TECHNICAL REPORT

PREDICTED IMPACTS ON PREY BY NORTHERN SNAKEHEAD

by

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Introduction

Invasive aquatic species can cause ecological harm to biodiversity and economic hardships (Pimentel et al. 2005). Northern snakehead *Channa argus* is an invasive, primarily fish-eating species that is native to Asia. It was introduced to temperate areas of North America in the early 2000s and has been considered a nuisance or invasive largely because of its life history traits (Courtenay and Williams 2004; ANSTF 2014). The species has increased in relative abundance by 10- to 100-fold since introduction in streams tributary to Potomac River, the second largest river of the Chesapeake Bay watershed, and has either maintained or slightly decreased in relative abundance in those streams (Odenkirk and Isel 2016). It has spread rapidly throughout the Chesapeake Bay watershed (Odenkirk and Owens 2005; Love et al. 2018) and in newly colonized areas, has gained abundance despite numerous initiatives to encourage lowering population sizes via harvest (Love and Genovese 2019). Negative consequences of this expansion include possible disease transmission (Iwanowicz et al. 2013), possible but minimal effects on population growth of largemouth bass *Micropterus salmoides* (Love and Newhard 2012; Love et al. 2015), and competition with other piscivores if resources become limiting (Saylor et al. 2012).

The ecological disturbance that northern snakehead has caused North American ecosystems has not been widely studied across its introduced range, leaving unresolved whether there are deleterious effects owed to introduction (Orth 2019). There is evidence that the species is a top predator that forages on a wide range of fishes (Saylor et al. 2012) and crayfish and amphibians (pers. obs., JWL; Isel and Odenkirk 2019). In extreme cases, exotic aquatic predators have elicited strong declines in abundance and changes in aquatic community structure (Pycha and King 1975; Awiti 2011; Gallardo et al. 2016). Introductions of a species can therefore constitute

a major disturbance to an ecosystem. Liu et al. (1998) demonstrated that the level of prey consumption by northern snakehead can vary with differences in water temperature and predator size. We parameterized their model with water temperature and population characteristics for stream populations in Potomac River. The objective of this study was to calculate the consumption of prey species by parameterizing the model of Liu et al. (1998) for species preyed upon by northern snakehead (Saylor et al. 2012).

Methods

Maximum consumption rate (C_{max}) for a fish was determined using a water temperature and size dependent model (Liu et al. 1998). The consumption rate model was:

$$\ln C_{max} = -6.718 + 0.522*\ln(W) + 0.440*T - 0.0077*T^2$$

where T is water temperature (degrees Celsius; °C) and W (grams; g) is weight of the fish. This model was parameterized with data for monthly water temperature and average weight for specific length groups (see below).

The vector of water temperatures used to calculate consumption rate were obtained from monthly water temperature (January 2018 – December 2018) measurements recorded approximately 1.8 meters below surface using a Hydrolab Surveyor 4a/5 (MDDNR 2018; see *Supplemental Material*, Data S1). These data were averaged from four locations with recent long-term water temperature data ranging from January to December for tidal freshwater in Potomac River (Figure 1).

In order to generate average weights for size classes of snakehead populations, populations were surveyed by boat electrofishing surveys that targeted northern snakehead from spring through summer (Smith-Root 5.0 or 9.0 gas-powered pulsator; amperage = 120 pulses per second) for three streams of Potomac River: Pomonkey Creek (2014 – 2015), Chopawamsic

Creek (2010 – 2013), and Nanjemoy River (2013; Figure 1). Total lengths (millimeters; mm) and weights for 939 individuals collected from these streams were recorded during field surveys (see *Supplemental Material*, Data S2). Total length ranged between 152 millimeters **–** 885 millimeters. Weight ranged between 0.03 kilograms **–** 6.70 kilograms. For analysis, the lengths were then grouped into 100 millimeters bin ranges for each stream. These length ranges do not represent age cohorts, which should instead be determined using otoliths (Gascho Landis et al. 2011; Odenkirk et al. 2013). Weight was averaged for each length range with its standard deviation (Table 1). These weights reflected observed averages from field collections and were considered appropriate for use with the consumption rate model.

Consumption rate for a fish of average weight within the length range was calculated for a day with an average monthly water temperature. This consumption rate was then extrapolated for the fish per month by multiplying C_{max} by the number of days (d) in each month (*i*). This was done for the average weight computed for each length range bin (*j*) in the population. The C_{max} per month, per length range (*j*) was multiplied by the number of fish within the length range (n_j). The n_j was determined by multiplying the proportion of fish expected in the length range bin by hypothetical population abundances (N = 300 – 650, increment = 50), which were suggested by a range of sizes reported for northern snakehead adults from a stream in Potomac River (Odenkirk and Isel 2016). The proportions of fish expected in the length range bin were calculated by fitting a linear model to a relationship of length bin (independent variable) and proportions of fish observed in the length range bin for three surveyed populations from Potomac River (as above; dependent variable). Some streams were surveyed multiple years and a median proportion was taken across years for each population prior to analysis. Because the sampling gear under-represented the number of younger northern snakehead during surveys, we used

proportions predicted from the linear model (a = 0.239, b = -0.000182, r^2 = 0.24, p = 0.02) to estimate n_j (Table 2).

Total annual consumption for the abundance of fish ($C_{max\text{-}N}$) was extrapolated to a year and population by summing across months and across length range bins,

$$C_{max-N} = \sum_{i}^{i=12} \sum_{j}^{j=7} C_{max_{ij}} * d_i * n_j$$

We determined $C_{max\text{-}N}$ for each hypothetical abundance and highlight values for a population size of 600, which was similar to the greatest abundance reported by Odenkirk and Isel (2016) for Little Hunting Creek (Figure 1). The population from Little Hunting Creek was used because of its time series of reported abundances. It also represents a stream that is similar to other lesser studied freshwater streams of Potomac River. A Monte Carlo randomization routine was used to simulate 1,000 runs of the model and compute an average $C_{max\text{-}N}$ for the species. Each iterative run of the model included values of water temperature and weight that varied within the natural limits observed within a month and length range, respectively. In this way, we incorporated natural variation in water temperature and weight, which enabled us to produce an additive variance estimate for $C_{max\text{-}N}$ at each population size tested here. Additionally, we determined the $C_{max\text{-}N}$ for principal prey items consumed by northern snakehead. We calculated these results for prey fish genera because that was the lowest, common taxonomic resolution used by Saylor et al. (2012). The relative proportion of each fish prey genus (r; by weight from Saylor et al. 2012) was multiplied by $C_{max\text{-}N}$. Prey items included: American eel *Anguilla rostrata* (r = 0.0222), bullheads *Amerius* spp. (r = 0.0007), killifishes *Fundulus* spp. (r = 0.0780), gizzard shad *Dorosoma cepedianum* (r = 0.0266), golden shiner (r = 0.0319), goldfish (r = 0.1510),

largemouth bass (r = 0.0204), sunfishes *Lepomis* spp. (r = 0.3020), *Pomoxis* spp. (r = 0.0133), white perch (r = 0.1143), and yellow perch (r = 0.2386).

Results

Consumption rates (C_{max}) predicted by the model ranged between 0.05 milligrams **–** 62.27 milligrams prey per gram of snakehead per day (*Supplemental Material*, Data S3). Consumption rates for colder monthly water temperatures (average = 4.6 °C) were predicted to be lower (average C_{max} = 0.44 mg/g/d, standard deviation = 0.33) than those when monthly water temperature was warmer (average = 19.4 °C; average C_{max} = 18.17 mg/g/d; standard deviation = 16.17). After summing consumption rates among months and across length ranges, total annual consumption ($C_{max\text{-}N}$) ranged between 1,093 kilograms per year **–** 2,371 kilograms per year, depending on population size (Figure 2A). Each additional snakehead added to the population was expected, on average, to increase total annual consumption by 3.6 kilograms of prey per year (Figure 2B). Assuming a population size of 600 for northern snakehead, we determined that total annual consumption was 2,190 kilograms per year and included: sunfishes *Lepomis* spp. (662 kg/yr); yellow perch *Perca flavescens* (522 kg/yr); goldfish *Crassius auratus* (332 kg/yr); white perch *Morone americana* (250 kg/yr); and killifishes *Fundulus* spp. (174 kg/yr). These prey species represented approximately 88.4 percent of the consumed biomass. The intensity of consumption for these species increased with population size (Figure 2C), particularly for bluegill and yellow perch.

Conclusions

Consumption rates for northern snakehead depended on water temperature (6.6 °C to 28.7 °C) and averaged 18.95 milligrams of prey per gram of predator per day. Consumption levels declined as water temperature warmed beyond 28 °C, possibly because of reduced thermal

optima and/or because of nest guarding (Gascho Landis et al. 2011). For smallmouth bass *M. dolomieu*, Vigg et al. (1991) found that consumption rates were twice as low during the spawning season (April through June) than in July and August. Average consumption rate modeled for northern snakehead were comparable to averages reported for other North American predaceous fishes such as smallmouth bass (28.7 mg/g/d) and walleye *Sander vitreus* (14.2 mg/g/d) from impounded water of Columbia River (Vigg et al. 1991). Even though northern snakehead may not be the eating machines depicted in horror movies (for example, Snakehead Terror 2004), consumption rates predicted from Liu et al. (1998) produced average values that were within realistic ranges for other primarily piscivorous fishes in North America. We conclude that northern snakehead populations can reduce biomass of multiple fish prey species through predation. This could explain some observed changes to aquatic communities in Blackwater River drainage (Newhard and Love 2019). Effects on an aquatic community owed to exotic predators depend on predator population size, habitat conditions (for example, water temperature), and ecosystem resiliency. Ecosystems may be resilient to a new predator or intense disturbance if prey species increase reproduction or develop behaviors to avoid predation. We recommend research into assessing the resiliency of aquatic ecosystems to further our understanding of northern snakehead impacts in North America.

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Table 1. Estimated population structure for northern snakehead *Channa argus* estimated from data collected for three populations in Potomac River (Chopawamsic Creek, Nanjemoy Creek, and Pomonkey Creek) surveyed in 2010 – 2015. For various total length (millimeters; mm) ranges for Northern Snakehead, average mass for fish (grams; g) with standard deviation (in parentheses) was calculated for use in bioconsumption modeling. The predicted proportion of individuals in each length range was predicted using linear regression of observed proportions in length ranges for three populations in Potomac River (Chopawamsic Creek, Nanjemoy Creek, Pomonkey Creek).

Total Length (mm)	Average Mass (g)	Proportion
150 – 249	109.0 (30.8)	0.1887
250 – 349	239.5 (79.9)	0.1705
350 – 449	580.6 (149.6)	0.1523
450 – 549	1242.4 (238.2)	0.1341
550 – 649	1986.8 (326.7)	0.1159
650 – 749	3248.0 (477.9)	0.0977
750 – 849	4530.2 (611.6)	0.0795
850 – 949	6279.6 (414.3)	0.0613

Figure 1. Map of Potomac River highlighting major streams tributary (labeled thumbtacks) to the mainstem that drains to the Chesapeake Bay (see inset). Black dots represent four locations where water temperature was measured during our study.

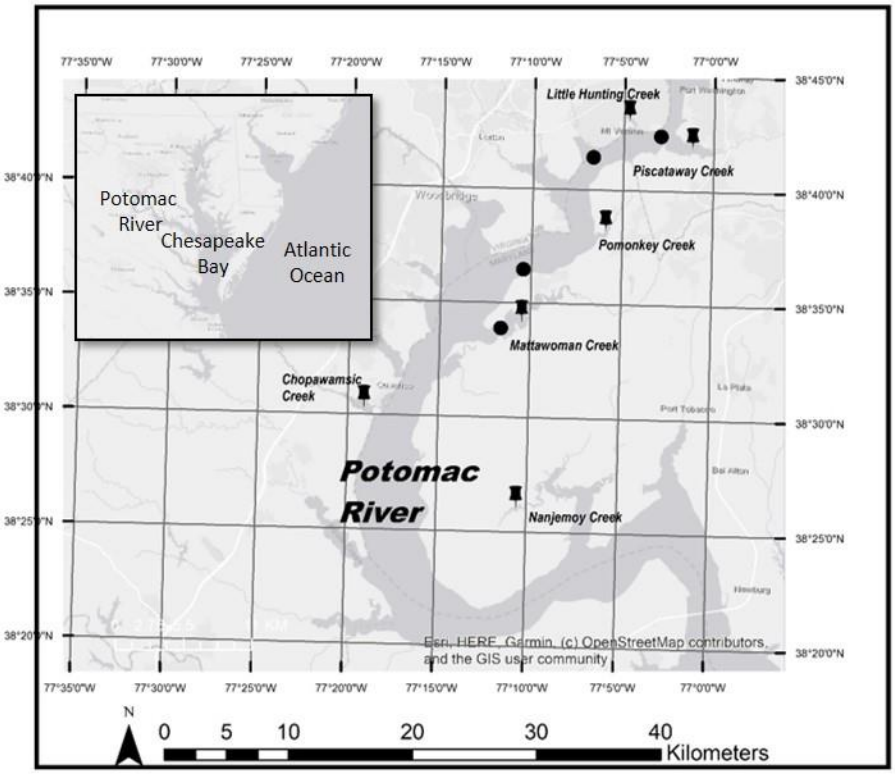
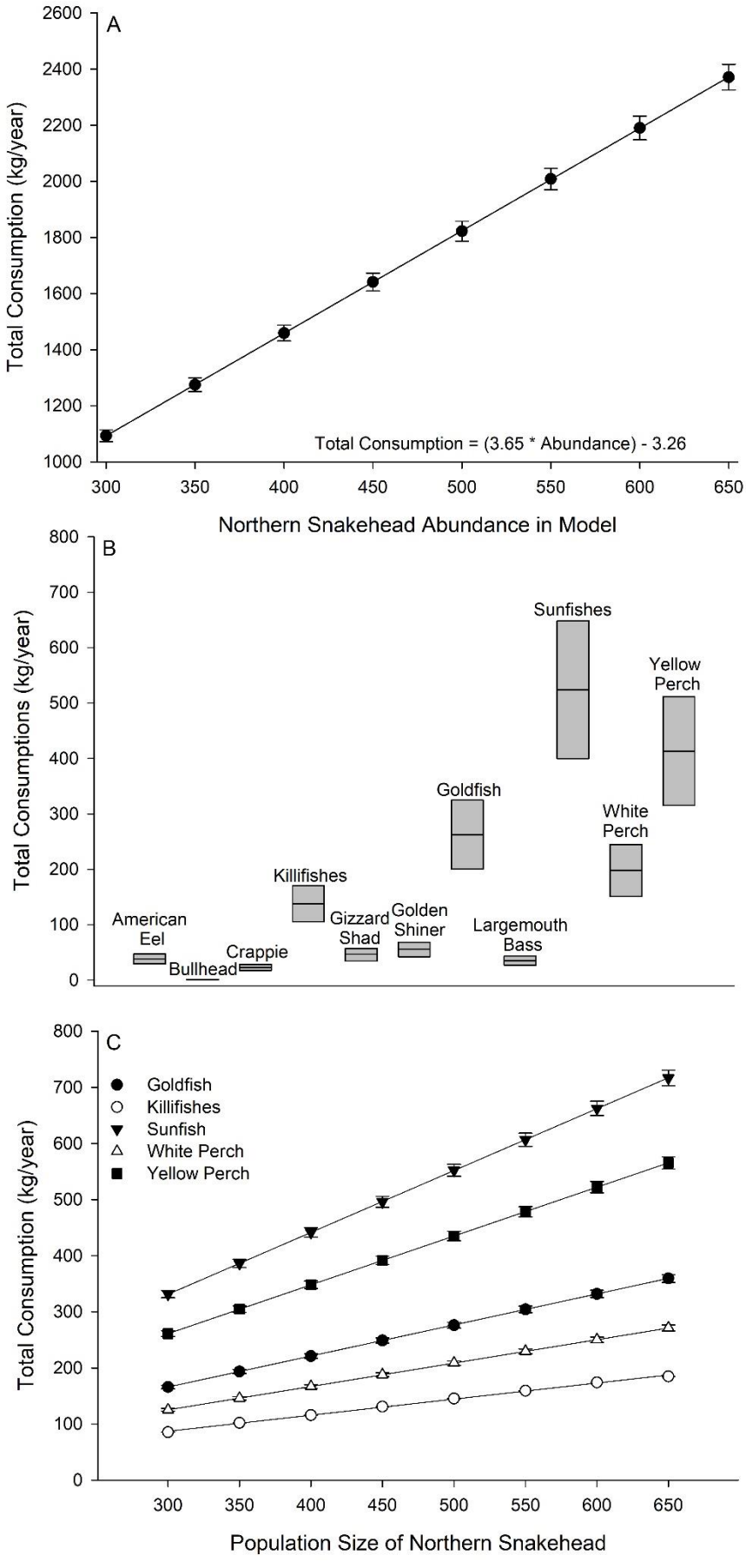


Figure 2. A: Relationship of total consumption (kg/yr) by northern snakehead *Channa argus* across various population sizes. The embedded linear regression model was fit to the relationship ($r^2 = 0.99$, $p < 0.0001$). B: Box plot of prey biomass consumed by northern snakehead, as predicted from total consumption and relative proportions of prey found in stomach contents. Horizontal lines in boxes represent medians bounded by lower 25th and upper 75th percentiles for all abundance levels examined here (300 to 650 snakeheads). Represented prey included: American eel *Anguilla rostrata*, sunfishes *Lepomis* spp., bullhead *Amerius* spp., crappie *Pomoxis* spp., killifishes *Fundulus* spp., gizzard shad *Dorosoma cepedianum*, golden shiner *Notemogonus chrysoleucas*, goldfish *Crassius auratus*, largemouth bass *Micropterus salmoides*, white perch *Morone americana*, and yellow perch *Perca flavescens*. Species were aggregated to genus for analysis and when only one species of the genus was reported, the species was noted in the figure. C: Relationship of total consumption for a commonly consumed subset of prey fishes and various population sizes of northern snakehead.


A
Total Consumption (kg/year)
2600
2400
2200
2000
1800
1600
1400
1200
1000
Total Consumption = (3.65 * Abundance) - 3.26
300
350
400
450
500
550
600
650
Northern Snakehead Abundance in Model
B
Total Consumptions (kg/year)
800
700
600
500
400
300
200
100
0
Sunfishes
Yellow Perch
Goldfish
White Perch
Killifishes
American Eel
Gizzard Shad
Golden Shiner
Largemouth Bass
Bullhead
Crappie
C
Total Consumption (kg/year)
Goldfish
Killifishes
Sunfish
White Perch
Yellow Perch
Population Size of Northern Snakehead

Supplemental Material S1. Monthly water temperature data (in °C) collected from four water quality monitoring stations on Potomac River (Maryland) and measured at approximately 1.8 meters within the river. Date of sampling, time of sampling, and depth (in meters) of measurement are provided the latitude (in decimal degrees) and longitude (in decimal degrees) of each monitoring station.

Station	Date	Time	Depth	Water Temperature	Latitude	Longitude
MAT0016	1/25/2018	10:46:00	5.3	2.2	38.56508	-77.19345
TF2.1	1/25/2018	12:08:00	4.6	3.5	38.70664	-77.04876
TF2.2	1/25/2018	11:52:00	4.6	3.5	38.69067	-77.11111
TF2.3	1/25/2018	11:24:00	4.6	2.8	38.6082	-77.1739
MAT0016	2/14/2018	11:35:00	5.6	7.3	38.56508	-77.19345
TF2.1	2/14/2018	13:03:00	4.6	4	38.70664	-77.04876
TF2.2	2/14/2018	12:41:00	4.6	4.2	38.69067	-77.11111
TF2.3	2/14/2018	12:11:00	4.6	4.6	38.6082	-77.1739
MAT0016	3/12/2018	11:02:00	5.1	6.2	38.56508	-77.19345
TF2.1	3/12/2018	12:33:00	4.6	6.4	38.70664	-77.04876
TF2.2	3/12/2018	12:12:00	4.6	6	38.69067	-77.11111
TF2.3	3/12/2018	11:35:00	4.6	6.4	38.6082	-77.1739
MAT0016	4/9/2018	11:34:00	6.2	9.6	38.56508	-77.19345
TF2.1	4/9/2018	13:09:00	4.6	9.3	38.70664	-77.04876
TF2.2	4/9/2018	12:51:00	4.6	9.4	38.69067	-77.11111
TF2.3	4/9/2018	12:14:00	4.6	9.8	38.6082	-77.1739
MAT0016	5/7/2018	10:28:00	6.2	19.8	38.56508	-77.19345
TF2.1	5/7/2018	11:54:00	4.6	20	38.70664	-77.04876
TF2.2	5/7/2018	11:37:00	4.6	19.7	38.69067	-77.11111
TF2.3	5/7/2018	11:05:00	4.6	19.4	38.6082	-77.1739
MAT0016	6/11/2018	12:16:00	3	24	38.56508	-77.19345
TF2.1	6/11/2018	13:50:00	4.6	21.6	38.70664	-77.04876
TF2.2	6/11/2018	13:29:00	4.6	21.6	38.69067	-77.11111
TF2.3	6/11/2018	12:57:00	4.6	21.6	38.6082	-77.1739
MAT0016	7/16/2018	10:24:00	5.4	28	38.56508	-77.19345
TF2.1	7/16/2018	11:50:00	4.6	28.2	38.70664	-77.04876
TF2.2	7/16/2018	11:35:00	4.6	28.1	38.69067	-77.11111
TF2.3	7/16/2018	11:03:00	4.6	28.2	38.6082	-77.1739
MAT0016	8/6/2018	9:48:00	5	28.5	38.56508	-77.19345
TF2.1	8/6/2018	10:58:00	4.6	24.6	38.70664	-77.04876
TF2.2	8/6/2018	10:39:00	4.6	24.4	38.69067	-77.11111
TF2.3	8/6/2018	10:15:00	4.6	24.7	38.6082	-77.1739
MAT0016	9/12/2018	11:07:00	5.7	21.6	38.56508	-77.19345

TF2.1	9/12/2018	12:19:00	4.6	18.6	38.70664	-77.04876
TF2.2	9/12/2018	12:03:00	4.6	18.4	38.69067	-77.11111
TF2.3	9/12/2018	11:35:00	4.6	18.8	38.6082	-77.1739
MAT0016	10/9/2018	11:07:00	5.4	22.8	38.56508	-77.19345
TF2.1	10/9/2018	12:22:00	4.6	22	38.70664	-77.04876
TF2.2	10/9/2018	12:07:00	4.6	21.9	38.69067	-77.11111
TF2.3	10/9/2018	11:41:00	4.6	21.8	38.6082	-77.1739
MAT0016	NA	NA	NA	NA	NA	NA
TF2.1	11/13/2018	8:18:00	4.6	8.6	38.70664	-77.04876
TF2.2	11/13/2018	8:35:00	4.6	8.8	38.69067	-77.11111
TF2.3	11/13/2018	8:58:00	4.6	9.5	38.6082	-77.1739
MAT0016	12/10/2018	11:53:00	5.9	3.5	38.56508	-77.19345
TF2.1	12/10/2018	13:10:00	4.6	4.5	38.70664	-77.04876
TF2.2	12/10/2018	12:50:00	4.6	4.6	38.69067	-77.11111
TF2.3	12/10/2018	12:25:00	4.6	5	38.6082	-77.1739

Supplemental Material S2. Total lengths (in millimeters) and weights (in grams, when available) for northern snakehead *Channa argus* collected from various locations (given as latitude and longitude in decimal degrees) in three streams of Potomac River that were surveyed between 2010 – 2015: Pomonkey Creek (Maryland), Nanjemoy Creek (Maryland), and Chopawamsic Creek (Virginia). NA = data not available.

Date	Latitude	Longitude	Total Length	Weight
10/13/2010	38.514317	-77.334883	169	40
9/20/2012	38.514350	-77.338650	185	NA
10/28/2010	38.514983	-77.337533	190	90
10/4/2011	38.514800	-77.335800	202	70
10/28/2010	38.514983	-77.337533	204	100
9/14/2011	38.510400	-77.325667	205	80
10/28/2010	38.514983	-77.337533	209	70
9/20/2012	38.514317	-77.340067	211	NA
10/28/2010	38.514983	-77.337533	212	80
10/13/2010	38.514850	-77.337317	214	70
10/28/2010	38.514983	-77.337533	218	110
10/28/2010	38.514983	-77.337533	218	120
10/13/2010	38.513933	-77.334083	219	90
9/20/2012	38.514450	-77.334617	219	NA
6/9/2011	38.510333	-77.327017	221	250
10/28/2010	38.514983	-77.337533	222	130
10/28/2010	38.514983	-77.337533	223	90
10/28/2010	38.514983	-77.337533	225	120
10/28/2010	38.515017	-77.337283	227	110
10/4/2011	38.514033	-77.339800	227	110
10/4/2011	38.514800	-77.335800	227	100
10/4/2011	38.514800	-77.335800	227	100
9/20/2012	38.510550	-77.331950	227	NA
10/28/2010	38.514983	-77.337533	228	100
10/28/2010	38.514983	-77.337533	228	120
10/28/2010	38.514983	-77.337533	229	130
10/28/2010	38.514983	-77.337533	230	110
10/4/2011	38.500917	-77.313750	230	90
10/4/2011	38.514567	-77.335133	231	100
9/20/2012	38.514883	-77.336567	231	NA

10/28/2010	38.514983	-77.337533	233	90
10/28/2010	38.514983	-77.337533	234	80
5/26/2011	38.507217	-77.313250	234	140
10/13/2010	38.513933	-77.334083	235	110
9/20/2012	38.514167	-77.337317	235	NA
10/4/2011	38.514800	-77.335800	238	110
10/13/2010	38.513917	-77.334283	240	140
10/4/2011	38.514017	-77.339233	240	120
9/20/2012	38.514850	-77.337783	241	NA
10/13/2010	38.514550	-77.334917	248	110
10/4/2011	38.514017	-77.339233	248	140
10/4/2011	38.514917	-77.337517	248	120
10/28/2010	38.514983	-77.337533	250	160
10/28/2010	38.515017	-77.337283	250	120
10/4/2011	38.514917	-77.337517	250	130
10/28/2010	38.514983	-77.337533	251	130
10/13/2010	38.512233	-77.330667	253	130
10/28/2010	38.514983	-77.337533	256	90
10/13/2010	38.514550	-77.334917	258	140
10/13/2010	38.514100	-77.334400	258	140
10/13/2010	38.512417	-77.332400	260	140
10/4/2011	38.514800	-77.335800	260	140
10/13/2010	38.511167	-77.328383	262	130
10/28/2010	38.514983	-77.337533	262	180
10/28/2010	38.514983	-77.337533	263	150
10/28/2010	38.514983	-77.337533	263	200
10/4/2011	38.510217	-77.327467	264	170
10/28/2010	38.514967	-77.337533	267	110
10/28/2010	38.514983	-77.337533	268	110
10/28/2010	38.514983	-77.337533	268	210
9/14/2011	38.509900	-77.317867	268	160
10/4/2011	38.510933	-77.331783	269	170
10/13/2010	38.514850	-77.337317	270	160
9/14/2011	38.509833	-77.323000	270	190
10/28/2010	38.514983	-77.337533	271	180
10/28/2010	38.514983	-77.337533	274	180
10/28/2010	38.514983	-77.337533	276	170
10/28/2010	38.514983	-77.337533	276	170
10/4/2011	38.514533	-77.338100	277	180
10/4/2011	38.515000	-77.336967	277	180

10/28/2010	38.514983	-77.337533	278	200
10/28/2010	38.514983	-77.337533	284	180
10/4/2011	38.511800	-77.332600	285	150
10/28/2010	38.514983	-77.337533	286	190
3/22/2011	38.514533	-77.334983	288	270
10/28/2010	38.514983	-77.337533	290	240
9/20/2012	38.514750	-77.335733	291	NA
10/28/2010	38.514983	-77.337533	292	250
10/13/2010	38.514683	-77.335350	293	210
10/28/2010	38.514983	-77.337533	293	270
10/13/2010	38.513283	-77.333783	294	230
10/28/2010	38.514983	-77.337533	296	260
10/28/2010	38.514983	-77.337533	298	210
10/28/2010	38.514983	-77.337533	298	260
10/4/2011	38.510167	-77.331167	298	200
10/28/2010	38.514983	-77.337533	301	260
5/19/2011	38.501267	-77.314817	301	90
10/28/2010	38.514983	-77.337533	303	290
10/28/2010	38.514983	-77.337533	304	210
10/28/2010	38.514983	-77.337533	304	290
10/13/2010	38.515000	-77.337817	305	240
9/20/2012	38.512400	-77.333000	305	NA
6/6/2013	38.514250	-77.334800	305	230
10/28/2010	38.514983	-77.337533	310	270
3/22/2011	38.514850	-77.338117	311	300
9/24/2013	38.514717	-77.335550	311	250
10/23/2013	NA	NA	315	270
10/13/2010	38.513767	-77.334183	316	270
9/24/2013	38.510000	-77.320350	317	210
10/28/2010	38.514983	-77.337533	328	320
9/24/2013	38.509950	-77.324550	330	310
10/28/2010	38.514983	-77.337533	332	380
10/28/2010	38.514983	-77.337533	338	330
6/1/2011	38.506700	-77.312717	339	360
6/6/2013	38.513967	-77.339683	340	300
4/22/2013	38.514500	-77.338600	342	310
6/15/2010	38.510033	-77.317967	345	370
11/18/2010	38.500667	-77.312633	345	510
11/4/2013	NA	NA	345	360
5/26/2011	38.504550	-77.327733	347	360

11/18/2010	38.501817	-77.312950	352	501
11/1/2011	38.501117	-77.313183	355	440
5/26/2011	38.503967	-77.311917	361	410
7/2/2013	38.514567	-77.338500	363	370
5/26/2011	38.505817	-77.312600	366	430
10/4/2011	38.502050	-77.315533	367	400
3/22/2011	38.515017	-77.337250	369	520
11/18/2010	38.500667	-77.312633	375	650
11/18/2010	38.501817	-77.312950	376	590
6/23/2011	38.504867	-77.325317	378	480
11/18/2010	38.500667	-77.312633	380	650
5/26/2011	38.507217	-77.313250	380	500
6/23/2011	38.504600	-77.326800	380	490
11/18/2010	38.501817	-77.312950	382	670
6/9/2011	38.510500	-77.327417	389	480
5/26/2011	38.507217	-77.313250	390	720
4/4/2011	38.509433	-77.327317	394	570
5/26/2011	38.510117	-77.302350	396	540
10/28/2010	38.514983	-77.337533	398	620
8/13/2013	38.515000	-77.337983	398	450
8/27/2013	38.504833	-77.313133	398	550
8/27/2013	38.510067	-77.327617	400	540
11/1/2011	38.501867	-77.312900	405	570
4/4/2011	38.504183	-77.320817	407	660
5/26/2011	38.506733	-77.312550	409	580
6/1/2011	38.506100	-77.312750	409	610
5/26/2011	38.505817	-77.312600	413	1170
6/9/2011	38.507633	-77.314683	415	860
8/18/2011	38.507583	-77.313850	416	750
9/10/2013	38.514083	-77.339417	420	600
9/24/2013	38.514683	-77.336650	420	580
7/26/2011	38.506433	-77.324000	424	690
7/2/2013	38.510150	-77.326067	428	660
6/6/2013	38.506383	-77.312483	430	720
6/6/2013	38.508400	-77.314483	434	690
6/23/2011	38.501500	-77.315617	435	730
7/26/2011	38.506117	-77.323683	436	720
6/28/2012	38.514000	-77.339267	436	730
8/27/2013	38.504917	-77.326733	439	NA
8/27/2013	38.506533	-77.313467	440	750

6/1/2011	38.509867	-77.323517	449	870
11/18/2010	38.500667	-77.312633	451	950
6/6/2013	38.510550	-77.320150	451	820
10/28/2010	38.514983	-77.337533	458	900
11/4/2013	NA	NA	459	NA
7/26/2011	38.504283	-77.322183	460	860
6/28/2011	38.506750	-77.312900	463	870
11/4/2013	NA	NA	464	NA
7/26/2011	38.503033	-77.316467	468	940
6/9/2011	38.514267	-77.338817	469	830
7/26/2011	38.510067	-77.321017	469	930
11/18/2010	38.500667	-77.312633	471	1200
7/26/2011	38.509800	-77.322267	471	1000
4/22/2013	38.514833	-77.337633	471	960
7/2/2013	38.514567	-77.338500	471	790
9/24/2013	38.514233	-77.334650	471	1050
6/23/2011	38.501250	-77.314767	472	1130
3/22/2011	38.506217	-77.329600	473	1050
11/18/2010	38.500667	-77.312633	474	1210
7/19/2011	38.503850	-77.312317	478	1060
7/26/2011	38.503250	-77.317917	479	1000
7/26/2011	38.504617	-77.321967	480	900
6/23/2011	38.502033	-77.316950	481	1100
11/18/2010	38.500667	-77.312633	482	1290
6/9/2011	38.514733	-77.335567	483	920
4/22/2013	38.514767	-77.338250	486	1010
9/24/2013	38.501217	-77.314583	488	1110
11/18/2010	38.501817	-77.312950	490	1130
11/18/2010	38.501817	-77.312950	490	1260
6/1/2011	38.514700	-77.337200	491	1040
7/26/2011	38.503800	-77.317017	491	1110
7/2/2013	38.514983	-77.337883	496	1040
10/4/2011	38.502050	-77.315533	497	1290
7/7/2011	38.501617	-77.311867	498	1150
7/26/2011	38.502583	-77.316450	499	1200
11/18/2010	38.500667	-77.312633	500	1330
10/23/2013	NA	NA	500	1160
6/23/2011	38.501217	-77.314400	502	970
6/5/2012	38.510200	-77.318983	504	1230
9/10/2013	38.506317	-77.329117	505	1300

5/19/2011	38.513833	-77.334000	507	1180
9/24/2013	38.501717	-77.316317	509	1130
11/18/2010	38.501817	-77.312950	510	1390
11/1/2011	38.501117	-77.312183	510	1280
9/24/2013	38.501400	-77.314933	510	1200
9/14/2011	38.514917	-77.338000	511	1150
6/9/2011	38.513917	-77.334033	514	1160
9/24/2013	38.509750	-77.323050	514	1320
3/22/2011	38.509217	-77.328300	515	1290
9/14/2011	38.514133	-77.339983	515	1200
11/18/2010	38.500667	-77.312633	516	1480
11/1/2011	38.502367	-77.312750	518	1670
7/2/2013	38.501100	-77.312017	518	1300
6/1/2011	38.514483	-77.338267	520	1380
7/26/2011	38.504333	-77.323067	520	1350
7/2/2013	38.510467	-77.327233	521	1340
6/5/2012	38.510000	-77.322450	522	1310
7/2/2013	38.515067	-77.337167	522	1180
5/17/2012	38.514017	-77.339233	523	1390
5/22/2013	38.505533	-77.328583	523	1170
9/14/2011	38.509933	-77.320983	524	1350
11/1/2011	38.500767	-77.313017	525	1540
11/1/2011	38.501800	-77.312450	525	1330
7/19/2011	38.509467	-77.315833	526	1280
11/18/2010	38.501817	-77.312950	527	1400
11/1/2011	38.502983	-77.312800	528	1460
11/1/2011	38.501800	-77.312450	528	1510
7/19/2011	38.514783	-77.342717	530	1190
8/18/2011	38.514350	-77.338600	530	1000
6/5/2012	38.509933	-77.324133	530	1480
7/7/2011	38.514467	-77.335250	531	1200
7/26/2011	38.504167	-77.322333	531	1440
11/1/2011	38.501800	-77.314883	533	1550
5/19/2011	38.514783	-77.342750	535	1530
7/26/2011	38.504183	-77.321833	535	1560
11/1/2011	38.501117	-77.312183	535	1510
5/26/2011	38.502950	-77.310100	538	1900
6/1/2011	38.506350	-77.312583	538	1600
8/13/2013	38.504867	-77.325383	538	1460
6/6/2013	38.514367	-77.338700	539	1400

10/4/2011	38.502050	-77.315533	540	1440
11/1/2011	38.502200	-77.312883	540	1380
4/22/2013	38.514217	-77.339983	540	NA
11/18/2010	38.501817	-77.312950	545	1860
11/1/2011	38.501883	-77.315367	545	1560
6/6/2013	38.513967	-77.339683	545	1440
6/5/2012	38.509933	-77.324133	546	1620
7/2/2013	38.509867	-77.323550	546	1460
6/1/2011	38.504550	-77.313117	547	1360
6/6/2013	38.507800	-77.313983	547	1420
9/10/2013	38.503867	-77.312083	549	1450
10/23/2013	NA	NA	549	1530
6/9/2011	38.514500	-77.334700	551	1490
7/2/2013	38.507400	-77.315317	551	1300
7/2/2013	38.514817	-77.338117	553	1450
6/1/2011	38.510483	-77.327783	554	1560
7/26/2011	38.509033	-77.324417	555	1280
8/13/2013	38.514200	-77.340250	556	1420
11/18/2010	38.501817	-77.312950	558	1690
6/9/2011	38.505317	-77.313183	558	1820
10/23/2013	NA	NA	558	1730
6/1/2011	38.510483	-77.327783	559	1580
7/26/2011	38.505767	-77.324283	559	1460
11/18/2010	38.500667	-77.312633	560	1940
7/7/2011	38.514667	-77.335983	560	1800
5/17/2012	38.515017	-77.336950	560	1610
6/15/2010	38.510183	-77.322250	561	1540
11/18/2010	38.501817	-77.312950	561	1980
6/5/2012	38.507950	-77.314017	561	1660
8/13/2013	38.502783	-77.311783	563	1530
10/4/2011	38.503850	-77.319783	565	1740
11/1/2011	38.501800	-77.314883	565	1790
11/1/2011	38.504300	-77.314283	568	1870
11/18/2010	38.500667	-77.312633	570	1810
6/28/2011	38.514733	-77.338217	570	1650
8/18/2011	38.514783	-77.336583	570	1250
11/1/2011	38.504017	-77.313600	570	1800
6/8/2010	38.514983	-77.337717	572	1430
5/17/2012	38.514800	-77.337833	572	1450
9/10/2013	38.508400	-77.314367	572	1410

6/28/2012	38.516550	-77.337700	573	1460
4/4/2011	38.511233	-77.329350	574	1950
11/1/2011	38.501117	-77.312183	575	2060
6/15/2010	38.514700	-77.338233	578	1770
3/22/2011	38.509883	-77.327900	578	2000
7/7/2011	38.501617	-77.311867	578	2000
5/17/2012	38.514533	-77.338483	579	1690
10/4/2011	38.504850	-77.321917	580	1910
11/4/2013	NA	NA	580	2040
5/17/2012	38.514817	-77.337067	581	1720
6/8/2010	38.514383	-77.338817	584	1720
7/7/2011	38.509983	-77.324450	584	1750
8/13/2013	38.504583	-77.324217	587	1790
11/4/2013	NA	NA	587	1950
11/1/2011	38.502000	-77.312750	588	1910
6/28/2012	38.501117	-77.313400	589	1850
4/22/2013	38.514483	-77.338400	589	1670
3/22/2011	38.505050	-77.327833	590	1740
11/4/2013	NA	NA	590	2060
6/6/2013	38.514833	-77.337500	594	1810
9/10/2013	38.504050	-77.312483	594	2260
4/22/2013	38.502083	-77.316283	596	1870
9/24/2013	38.501767	-77.317450	596	2010
9/10/2013	38.504817	-77.327883	597	2430
5/26/2011	38.507600	-77.313850	598	2000
10/4/2011	38.502050	-77.315533	599	2260
8/13/2013	38.502200	-77.312033	599	1940
7/26/2011	38.503050	-77.317833	600	2240
10/4/2011	38.503017	-77.317917	600	2230
9/24/2013	38.506817	-77.313250	600	1930
7/19/2011	38.510717	-77.327117	602	1460
7/26/2011	38.503417	-77.317617	602	1900
9/10/2013	38.504883	-77.325683	602	1810
11/18/2010	38.501817	-77.312950	603	2330
5/17/2012	38.514533	-77.338483	604	2260
8/13/2013	38.509883	-77.316300	604	2020
8/18/2011	38.514333	-77.338967	605	1750
11/1/2011	38.502617	-77.315500	605	2170
6/5/2012	38.514817	-77.337150	605	2060
9/24/2013	38.505100	-77.327967	605	1770

6/5/2012	38.510500	-77.320483	608	2040
6/15/2010	38.510033	-77.324717	609	2020
6/9/2011	38.515033	-77.337150	609	2030
6/5/2012	38.510833	-77.327200	609	1920
7/7/2011	38.506633	-77.312483	610	2260
6/5/2012	38.510067	-77.318567	610	2230
10/4/2011	38.510167	-77.331167	611	2420
7/2/2013	38.514050	-77.339600	611	1960
8/27/2013	38.501950	-77.316583	611	NA
11/18/2010	38.500667	-77.312633	615	2490
8/27/2013	38.503950	-77.321783	615	2280
11/4/2013	NA	NA	615	2580
7/26/2011	38.503300	-77.318033	616	1940
7/19/2011	38.514283	-77.346083	619	1670
6/6/2013	38.509850	-77.323867	619	2250
7/26/2011	38.504183	-77.320317	622	2110
6/15/2010	38.510533	-77.320550	623	2280
6/28/2012	38.514800	-77.336767	626	1990
6/5/2012	38.515217	-77.338117	628	2290
5/26/2011	38.507817	-77.314067	629	2300
6/1/2011	38.514150	-77.339217	629	2330
8/18/2011	38.514883	-77.337183	630	2500
9/14/2011	38.509883	-77.324967	630	2150
6/15/2010	38.511283	-77.328400	631	2330
7/2/2013	38.505350	-77.311450	632	2220
8/27/2013	38.504033	-77.321067	632	NA
7/7/2011	38.501517	-77.311867	635	2400
5/17/2012	38.510483	-77.327250	637	2480
5/17/2012	38.502567	-77.316267	640	2540
5/17/2012	38.514017	-77.339233	642	2540
9/10/2013	38.505033	-77.330000	642	2070
7/7/2011	38.514667	-77.336033	645	2300
6/1/2011	38.514550	-77.338483	646	2440
8/27/2013	38.509833	-77.326033	647	2170
9/10/2013	38.504833	-77.326083	647	2440
6/1/2011	38.514483	-77.338267	649	2070
10/23/2013	NA	NA	650	3710
5/19/2011	38.514983	-77.343400	651	2970
8/27/2013	38.500067	-77.314933	653	NA
9/24/2013	38.509717	-77.318783	655	2860

8/13/2013	38.514450	-77.341500	656	2080
6/9/2011	38.514517	-77.341833	657	2480
5/19/2011	38.514883	-77.343017	658	2770
4/22/2013	38.500950	-77.313567	658	2460
8/18/2011	38.507583	-77.313850	660	2750
5/26/2011	38.504450	-77.324100	665	2930
10/23/2013	NA	NA	668	2650
6/5/2012	38.509900	-77.323850	670	2800
5/26/2011	38.510000	-77.322567	676	3500
7/2/2013	38.501100	-77.312017	676	3210
11/18/2010	38.500667	-77.312633	682	3050
11/18/2010	38.500667	-77.312633	682	3110
7/26/2011	38.510300	-77.319800	682	2760
6/6/2013	38.514250	-77.334800	685	2950
7/26/2011	38.504767	-77.323433	690	2860
11/1/2011	38.501117	-77.313183	690	3250
7/2/2013	38.514433	-77.338817	690	2650
10/23/2013	NA	NA	690	2730
5/19/2011	38.514983	-77.343400	694	2910
6/28/2011	38.514200	-77.339150	698	2550
7/7/2011	38.514483	-77.338600	698	2830
11/1/2011	38.501417	-77.314300	698	3410
7/2/2013	38.505217	-77.311717	698	2740
6/8/2010	38.514983	-77.338817	700	3130
10/23/2013	NA	NA	702	3410
11/1/2011	38.501650	-77.314400	706	3370
8/18/2011	38.514883	-77.337667	707	3250
8/13/2013	38.503750	-77.321250	709	3100
11/1/2011	38.501800	-77.314883	710	3560
6/5/2012	38.510117	-77.322733	710	2990
6/28/2012	38.500683	-77.313217	710	3290
4/22/2013	38.514367	-77.338867	710	3080
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6/6/2013	38.510867	-77.329900	727	3910
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6/28/2012	38.514683	-77.336133	738	3210
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6/15/2010	38.510617	-77.320183	745	3420
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9/3/2014	38.877	NA	220	100
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9/3/2014	38.862	NA	228	112
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9/3/2014	38.423	NA	229	113
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9/3/2014	38.389	NA	254	155
5/21/2014	NA	NA	255	157
5/14/2015	38.538	NA	255	157
9/3/2014	38.709	NA	256	159
9/3/2014	38.484	NA	259	164
9/3/2014	38.542	NA	260	166
9/3/2014	38.24	NA	260	166
9/3/2014	38.332	NA	260	166
9/3/2014	38.389	NA	260	166
9/3/2014	38.187	NA	264	174
9/3/2014	38.53	NA	267	180
9/3/2014	38.234	NA	267	180
5/14/2015	38.599	NA	269	184
5/14/2015	38.712	NA	270	186
5/14/2015	38.047	NA	270	186
5/14/2015	38.749	NA	275	197
5/14/2015	38.675	NA	275	197
5/15/2015	NA	NA	281	210
5/22/2014	38.109	NA	285	219
6/11/2015	38.88	NA	285	219
5/21/2014	NA	NA	290	231
5/15/2015	NA	NA	290	231
5/21/2015	NA	NA	290	231
9/3/2014	38.083	NA	294	241
6/11/2014	38.514	NA	295	243
5/14/2015	38.102	NA	295	243
9/3/2014	38.093	NA	298	251
5/15/2015	38.411	NA	299	254

5/14/2015	38.025	NA	300	256
5/21/2015	NA	NA	300	256
5/21/2015	NA	NA	300	256
6/11/2015	38.609	NA	300	256
6/11/2014	38.153	NA	303	264
5/20/2014	38.715	NA	306	272
5/14/2015	38.603	NA	309	280
5/14/2015	38.131	NA	310	283
5/14/2015	38.408	NA	310	283
6/11/2015	38.648	NA	310	283
5/21/2015	NA	NA	315	297
5/21/2015	NA	NA	315	297
5/14/2015	38.037	NA	319	308
5/14/2015	38.676	NA	320	311
5/14/2015	38.25	NA	320	311
5/14/2015	38.318	NA	320	311
5/14/2015	38.369	NA	320	311
5/14/2015	38.592	NA	322	317
6/11/2015	38.88	NA	322	317
6/11/2014	38.747	NA	324	323
5/14/2015	38.188	NA	324	323
5/14/2015	38.722	NA	325	326
5/14/2015	38.057	NA	325	326
5/14/2015	38.188	NA	325	326
5/15/2015	38.279	NA	328	335
5/14/2015	38.652	NA	330	341
5/21/2015	NA	NA	334	354
5/14/2015	38.72	NA	335	357
5/14/2015	38.45	NA	335	357
5/14/2015	38.13	NA	339	370
5/15/2015	38.602	NA	339	370
5/14/2015	38.088	NA	340	374
5/14/2015	38.11	NA	344	387
5/15/2015	38.302	NA	345	390
5/14/2015	38.599	NA	347	397
6/11/2015	38.537	NA	350	408
5/15/2015	38.573	NA	355	426

5/21/2015	NA	NA	355	426
5/14/2015	38.609	NA	357	433
5/14/2015	38.608	NA	358	437
5/14/2015	38.047	NA	358	437
5/15/2015	38.128	NA	358	437
5/15/2015	38.712	NA	359	440
5/21/2015	NA	NA	360	444
5/14/2015	38.037	NA	361	448
5/15/2015	38.289	NA	364	459
6/11/2015	38.822	NA	365	463
5/14/2015	38.538	NA	368	474
5/15/2015	38.688	NA	369	478
5/14/2015	38.036	NA	370	482
5/21/2015	NA	NA	370	482
6/11/2015	38.721	NA	370	482
6/30/2015	NA	NA	370	390
6/30/2015	NA	NA	372	392
6/11/2015	38.721	NA	373	494
6/11/2015	38.304	NA	377	510
5/15/2015	38.154	NA	379	519
6/30/2015	NA	NA	380	472
5/21/2015	NA	NA	385	544
5/14/2015	38.111	NA	389	561
5/21/2015	NA	NA	390	565
5/21/2015	NA	NA	390	565
5/21/2015	NA	NA	390	565
6/11/2015	38.095	NA	390	565
5/14/2015	38.13	NA	391	570
9/3/2014	38.318	NA	396	592
5/15/2015	38.019	NA	398	601
7/8/2014	38.131	NA	399	606
6/11/2015	38.598	NA	402	619
7/8/2014	38.022	NA	407	643
7/8/2014	38.681	NA	410	657
7/8/2014	38.048	NA	410	657
7/8/2014	38.604	NA	411	662
5/15/2015	38.411	NA	411	662

7/8/2014	38.036	NA	412	667
7/8/2014	38.427	NA	420	707
7/20/2015	NA	NA	420	1140
7/20/2015	NA	NA	425	648
7/21/2015	NA	NA	430	NA
5/14/2015	38.616	NA	439	808
6/11/2015	38.851	NA	445	842
5/20/2014	38.725	NA	455	900
6/30/2015	NA	NA	455	779
6/30/2015	NA	NA	460	862
5/15/2015	38.14	NA	465	961
7/22/2015	NA	NA	470	868
6/30/2015	NA	NA	475	964
7/21/2015	NA	NA	485	NA
6/30/2015	NA	NA	490	1072
5/15/2015	38.75	NA	499	1189
7/21/2015	NA	NA	500	NA
5/14/2015	38.278	NA	505	1233
5/14/2015	38.592	NA	510	1270
7/21/2015	NA	NA	514	NA
5/15/2015	38.404	NA	531	1434
6/11/2015	38.609	NA	532	1442
5/14/2015	38.431	NA	535	1467
5/21/2014	NA	NA	540	1509
7/8/2014	38.627	NA	540	1509
6/11/2015	38.717	NA	543	1534
7/8/2014	38.131	NA	544	1543
5/21/2015	NA	NA	556	1648
6/11/2015	38.696	NA	559	1675
5/20/2014	38.14	NA	565	1730
7/8/2014	38.466	NA	573	1804
7/21/2015	NA	NA	578	NA
5/21/2015	NA	NA	580	1872
6/11/2015	38.916	NA	580	1872
7/8/2014	38.604	NA	585	1921
5/14/2015	38.188	NA	587	1941
6/11/2015	38.88	NA	589	1961

6/11/2014	38.729	NA	591	1981
5/14/2015	38.565	NA	592	1991
6/11/2015	38.557	NA	598	2120
6/11/2015	38.602	NA	599	2200
8/13/2014	38.883	NA	600	2073
5/21/2015	NA	NA	605	2126
7/21/2015	NA	NA	605	NA
6/11/2015	38.503	NA	610	2140
8/13/2014	38.941	NA	615	2234
5/21/2015	NA	NA	620	2289
5/20/2014	38.724	NA	630	2402
7/8/2014	38.466	NA	635	2460
8/13/2014	38.217	NA	640	2519
5/14/2015	38.717	NA	641	2531
6/11/2015	38.64	NA	642	2543
6/30/2015	NA	NA	642	2458
5/21/2014	NA	NA	645	2579
6/11/2014	38.534	NA	647	2603
5/14/2015	38.55	NA	648	2615
7/8/2014	38.565	NA	650	2640
6/11/2015	38.717	NA	650	2640
6/11/2014	38.542	NA	656	2714
7/8/2014	38.055	NA	656	2714
5/14/2015	38.093	NA	659	2752
7/8/2014	38.604	NA	660	2764
9/3/2014	38.53	NA	665	2828
6/11/2015	38.851	NA	665	2828
6/11/2015	38.519	NA	666	2600
5/22/2014	38.771	NA	670	2892
5/21/2014	NA	NA	675	2958
7/20/2015	NA	NA	675	2933
7/8/2014	38.327	NA	680	3025
5/14/2015	38.608	NA	680	3025
6/11/2014	38.318	NA	681	3038
7/21/2015	NA	NA	687	NA
5/14/2015	38.578	NA	695	3231
7/21/2015	NA	NA	695	NA

5/21/2014	NA	NA	700	3301
6/30/2015	NA	NA	700	3210
6/11/2014	38.851	NA	705	3373
8/13/2014	38.565	NA	709	3431
5/20/2014	38.186	NA	710	3445
5/21/2015	NA	NA	710	3445
6/11/2014	38.611	NA	711	3460
5/21/2014	NA	NA	720	3594
6/30/2015	NA	NA	720	3139
9/3/2014	38.722	NA	722	3624
6/11/2015	38.095	NA	728	3716
5/20/2014	38.904	NA	730	3747
7/8/2014	38.538	NA	730	3747
5/14/2015	38.703	NA	730	3747
9/3/2014	38.246	NA	735	3825
7/8/2014	38.483	NA	739	3888
5/21/2015	NA	NA	740	3904
6/11/2015	38.855	NA	743	3952
5/20/2014	38.143	NA	750	4065
5/14/2015	38.068	NA	753	4114
7/8/2014	38.425	NA	758	4197
7/21/2015	NA	NA	760	NA
6/11/2015	38.561	NA	765	4400
6/11/2015	38.876	NA	771	4418
5/21/2014	NA	NA	772	4436
6/11/2014	38.079	NA	776	4505
5/14/2015	38.711	NA	780	4576
5/15/2015	38.09	NA	790	4755
6/11/2015	38.783	NA	795	4650
6/11/2014	38.584	NA	805	5033
5/21/2014	NA	NA	820	5321
6/11/2015	38.503	NA	821	4960
7/21/2015	NA	NA	825	NA
6/11/2015	38.425	NA	840	5460
7/21/2015	NA	NA	840	NA
6/11/2014	38.584	NA	845	5825
5/21/2015	NA	NA	845	5825

5/14/2015	38.565	NA	867	6295
5/22/2014	38.836	NA	884	6675
5/21/2014	NA	NA	885	6698

Supplemental Material S3. Maximum consumption rates (Cmax) expressed in milligrams per gram per day (mg/g/d) was estimated using a consumption model parameterized by water temperature (°C) that varied across months for different population sizes (Nt) that ranged between 300 – 650 northern snakehead *Channa argus*.

Month	Nt	Water Temperature (°C)	Cmax (mg/g/d)
January	300	3.579802654	0.049528274
January	300	3.617409628	0.073110608
January	300	3.220863659	0.118508416
January	300	2.71907707	0.179249453
January	300	3.997751938	0.227604615
January	300	3.196518906	0.292660765
January	300	3.407048607	0.355979829
January	300	3.679162693	0.420320292
January	350	3.907835689	0.049620257
January	350	3.035235468	0.07293885
January	350	2.428787705	0.120186602
January	350	2.758889444	0.176887182
January	350	1.951514848	0.227736628
January	350	2.352128658	0.294820675
January	350	2.695030794	0.34548557
January	350	3.139481279	0.416209433
January	400	3.660860713	0.050408303
January	400	3.586642951	0.074498385
January	400	2.778046644	0.120851186
January	400	4.110226062	0.178863044
January	400	3.363760992	0.226084864
January	400	2.737433229	0.29010724
January	400	3.123233938	0.354034863
January	400	2.937835057	0.421217769
January	450	3.688533526	0.049124014
January	450	2.879410948	0.073644914
January	450	4.072744808	0.118474921
January	450	2.385068508	0.177423218
January	450	2.749339801	0.22116974
January	450	3.712481586	0.298025597
January	450	3.786190336	0.350776508
January	450	3.420278676	0.415581703
January	500	2.546411784	0.050261163
January	500	2.743500706	0.075494302

January	500	2.406839357	0.121191835
January	500	3.076154519	0.176316516
January	500	4.136798985	0.230105857
January	500	2.978641274	0.297706287
January	500	3.012490067	0.347641586
January	500	1.332729934	0.417430192
January	550	3.347770005	0.050286864
January	550	2.889773819	0.07742278
January	550	2.854469748	0.118208233
January	550	2.744829402	0.179028246
January	550	2.977400354	0.226555263
January	550	1.865133237	0.292915467
January	550	1.834609181	0.352105219
January	550	2.982244788	0.410729008
January	600	2.558103678	0.050174967
January	600	2.091014055	0.074373067
January	600	2.652089318	0.120324775
January	600	3.125584876	0.180400437
January	600	3.63249774	0.231043916
January	600	2.558156076	0.295554034
January	600	2.641015417	0.353546644
January	600	3.104149517	0.424913205
January	650	4.266133282	0.049134015
January	650	2.547421708	0.074057716
January	650	3.694625789	0.119339212
January	650	2.875582598	0.180345183
January	650	4.639080985	0.230473114
January	650	2.155784518	0.296273511
January	650	3.025632083	0.356275047
January	650	3.067403884	0.414953695
December	300	4.238692523	0.084142206
December	300	4.864689832	0.12727431
December	300	5.207111335	0.202975955
December	300	4.775174231	0.302464427
December	300	4.627903139	0.387847578
December	300	3.73767462	0.50482669
December	300	4.997472145	0.598127217
December	300	4.897622843	0.704595667
December	350	4.427418655	0.084854104
December	350	3.827636314	0.126641875
December	350	4.997274718	0.201984105
December	350	3.929581925	0.301245227
December	350	5.691016636	0.396816639

December	350	4.40530125	0.503652615
December	350	4.801807525	0.59310455
December	350	4.867466956	0.713898782
December	400	5.905645397	0.084276262
December	400	3.672325984	0.130227113
December	400	5.079478828	0.205349338
December	400	4.809930395	0.297055028
December	400	3.794483464	0.387642025
December	400	3.847097637	0.496063485
December	400	4.528758948	0.590502553
December	400	4.376432072	0.716930233
December	450	3.837985861	0.085653666
December	450	5.178038087	0.12675879
December	450	4.158272874	0.20550566
December	450	4.444076877	0.308128102
December	450	5.059761346	0.387536331
December	450	4.357446738	0.499291257
December	450	3.005094493	0.600729655
December	450	4.214420057	0.713050834
December	500	3.866268378	0.083722423
December	500	4.61110152	0.126572191
December	500	3.995581833	0.206657532
December	500	4.496754236	0.30500406
December	500	4.931377804	0.38746608
December	500	2.756824274	0.499756006
December	500	4.634728428	0.595281928
December	500	4.186519642	0.712489388
December	550	4.370553027	0.08470583
December	550	4.933718263	0.125663024
December	550	4.797346504	0.200466045
December	550	4.656991726	0.304726721
December	550	5.920813952	0.386636649
December	550	4.792913721	0.500893125
December	550	3.864386064	0.600288259
December	550	5.146497695	0.713479433
December	600	4.462621404	0.084643905
December	600	5.280677042	0.127007929
December	600	4.28162142	0.204464714
December	600	4.642305173	0.302412702
December	600	4.265350385	0.394225035
December	600	3.673860602	0.507588553
December	600	4.460117933	0.593614611
December	600	4.366524765	0.701387288

December	650	4.947219006	0.084277741
December	650	5.1719947	0.127314558
December	650	4.511729107	0.207059701
December	650	4.167105816	0.301888164
December	650	4.168975246	0.387072453
December	650	5.36656671	0.505459977
December	650	4.362472673	0.604145002
December	650	4.863673081	0.70916779
March	300	6.20200765	0.159594339
March	300	6.030520025	0.241574714
March	300	6.269859039	0.383576522
March	300	6.358930212	0.573912063
March	300	6.311146869	0.733534169
March	300	6.545179126	0.95154364
March	300	6.116601343	1.131505125
March	300	6.231545838	1.344173502
March	350	6.424092594	0.160101636
March	350	6.013246564	0.239382204
March	350	6.109290333	0.384283212
March	350	6.338360221	0.575241309
March	350	6.200401735	0.739952822
March	350	6.569718372	0.949549486
March	350	6.435761006	1.130907268
March	350	6.172247213	1.35047474
March	400	6.294312201	0.16042506
March	400	6.178143126	0.241139131
March	400	6.302079736	0.383247838
March	400	6.385852438	0.574106159
March	400	6.335932258	0.735070397
March	400	6.366540533	0.957058566
March	400	6.426058428	1.131640731
March	400	6.280116726	1.343170603
March	450	5.992861943	0.160123074
March	450	6.128632035	0.24040556
March	450	6.053573948	0.388451362
March	450	6.142650584	0.577083552
March	450	6.215567595	0.735949918
March	450	6.303841917	0.951342903
March	450	6.422974282	1.13353127
March	450	6.437922639	1.35170371
March	500	6.374329299	0.160494085
March	500	5.956440011	0.244377209
March	500	6.344777758	0.383829897

March	500	6.422505612	0.574514405
March	500	5.990746341	0.736170886
March	500	5.968781023	0.951639036
March	500	6.447519821	1.13420222
March	500	6.29068944	1.348335432
March	550	6.373616696	0.160742672
March	550	6.16292758	0.244299355
March	550	6.327879882	0.385594374
March	550	6.248377662	0.577806605
March	550	6.241355002	0.734698036
March	550	6.147706114	0.953421726
March	550	6.311793273	1.135011759
March	550	6.224437269	1.344241198
March	600	6.354544472	0.160679972
March	600	6.331238008	0.240025623
March	600	6.166790902	0.384510089
March	600	6.693361388	0.573807848
March	600	6.293910418	0.737910858
March	600	6.194959058	0.953593315
March	600	6.392351376	1.131333619
March	600	5.863764416	1.351104056
March	650	6.132105319	0.159845298
March	650	6.511490735	0.240178582
March	650	6.04672079	0.385367578
March	650	6.229383196	0.574286076
March	650	5.964779118	0.736032481
March	650	6.238334659	0.955526222
March	650	6.394238707	1.131565594
March	650	6.367744831	1.342207135
February	300	4.745150459	0.116411995
February	300	3.26835635	0.177243042
February	300	6.372931436	0.294983763
February	300	5.650704508	0.424869455
February	300	4.666359905	0.545033155
February	300	3.857659443	0.679481447
February	300	0.940220389	0.847467628
February	300	5.284353308	0.982082173
February	350	4.959593386	0.116066667
February	350	4.527440169	0.173052989
February	350	5.163209398	0.293687443
February	350	3.061402378	0.426453885
February	350	3.337442098	0.544495474
February	350	4.710115284	0.705603269

February	350	5.547627098	0.837495732
February	350	4.133043144	1.029414464
February	400	5.024975587	0.116842381
February	400	6.675618188	0.183234397
February	400	2.836059221	0.286834664
February	400	5.60976772	0.423749994
February	400	2.332322877	0.522863747
February	400	5.184551921	0.714789839
February	400	3.868987712	0.832519895
February	400	6.465290404	0.976608424
February	450	4.503076262	0.12084282
February	450	1.635505515	0.179520132
February	450	5.900396126	0.278173299
February	450	3.894941522	0.42759784
February	450	4.135948605	0.553980515
February	450	4.189204678	0.701180025
February	450	5.978681114	0.842878281
February	450	6.302329497	0.979708738
February	500	6.724725338	0.118576578
February	500	4.811555728	0.176284116
February	500	3.192414065	0.289480882
February	500	6.60486986	0.416947485
February	500	4.875768419	0.542013391
February	500	2.913640351	0.701689281
February	500	6.941266	0.854838318
February	500	2.714482703	1.016700582
February	550	7.795757	0.120131435
February	550	4.427365807	0.17289321
February	550	3.807925666	0.284011016
February	550	4.921941939	0.419884549
February	550	7.210469821	0.543674738
February	550	5.045330793	0.714299369
February	550	5.075862126	0.830517704
February	550	5.74859369	0.977921101
February	600	4.756525609	0.115224414
February	600	5.236965476	0.177515756
February	600	5.805008966	0.274431621
February	600	5.73526357	0.429966792
February	600	7.562066817	0.545981981
February	600	4.665504276	0.715439243
February	600	6.311954324	0.847153284
February	600	5.402323846	0.99720339
February	650	2.77287953	0.115601636

February	650	4.6878067	0.179354148
February	650	6.422096899	0.283933573
February	650	6.494020673	0.415465442
February	650	4.523111019	0.542863736
February	650	5.494473642	0.696932095
February	650	5.775840665	0.848127706
February	650	5.60890788	0.995896756
April	300	9.646290019	0.455777126
April	300	9.803178951	0.688820728
April	300	9.577538522	1.083504283
April	300	9.164061641	1.631352255
April	300	9.432737878	2.096213172
April	300	9.553756978	2.702402694
April	300	9.177806043	3.213284904
April	300	9.581219947	3.826225845
April	350	9.713847102	0.456704567
April	350	9.634187398	0.692535972
April	350	9.496276007	1.093589092
April	350	9.742335676	1.636178682
April	350	9.674988371	2.087762276
April	350	9.813185075	2.72301806
April	350	9.435105168	3.226620341
April	350	9.756233182	3.812302305
April	400	9.67395949	0.45606159
April	400	9.532650848	0.696135946
April	400	9.503997648	1.096007297
April	400	9.528789841	1.633121081
April	400	9.652623417	2.09016774
April	400	9.332488226	2.707845263
April	400	9.340613907	3.214262183
April	400	9.439250337	3.847225572
April	450	9.423517456	0.449948489
April	450	9.646560298	0.679703391
April	450	9.190087318	1.086052415
April	450	9.341179783	1.634000482
April	450	9.418378347	2.093450023
April	450	9.428629107	2.712410149
April	450	9.184139835	3.209341097
April	450	9.429195651	3.814383218
April	500	9.46772711	0.458928086
April	500	9.711529528	0.682214042
April	500	9.789882459	1.095000427
April	500	9.351674049	1.633241297

April	500	9.209788898	2.089603802
April	500	9.139854495	2.704091459
April	500	9.419928943	3.209593545
April	500	9.654567938	3.820030676
April	550	9.816877196	0.452803834
April	550	9.994044574	0.683617513
April	550	9.259145957	1.095458385
April	550	9.615179502	1.633661238
April	550	9.364062933	2.112291942
April	550	9.280926792	2.709421335
April	550	9.493855742	3.223798518
April	550	9.638508257	3.816886125
April	600	9.582857029	0.454076277
April	600	9.547271219	0.672296315
April	600	9.167033275	1.093934573
April	600	9.353926737	1.626343988
April	600	10.00775959	2.09335947
April	600	9.557583687	2.710114751
April	600	9.294595328	3.203468189
April	600	9.677904105	3.826960876
April	650	9.610468681	0.453642642
April	650	9.784212107	0.68416956
April	650	9.163275126	1.085474753
April	650	9.276445031	1.625131423
April	650	9.836377362	2.099140936
April	650	9.178235484	2.709907541
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April	650	9.562724263	3.826118761
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November	300	9.391997963	0.583304389
November	300	9.21741164	0.946590968
November	300	8.803994678	1.392483236
November	300	8.603724028	1.757370482
November	300	8.878352339	2.317424859
November	300	9.308839018	2.759790148
November	300	7.796388242	3.246697185
November	350	8.456369638	0.389928343
November	350	9.027073917	0.579567685
November	350	8.417917018	0.94084151
November	350	8.711822359	1.393887139
November	350	9.279806269	1.774000652
November	350	9.234141892	2.295024968
November	350	8.283789346	2.751982249

November	350	8.793233402	3.26868278
November	400	8.077945573	0.390738786
November	400	9.329974013	0.587515576
November	400	8.174415543	0.936699809
November	400	8.697660056	1.399853636
November	400	9.541037764	1.776531703
November	400	9.483804627	2.323901357
November	400	9.352698173	2.751425041
November	400	9.077306188	3.267906691
November	450	8.985196634	0.387866539
November	450	10.00555636	0.579245415
November	450	9.149147854	0.934777503
November	450	8.623669552	1.391531715
November	450	8.702734322	1.773824213
November	450	8.897022202	2.288871714
November	450	8.767362867	2.723185612
November	450	9.102076532	3.253420698
November	500	9.082087756	0.388841998
November	500	9.319854206	0.584832072
November	500	8.956216968	0.934487272
November	500	9.11459604	1.401685341
November	500	8.683534659	1.782663518
November	500	9.109060154	2.274596676
November	500	8.795403337	2.770826337
November	500	8.957513057	3.26621842
November	550	9.673094122	0.386148806
November	550	8.907957618	0.582676152
November	550	9.527199832	0.929685667
November	550	9.189314794	1.400426025
November	550	8.935206814	1.778719486
November	550	8.348259401	2.302877191
November	550	8.052846378	2.770143171
November	550	8.509142627	3.264139245
November	600	8.901197067	0.388158424
November	600	9.186501672	0.585812814
November	600	9.642667764	0.929962771
November	600	8.760185285	1.389396353
November	600	8.825124258	1.782592246
November	600	9.888821057	2.312234399
November	600	8.684860946	2.740673859
November	600	8.233786561	3.252886668
November	650	8.617790928	0.387453307
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November	650	9.126734896	1.379927494
November	650	8.684406739	1.784046569
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May	300	20.11259805	6.102197111
May	300	20.09499468	9.729991671
May	300	19.93469928	14.57751489
May	300	19.83256053	18.65425408
May	300	19.80831543	24.14100892
May	300	19.32906235	28.79555991
May	300	19.84908368	34.00917756
May	350	19.56396507	4.032162653
May	350	19.67879092	6.074062108
May	350	19.72995254	9.753370153
May	350	19.46338606	14.50179778
May	350	19.98993496	18.64529596
May	350	19.63795783	24.20126055
May	350	19.93114543	28.6644419
May	350	19.62838712	34.07242441
May	400	19.79833254	4.042211041
May	400	19.88916744	6.052116437
May	400	19.63566437	9.778808039
May	400	19.60272221	14.57640196
May	400	19.33336677	18.65764067
May	400	19.34709501	24.18348536
May	400	19.35485957	28.66351326
May	400	20.24739191	34.21861836
May	450	19.62609372	4.068109014
May	450	19.52524423	6.123603612
May	450	19.26641825	9.80572499
May	450	20.22390288	14.54116186
May	450	19.89826097	18.70740823
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May	450	19.42167986	28.78450745
May	450	19.44342639	34.1246809
May	500	19.60485679	4.067067342
May	500	19.82480895	6.144088901
May	500	19.64077009	9.786106965
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May	550	19.64363369	14.61789928
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May	600	19.83099687	6.154241837
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September	300	18.36138644	27.34763353
September	300	21.68784716	32.64141781
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September	350	16.09248486	5.873189655
September	350	19.04245542	9.328984596
September	350	20.92395711	13.94937879
September	350	18.44681873	17.76870495
September	350	19.35071433	23.13193397
September	350	22.48204198	27.39466267
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September	400	18.50130767	5.748510646
September	400	18.25993854	9.251770304
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September	400	18.1754227	17.8969165
September	400	19.28166268	22.90219101
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September	450	21.56646315	3.853923535
September	450	19.40853339	5.766052663
September	450	19.83302135	9.309604114
September	450	18.55952145	13.96094755
September	450	17.56957775	17.50395444
September	450	18.04606688	23.20232332
September	450	19.71931688	27.23583798
September	450	17.43397676	32.6667993
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October	350	22.07032746	12.85795069
October	350	22.20085172	19.20258521
October	350	22.17513353	24.71109663
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October	400	21.9856911	19.16905032
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July	350	28.3217174	7.485885825
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July	350	28.01737029	52.26237393
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July	400	28.15723376	7.485973156
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July	450	28.1282498	11.14535538
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July	450	28.08478846	26.50308495
July	450	28.11011735	34.03788668
July	450	28.05548712	43.83670333
July	450	28.20990974	52.44684137
July	450	28.18209564	62.11417033
July	500	28.1499115	7.467498231
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July	500	28.29764438	62.09554405
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July	550	28.01442728	26.66093572
July	550	28.15498609	33.9965935
July	550	27.99139813	43.95858266
July	550	28.05951277	52.41473681
July	550	28.1269782	62.23868682
July	600	28.11382288	7.408252981
July	600	28.04701365	11.05513633
July	600	28.07353932	17.77551934
July	600	28.29038206	26.59405199
July	600	27.99353051	33.97950678
July	600	28.08308858	43.90870719
July	600	28.02030855	52.2524289
July	600	28.20188092	62.2608242
July	650	28.07640172	7.406123568
July	650	28.11222411	11.04116902
July	650	28.29294349	17.68296176
July	650	27.96598599	26.48201021
July	650	27.95842272	34.02156826
July	650	28.34519051	43.75532948
July	650	28.11120057	52.4397601
July	650	28.16261039	62.10926775
August	300	26.56673585	6.727205057
August	300	25.8647621	10.06218609
August	300	21.83187685	16.3021353
August	300	26.75541643	24.10303687
August	300	22.72680552	30.98938616
August	300	26.1771072	40.0551314
August	300	27.78073163	47.7000594
August	300	25.57475372	56.82780591
August	350	27.05378724	6.761680321
August	350	27.54564917	10.22841887
August	350	24.03944214	16.17387111
August	350	25.00989186	24.35478739
August	350	24.5240174	30.78107765
August	350	26.96762651	39.94788453
August	350	23.74254923	47.81107935
August	350	23.1065782	56.52168867
August	400	25.3659752	6.80641557
August	400	26.98700653	10.12406309

August	400	23.31695697	16.36978119
August	400	26.73061346	24.23655184
August	400	24.65977666	31.1391292
August	400	27.20807446	40.27443235
August	400	24.19539264	47.62818924
August	400	27.00604006	56.34610777
August	450	27.93399226	6.737619147
August	450	26.81745818	10.10114747
August	450	26.95795099	16.20774099
August	450	28.92610561	24.16708593
August	450	26.5022441	31.13411799
August	450	26.69949922	39.97254819
August	450	25.7346817	47.64664235
August	450	24.48506744	56.73146642
August	500	27.45430961	6.790279132
August	500	21.29865549	10.13967284
August	500	26.08148496	16.27461691
August	500	25.27781816	24.3047258
August	500	25.60146674	30.86119718
August	500	25.03905772	39.71380939
August	500	25.75597722	47.56014254
August	500	27.31193827	56.47461785
August	550	27.4576019	6.745477404
August	550	23.69030971	10.15075888
August	550	25.02577811	16.30224621
August	550	27.05632547	24.10748737
August	550	29.2909647	30.84205767
August	550	29.66319178	39.81535248
August	550	25.76866432	47.63105164
August	550	26.75313004	56.86216929
August	600	26.76219731	6.742357859
August	600	24.3857422	10.12515266
August	600	22.90867406	16.18818143
August	600	24.6956123	24.20438162
August	600	26.91530884	30.88459967
August	600	27.12915061	40.27302225
August	600	27.90631425	47.64747222
August	600	26.24072505	56.70048312
August	650	21.0688585	6.763093594
August	650	27.05029826	10.13607189
August	650	24.01696018	16.29790203
August	650	24.5144205	24.32382473
August	650	26.85136811	31.07807246

August	650	24.34226968	39.7639294
August	650	24.0752298	47.5364044
August	650	22.99860421	56.95144142