	THG	Immigrate	208	238	145.66	4	11.04	F	7.58	1.00
20160310	1815	10	9.75	Day	16WAUPAW216	THG	Immigrate	212	243	150.59	4	8.76	M	5.82	0.99
20160310	1815	10	9.75	Day	16WAUPAW217	THG	Immigrate	224	255	186.48	8	10.71	M	5.74	1.06
20160227	800	8	11.75	Night	16WAUPAW218	THG	Immigrate	220	280	167.79	4	11.12	M	6.63	0.71
20160227	800	8	11.75	Night	16WAUPAW219	THG	Immigrate	223	254	166.86	4	8.39	M	5.03	0.97
20160319	830	11	8.75	Night	16WAUPAW22	SHG	Emigrate	224	235	152.62	5	4.07	F	2.67	1.14
20160310	1800	10	8.5	Day	16WAUPAW220	SHG	Immigrate	242	270	216.22	6	29.72	F	13.75	0.95
20160310	1800	10	8.5	Day	16WAUPAW221	SHG	Immigrate	223	254	185.8	6	16.27	F	8.76	1.03
20160310	1800	10	8.5	Day	16WAUPAW222	SHG	Immigrate	201	231	129.15	5	4.45	M	3.45	1.01
20160311	715	10	13.25	Night	16WAUPAW223	SHG	Immigrate	228	262	185.28	4	19.37	F	10.45	0.92
20160227	815	8	11.5	Night	16WAUPAW224	SHG	Immigrate	230	264	199.55	5	14.51	F	7.27	1.01
20160227	815	8	11.5	Night	16WAUPAW225	SHG	Immigrate	235	270	210.29	4	21.08	F	10.02	0.96
20160227	815	8	11.5	Night	16WAUPAW226	SHG	Immigrate	223	255	192.8	5	20.88	F	10.83	1.04
20160227	815	8	11.5	Night	16WAUPAW227	SHG	Immigrate	217	248	159.83	4	7.67	M	4.8	1.00
20160227	815	8	11.5	Night	16WAUPAW228	SHG	Immigrate	215	243	148.4	5	9.16	M	6.17	0.97

20160227	815	8	11.5	Night	16WAUPAW229	SHG	Immigrate	218	250	157.57	5	7.9	M	5.01	0.96
20160319	800	11	8	Night	16WAUPAW23	THG	Immigrate			118.82	7	6.42	M	5.4	
20160227	815	8	11.5	Night	16WAUPAW230	SHG	Immigrate	235	268	221.52	6	17.67	F	7.98	1.06
20160226	900	8	13.75	Night	16WAUPAW231	SHG	Immigrate	220	251	160.56	4	7.26	M	4.52	0.97
20160226	900	8	13.75	Night	16WAUPAW232	SHG	Immigrate	216	251	163.16	4	11.39	F	6.98	0.96
20160226	900	8	13.75	Night	16WAUPAW233	SHG	Immigrate	216	249	173.84	5	12.2	M	7.02	1.05
20160226	900	8	13.75	Night	16WAUPAW234	SHG	Immigrate	210	240	141.92	6	6.82	M	4.81	0.98
20160226	900	8	13.75	Night	16WAUPAW235	SHG	Immigrate	196	221	115.23	5	3.18	M	2.76	1.04
20160303	1000	9	14	Night	16WAUPAW236	THG	Immigrate	237	272	203.33	5	19.89	F	9.78	0.91
20160303	1000	9	14	Night	16WAUPAW237	THG	Immigrate	208	240	142.23	6	7.18	M	5.05	0.98
20160303	1000	9	14	Night	16WAUPAW238	THG	Immigrate	212	244	160.29	5	9.43	M	5.88	1.04
20160303	1000	9	14	Night	16WAUPAW239	THG	Immigrate	232	264	176.94	5	16.99	F	9.6	0.87
20160318	800	11	8	Night	16WAUPAW24	THG	Emigrate	203	234	138.85	7	2.11	M	1.52	1.07
20160303	1000	9	14	Night	16WAUPAW240	THG	Immigrate	228	261	203.2	5	22.78	F	11.21	1.01
20160303	1000	9	14	Night	16WAUPAW241	THG	Immigrate	219	254	183.27	5	10.31	M	5.63	1.06
20160303	1000	9	14	Night	16WAUPAW242	THG	Immigrate	225	259	178.68	4	8.07	M	4.52	0.98
20160303	1000	9	14	Night	16WAUPAW243	THG	Immigrate	218	249	163.65	7	19.05	F	11.64	0.94
20160226	800	8	12	Night	16WAUPAW244	THG	Immigrate	234	264	213.4	4	12.01	M	5.63	1.09
20160226	800	8	12	Night	16WAUPAW245	THG	Immigrate	205	234	124.96	5	7.25	M	5.8	0.92
20160226	800	8	12	Night	16WAUPAW246	THG	Immigrate	214	248	148.88	6	8.15	M	5.47	0.92
20160226	800	8	12	Night	16WAUPAW247	THG	Immigrate	235	270	216.54	5	18.61	F	8.59	1.01
20160226	800	8	12	Night	16WAUPAW248	THG	Immigrate	213	243	154.5	5	10.85	F	7.02	1.00
20160226	800	8	12	Night	16WAUPAW249	THG	Immigrate	225	260	164.91	7	13.4	F	8.13	0.86
20160318	2345	11	7.5	Night	16WAUPAW25	THG	Immigrate	197	228	119.38	6	6.17	M	5.17	0.96
20160226	800	8	12	Night	16WAUPAW250	THG	Immigrate	214	244	169.96	7	17.76	F	10.45	1.05
20160226	800	8	12	Night	16WAUPAW251	THG	Immigrate	201	233	127.21	4	6.56	M	5.16	0.95
20160226	800	8	12	Night	16WAUPAW252	THG	Immigrate	211	243	155.51	6	7.37	M	4.74	1.03
20160303	800	9	13	Night	16WAUPAW253	SHG	Immigrate	220	253	176.93	7	16.76	F	9.47	0.99
20160303	800	9	13	Night	16WAUPAW254	SHG	Immigrate	230	263	195.48	6	12.95	M	6.62	1.00
20160303	800	9	13	Night	16WAUPAW255	SHG	Immigrate	208	239	153.46	6	12.11	F	7.89	1.04
20160303	800	9	13	Night	16WAUPAW256	SHG	Immigrate	228	261	179.18	5	8.37	M	4.67	0.96
20160303	800	9	13	Night	16WAUPAW257	SHG	Immigrate	257	293	281.97	5	37.97	F	13.47	0.97
20160303	800	9	13	Night	16WAUPAW258	SHG	Immigrate	228	264	206.7	6	11.55	M	5.59	1.06

20160303	800	9	13	Night	16WAUPAW259	SHG	Immigrate	196	228	128.09	4	6.03	M	4.71	1.03
20160415	2015	15	11	Day	16WAUPAW26	SHG	Emigrate	225	259	138.42	8	2.15	F	1.55	0.78
20160303	800	9	13	Night	16WAUPAW260	SHG	Immigrate	205	235	129.73	5	7.77	M	5.99	0.94
20160303	800	9	13	Night	16WAUPAW261	SHG	Immigrate	225	257	161.43	5	9.65	M	5.98	0.89
20160423	1700	16	7.25	Day	16WAUPAW27	SHG	Emigrate	237	269	144.49	7	3.18	F	2.2	0.73
20160423	1700	16	7.25	Day	16WAUPAW28	SHG	Immigrate	216	248	104.67	7	0.23	M	0.22	0.68
20160423	1700	16	7.25	Day	16WAUPAW29	SHG	Immigrate	228	262	127.14	8	2.6	F	2.04	0.69
20160423	1700	16	7.25	Day	16WAUPAW30	SHG	Immigrate	222	252	115.74	6	1.75	F	1.51	0.71
20160415	830	15	13.25	Night	16WAUPAW31	SHG	Immigrate	215	243	164.91	6	19.54	F	11.85	1.01
20160415	830	15	13.25	Night	16WAUPAW32	SHG	Immigrate	212	243	160.13	7	7.93	M	4.95	1.06
20160424	800	16	14	Night	16WAUPAW33	THG	Immigrate	210	243	112.31	5	0.47	M	0.42	0.78
20160423	830	16	13.5	Night	16WAUPAW34	SHG	Emigrate	105	125	17.81	3			0	0.91
20160423	830	16	13.5	Night	16WAUPAW35	SHG	Emigrate	236	271	156.33	7	10.82	F	6.92	0.73
20160423	830	16	13.5	Night	16WAUPAW36	SHG	Emigrate	214	244	131.29	5	2.75	M	2.09	0.88
20160414	1845	15	7.75	Day	16WAUPAW37	SHG	Emigrate	202	228	89.53	7	0.23	M	0.26	0.75
20160416	900	15	12.5	Night	16WAUPAW38	SHG	Immigrate	224	256	171.22	6	10.88	M	6.35	0.96
20160429	2100	17	13	Day	16WAUPAW39	SHG	Emigrate	234	266	158.3	5	4.08	F	2.58	0.82
20160422	1845	16	6.75	Day	16WAUPAW40	SHG	Emigrate	212	238	112.56	4	6.84	F	6.08	0.78
20160422	1845	16	6.75	Day	16WAUPAW41	SHG	Emigrate	231	264	149.19	6	3.16	F	2.12	0.79
20160422	1845	16	6.75	Day	16WAUPAW42	SHG	Emigrate	218	250	131.34	8	2.5	M	1.9	0.82
20160422	1845	16	6.75	Day	16WAUPAW43	SHG	Emigrate	219	252	111.2	8	1.25	F	1.12	0.69
20160422	1845	16	6.75	Day	16WAUPAW44	SHG	Emigrate	222	258	130.79	8	1.18	M	0.9	0.75
20160422	1845	16	6.75	Day	16WAUPAW45	SHG	Emigrate	222	254	134.29	7	1.72	M	1.28	0.81
20160424	700	16	13.5	Night	16WAUPAW46	SHG	Emigrate	216	246	118.39	6	0.38	M	0.32	0.79
20160424	700	16	13.5	Night	16WAUPAW47	SHG	Emigrate	226		130.92	7	0.62	M	0.47	
20160424	700	16	13.5	Night	16WAUPAW48	SHG	Emigrate	221	254	129.06	5	7.18	F	5.56	0.74
20160424	700	16	13.5	Night	16WAUPAW49	SHG	Emigrate	240	270	145.96	8	1.79	F	1.23	0.73
20160424	700	16	13.5	Night	16WAUPAW50	SHG	Emigrate	228	261	142.97	6	0.93	M	0.65	0.80
20160415	830	15	13.25	Night	16WAUPAW51	SHG	Emigrate	202	235	109.98	5	0.71	M	0.65	0.84
20160415	830	15	13.25	Night	16WAUPAW52	SHG	Emigrate	235	266	167.92	7	1.07	M	0.64	0.89
20160415	830	15	13.25	Night	16WAUPAW53	SHG	Emigrate	243	280	183.71	6	12.83	F	6.98	0.78
20160415	830	15	13.25	Night	16WAUPAW54	SHG	Emigrate	214	244	129.58	4	2.55	F	1.97	0.87
20160415	830	15	13.25	Night	16WAUPAW55	SHG	Emigrate	218	253	128.09	4	0.83	M	0.65	0.79

20160324	1830	12	9	Day	16WAUPAW56	SHG	Emigrate	225	251	141.15	4	4.37	F	3.1	0.86
20160324	1830	12	9	Day	16WAUPAW57	SHG	Emigrate	217	246	137.39	4	0.77	M	0.56	0.92
20160402	730	13	13.5	Night	16WAUPAW58	SHG	Emigrate	228	262	136.05	5	3.68	F	2.7	0.74
20160402	730	13	13.5	Night	16WAUPAW59	SHG	Emigrate	223	254	144.02	7	3.29	F	2.28	0.86
20160402	730	13	13.5	Night	16WAUPAW60	SHG	Emigrate	212	243	114.39	6	3.33	F	2.91	0.77
20160402	730	13	13.5	Night	16WAUPAW61	SHG	Emigrate			172.05	5	4.77	F	2.77	
20160406	845	14	13.75	Night	16WAUPAW62	SHG	Emigrate	221	254	106.95	4	0.28	M	0.26	0.65
20160402	730	13	13.5	Night	16WAUPAW63	SHG	Immigrate	233	267	201.58	4	28.29	F	14.03	0.91
20160402	730	13	13.5	Night	16WAUPAW64	SHG	Immigrate	230	259	182.68	5	25.78	F	14.11	0.90
20160401	1100	13	14	Night	16WAUPAW65	THG	Immigrate	232	267	202.78	8	14.59	M	7.19	0.99
20160401	1100	13	14	Night	16WAUPAW66	THG	Immigrate	200	239	144.98	5	12.98	F	8.95	0.97
20160324	1800	12	8	Day	16WAUPAW67	THG	Immigrate	219	252	157.25	5	9.3	M	5.91	0.92
20160324	1800	12	8	Day	16WAUPAW68	THG	Immigrate	234	270	228.71	5	27.21	F	11.9	1.02
20160406	845	14	13.75	Night	16WAUPAW69	SHG	Immigrate	222	255	188.3	4	27.65	F	14.68	0.97
20160406	845	14	13.75	Night	16WAUPAW70	SHG	Immigrate	233		208.8		23.18	F	11.1	
20160406	845	14	13.75	Night	16WAUPAW71	SHG	Immigrate	206	239	141.58	8	6.93	M	4.89	0.99
20160406	845	14	13.75	Night	16WAUPAW72	SHG	Immigrate	227	260	167.53	6	9.96	M	5.95	0.90
20160324	1830	12	9	Day	16WAUPAW73	SHG	Immigrate	222	254	189.42	7	10.32	M	5.45	1.09
20160324	1830	12	9	Day	16WAUPAW74	SHG	Immigrate	224	256	173.39	6	12.66	M	7.3	0.96
20160324	1830	12	9	Day	16WAUPAW75	SHG	Immigrate	219	252	165.16	5	9.22	M	5.58	0.97
20160324	1830	12	9	Day	16WAUPAW76	SHG	Immigrate	214	247	166.51	4	7.97	M	4.79	1.05
20160324	1830	12	9	Day	16WAUPAW77	SHG	Immigrate	243	274	211.48	4	27.02	F	12.78	0.90
20160324	1830	12	9	Day	16WAUPAW78	SHG	Immigrate	217	251	167.68	5	10.36	M	6.18	0.99
20160401	930	13	12.5	Night	16WAUPAW79	SHG	Emigrate	219	252	124.64	4	2.98	F	2.39	0.76
20160401	930	13	12.5	Night	16WAUPAW80	SHG	Emigrate			145.14	5	3.83	F	2.64	
20160401	930	13	12.5	Night	16WAUPAW81	SHG	Emigrate			125.96	4	0.95	M	0.75	
20160401	930	13	12.5	Night	16WAUPAW82	SHG	Emigrate	235	268	159.48	7	2.82	F	1.77	0.81
20160401	930	13	12.5	Night	16WAUPAW83	SHG	Emigrate	219	252	116.79	5	0.8	F	0.68	0.72
20160401	930	13	12.5	Night	16WAUPAW84	SHG	Emigrate	225	256	120.21	5	0.31	M	0.26	0.71
20160402	1800	13	9.5	Day	16WAUPAW85	SHG	Emigrate	217	242	137.36	7	5.22	M	3.8	0.93
20160325	1800	12	10	Day	16WAUPAW86	THG	Immigrate	223	253	180.03	6	25.87	F	14.37	0.95
20160406	1845	14	9.5	Day	16WAUPAW87	SHG	Emigrate	221	254	120.04	6	3.87	F	3.22	0.71
20160406	1845	14	9.5	Day	16WAUPAW88	SHG	Emigrate	218	251	122.24	5	8.06	F	6.59	0.72

20160406	1845	14	9.5	Day	16WAUPAW89	SHG	Immigrate	225	260	190.87	5	30	F	15.72	0.92
20160406	1845	14	9.5	Day	16WAUPAW90	SHG	Immigrate	242	275	235.01	4	32.82	F	13.97	0.97
20160324	900	12	13	Night	16WAUPAW91	SHG	Immigrate	225		168.51	4	10.62	M	6.3	
20160324	900	12	13	Night	16WAUPAW92	SHG	Immigrate	226	260	208.42	5	29	F	13.91	1.02
20160324	900	12	13	Night	16WAUPAW93	SHG	Immigrate	214	246	141.43	5	6.39	M	4.52	0.91
20160325	830	12	13.5	Night	16WAUPAW94	SHG	Immigrate	233	265	209.88	5	29.98	F	14.28	0.97
20160325	830	12	13.5	Night	16WAUPAW95	SHG	Immigrate	224	259	202.32	4	25.33	F	12.52	1.02
20160407	1900	14	9.25	Day	16WAUPAW98	SHG	Emigrate	212	244	115.57	5	6.29	F	5.44	0.75
20160407	1900	14	9.25	Day	16WAUPAW99	SHG	Emigrate	229	265	121.99	4	2.17	F	1.78	0.64