ONTARIO POWER GENERATION

Report

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PICKERING NUCLEAR GENERATING STATION 2019 IMPINGEMENT MONITORING REPORT

Pickering Nuclear Generating Station
2019 Impingement Monitoring Report

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Revision Summary

Revision Number	Date	Comments
R000	2020-04-29	Initial issue.

Executive Summary

This report documents outcomes of impingement mitigation measures and impingement monitoring for the 2019 calendar year. The report satisfies both condition 3.1 and condition 3.2.1 of the *Fisheries Act* Authorization for the Ontario Power Generation (OPG) Pickering Nuclear Generating Station (PNGS), which was issued in January 2018.

The primary measure to avoid or mitigate fish impingement at PNGS is the Fish Diversion System (FDS). The FDS is a net comprised of 20 mesh panels that extend from the bottom to the surface and encompass the intake. Connected, the FDS panels have a combined length of 610 m. Primary and secondary skirts are attached to the main net and are designed to deploy if the float line of the main net sinks or is pulled beneath the surface. The FDS was in place and functioning from April 30th to November 3rd, 2019. Installation and removal dates complied with condition 2.1.1.1 and condition 2.1.1.2 of the Authorization, respectively.

Consistent with prior monitoring, depth loggers, recording instantaneous depth at 15-minute intervals, were installed on the FDS in 2019 to monitor the float line depth relative to the water surface. The loggers are attached to the main net, the primary skirt and the secondary skirt. According to logger data, the secondary skirt on the West, East and South aspect functioned as designed and was at the surface, 96%, 92% and 88% of the time, respectively. The primary skirt was also located at the surface most of the time (80 to 90%) on all three aspects.

Impingement monitoring was scheduled throughout the calendar year. Fish collected in bar screen and travelling screen bins over the sampling period were identified, counted and weighed to calculate impingement numbers, biomass and rates of biomass impinged per unit volume of intake water used by the condenser cooling water (CCW) pumps. In 2019, 353 bins were assessed.

A total of 35 taxa, identifiable to the species level were impinged. The combined biomass of all species and ages impinged in 2019 was 15,114.5 kg, a rate equivalent to 2.87 kg per million cubic metres of station intake volume. Alewife (11,194 kg; 74.1% of total biomass), and Gizzard Shad (2,707 kg; 17.9% of total biomass) were most common, as expected.

There were no Species at Risk Act (SARA) Schedule 1 fish species observed impinged in 2019. Twelve American Eel, with a combined biomass of 17.2 kg, were documented during impingement monitoring. The extrapolated number is 42 individuals with an estimated combined biomass of 58.8 kg. Two additional American Eel were impinged outside the normal sampling period. Twenty-one Northern Pike were documented. The annualized estimate was 92 individuals with a combined biomass of 143 kg. There were no episodic fish kill events in 2019.

Fish impingement in 2019 was higher than recorded in the prior five years. The impingement estimate for the year was influenced by above average impingement rates in January, June, November and December. Subsequent investigation (Patrick, 2020) determined that none of the exceedances were caused by PNGS operations and were primarily attributed to unusually cold weather and other environmental phenomena.

1.0 INTRODUCTION

Ontario Power Generation Inc. (OPG) is the owner and operator of the Pickering Nuclear Generating Station (PNGS). PNGS, located on the north shore of Lake Ontario, has eight CANDU pressurized heavy water reactors (Units) on the site. PNGS has six Units operating with two Units in Safe Storage state. PNGS has been operating safely and generating electric power since 1971. PNGS draws large volumes of lake water, through a surface water intake, for cooling purposes. An environmental effect of using lake water for cooling is impingement and entrainment of aquatic organisms.

OPG has monitored impingement at PNGS on multiple occasions since operations commenced. OPG has conducted consecutive annual monitoring since 2010, with mitigation efforts and results of monitoring reported to the Canadian Nuclear Safety Commission (CNSC).

In 2009, a fish diversion system (FDS), consisting of a barrier net in front of the PNGS intake, was installed on a trial basis. Its capability to reduce impingement was studied through to 2011, inclusive. Trial results indicated that the FDS met or exceeded the 80% impingement reduction target in each trial year. As a result, in 2012, the CNSC accepted the FDS as a permanent mitigation measure to reduce fish impingement for all species, except Northern Pike, (CNSC, 2012) during the period it is installed. During the trial period, the FDS was not as effective for adult Northern Pike, since this species was impinged primarily in winter months when the FDS is removed.

A *Fisheries Act* Authorization (the Authorization) was issued to OPG on January 17, 2018 (DFO, 2018). The Authorization period extends from the date of issue to December 31, 2028 and encompasses the remaining Operations Phase (2018-2024) and Stabilization Phase (2025-2028) at PNGS.

OPG committed to the FDS as the primary measure to avoid or mitigate impingement and to install the FDS main net by May 1 and retaining it in place to at least November 1 of each year. OPG also agreed to complete annual impingement monitoring through the Authorization period. The Authorization defines the biomass of impingement losses that are annually allowed and contains several conditions associated with avoidance and mitigation measures, contingency measures, monitoring, offsetting, reporting, and limitations.

This report is being submitted to satisfy both condition 3.1 and condition 3.2.1 of the Authorization.

2.0 IMPINGEMENT AVOIDANCE AND MITIGATION MEASURES

2.1 Fish Diversion System

2.1.1 Design and Design Modifications

The FDS is the primary measure to avoid and mitigate impingement. The FDS design consists of a main net, which covers the entire depth of the water column, and a primary skirt and secondary skirt that can be deployed when water depths increase and the main net is pulled subsurface. The secondary skirt was added in 2011 to reduce fish impingement in circumstances where portions of the main net and primary skirt became submerged (Poulton, 2012).

There were no modifications made to the FDS design 2019.

2.1.2 Installation and Removal

A complete check of the FDS system components was completed by OPG prior to installation.

OPG completed installation of the FDS main net and primary skirt on April 30th, 2019. Installation of the secondary skirt was completed on May 22nd, 2019. The installation completion dates comply with condition 2.1.1.1 of the Authorization which requires installation of the main net by May 1st of each year and installation of the secondary net by June 1st of each year.

The FDS, in its entirety, was in place and functioning until November 3rd, 2019. Removal of the secondary net started on November 4th, 2019 and was completed November 8th, 2019. Removal of the primary net started on November 11th, 2019 and was completed on November 26th, 2019. The removal date complies with condition 2.1.1.2 of the Authorization which requires the FDS, in its entirety, to remain in place and functioning until November 1st of each year.

2.1.3 Operations and Maintenance

While installed, the FDS was inspected and maintained on an ongoing basis. Inspection and maintenance consisted of:

- Visual checks of net floats by Nuclear Security Officers to assess if main, primary or secondary floats were below the surface;
- If visual checks indicated some of the floats were submerged, follow up checks were completed to determine the cause of the net sag and whether or not additional maintenance was necessary; and

- Multi-day per week subsurface inspection, hydraulic cleaning, and net maintenance by the Dive Operations team of OPG's Inspection & Reactor Innovation (IRI) Department.

2.1.4 Functionality and Performance

The Authorization requires OPG to demonstrate the FDS is functioning as intended. If the FDS fails in any capacity, repair is required and visual inspections are to be increased until functionality is restored.

During operations, functionality and performance are measured through visual checks, inspections and maintenance described above. If the FDS is not functioning as intended, the cause is investigated and addressed.

The availability of the net (portion of time that floats are on or within 30 cm of the surface) was also assessed using depth loggers. The loggers are attached to the FDS while it is installed and are removed and downloaded after the FDS is removed. The data can be used to validate visual or field observations described below.

In late May, it was reported that the net crown floats on the north corners by the groynes were under water by about 30 cm as a result of the elevated Lake Ontario water levels. Diver inspections found that parts of the net were shorter than the water depth and the net floats were pulling the ground chain off the bottom of the Lake, creating gaps of up to 15 cm. To assess this risk, FDS design specifications were compared to observed water levels and projected trends. The assessment determined that 1) small gaps near the bottom represent a very small area relative to the total area of the FDS panels; 2) the risk of intrusion is limited primarily to benthic species, which typically represent a small proportion of impinged fishes and 3) if water levels stabilized, or loading increased the panels would sink further and the issue would be resolved. Installation of mid-water floats was planned for completion in 2019, but was not completed since the addition of floats would have exacerbated net lifting being caused by the record high water levels.

On June 14th, Nuclear Safety Officers noticed submergence of floats on the main, primary and secondary net on the West aspect. This was reported and FDS status was checked in the field by IRI divers. The situation was monitored to assess if weather conditions were temporarily impacting the FDS. The FDS was reported to be functional on June 15th and the temporary submergence was attributed to historically high water depths. FDS logger data confirmed submergence of net more than 40 cm on June 14th for a brief period of time (several hours).

A total of twenty-one depth loggers were installed on the FDS in 2019 to monitor the depth of the main net, primary skirt and secondary skirt float lines relative to the water surface. There are four loggers attached to each aspect of the secondary skirt, two loggers to each aspect of the primary skirt and one logger on each aspect of the main net. Each depth logger records water pressure at 15-minute intervals. Atmospheric pressure is subtracted from the logger pressure and the resulting value is multiplied by a conversion factor to calculate depth below the water surface. Due to function checks

and battery replacement, depth loggers were not attached to the nets until the beginning of June. Therefore, there is no logger data available for the month of May. Security reports (visual observations) showed net was fully functional in May.

If a logger recorded a value that is below surface and the reading was not suspect, it was conservatively assumed that the net float line at that logger location was submerged. The risk of fish swimming above a submerged float line and into the intake channel is conservatively assumed to be elevated when the number of logger locations and the depth of submergence increases. By design, gaps typically occur only if the main net, primary skirt and secondary skirt are all submerged simultaneously. For impingement risk to increase, fish also would need to be in the vicinity, find the gap, and swim through the gap and into the intake forebay. For monitoring purposes, FDS performance is deemed acceptable when the loggers on the secondary skirt are at the surface or submerged to depths not exceeding 30 cm.

In 2019, all 21 loggers were retrieved. Table 1 provides a weekly summary of the percentage of time that floats on the secondary skirt were at surface or not greater than 30 cm depth, for each aspect of the FDS, for the period it was in service. The secondary skirt on the East, South and West aspect was at the surface most of the year. For reference, five hours of submergence time below 30 cm depth equates to 3% of a week.

Table 1: Fraction of week that each aspect of the FDS secondary skirt was at the surface or not greater than 30 cm below the surface from June to November 2019.

Week		Aspect		
Start	End	East	South	West
04-Jun-19	11-Jun-19	100%	100%	100%
11-Jun-19	18-Jun-19	100%	98%	95%
18-Jun-19	25-Jun-19	100%	100%	98%
25-Jun-19	02-Jul-19	100%	99%	95%
02-Jul-19	09-Jul-19	100%	100%	99%
09-Jul-19	16-Jul-19	100%	100%	100%
16-Jul-19	23-Jul-19	100%	100%	100%
23-Jul-19	30-Jul-19	100%	96%	94%
30-Jul-19	06-Aug-19	99%	92%	97%
06-Aug-19	13-Aug-19	98%	65%	81%
13-Aug-19	20-Aug-19	89%	55%	79%
20-Aug-19	27-Aug-19	98%	100%	97%
27-Aug-19	03-Sep-19	93%	73%	93%
03-Sep-19	10-Sep-19	92%	55%	92%
10-Sep-19	17-Sep-19	88%	91%	100%
17-Sep-19	24-Sep-19	100%	94%	100%
24-Sep-19	01-Oct-19	95%	70%	97%

Week		Aspect		
Start	End	East	South	West
01-Oct-19	08-Oct-19	68%	82%	100%
08-Oct-19	15-Oct-19	74%	93%	100%
15-Oct-19	22-Oct-19	59%	86%	99%
22-Oct-19	29-Oct-19	79%	92%	100%
29-Oct-19	05-Nov-19	80%	99%	100%

Figure 1, Figure 2 and Figure 3 provide the time series of average daily depth of the east, south and west aspects of the FDS, respectively. Table 2 provides a summary of the depth data as a frequency distribution during the monitoring period. The secondary skirt was most frequently located within 30 cm of the water surface, 96%, 92% and 88% of the time for West, East and South, respectively. The South secondary skirt dipped below 30 cm for several days, from August 10th to 16th according to the logger data. The West secondary skirt was below 30 cm for several hours on June 14th, although average daily depth (Figure 3) remained above the 30 cm performance threshold. The primary skirt was located at the surface most of the time (80 to 90%) on all three aspects, though it was submerged to 2 m below the surface on the West aspect on August 10th and more than 1.5 m on the South aspect on August 16th. The main net was located within 50 cm of the water surface (in the 0-30 and 30-50 cm range), 55%, 76% and 35% of the time for West, East and South aspect, respectively.

Figure 1: Daily average depth of FDS float lines on the East facing aspect.

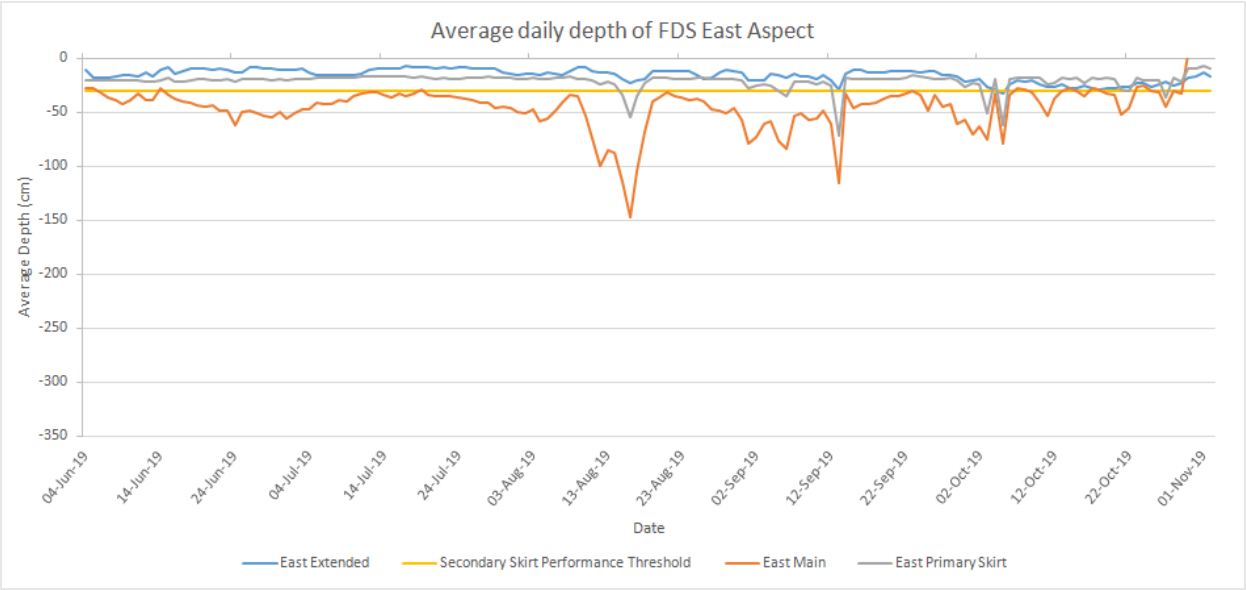


Figure 2: Daily average depth of FDS float lines on the South facing aspect.

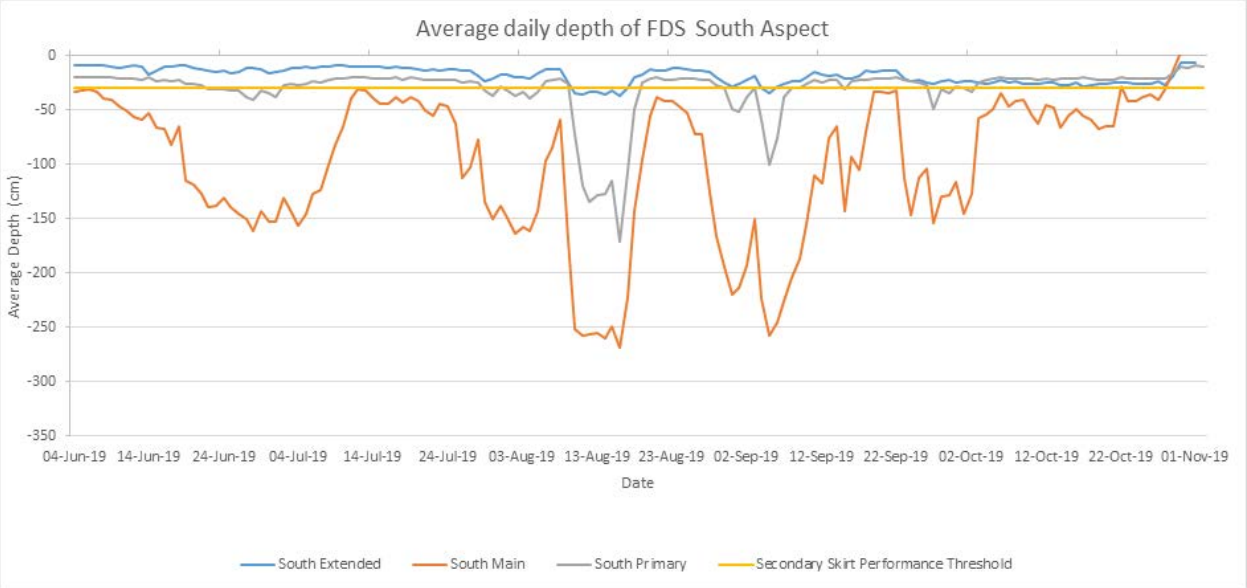


Figure 3: Daily average depth of FDS float lines on the West facing aspect.

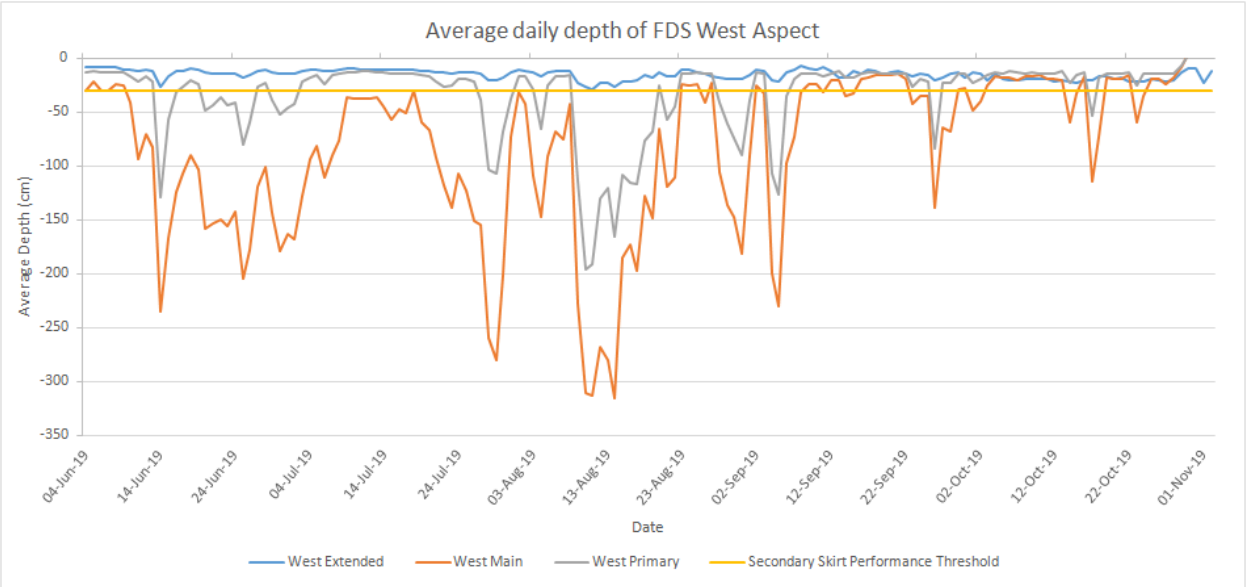


Table 2: Time frequency that primary and secondary float lines were in individual depth ranges based on depth logger data.

Depth Range	West			South			East		
	2nd Skirt	1st Skirt	Main Net	2nd Skirt	1st Skirt	Main Net	2nd Skirt	1st Skirt	Main Net
0-30	96%	82%	43%	88%	81%	8%	92%	93%	18%
30-50	4%	3%	12%	12%	10%	27%	8%	5%	58%
50-100	0%	5%	11%	0%	5%	21%	0%	1%	20%
100-200	0%	8%	22%	0%	4%	34%	0%	1%	4%
200-300	0%	2%	8%	0%	0%	10%	0%	0%	0%
> 300	0%	0%	3%	0%	0%	0%	0%	0%	0%

3.0 IMPINGEMENT MONITORING

3.1 Monitoring Effort

From 2010 to 2012, OPG undertook an extensive trial study to demonstrate that the FDS was capable of meeting the CNSC impingement reduction targets. In 2012, the CNSC accepted that the FDS met the trial target of 80% reduction (CNSC 2012). Subsequently, in 2013, the objective of the sampling program was changed from performance demonstration to compliance verification. Consequently, in April 2013 the sampling program to monitor fish impingement was reduced from five events per week to one event per week (OPG, 2013). Impingement monitoring effort during the Authorization period was proposed in the FAA and is based on the effort employed during the 2013-2017 compliance verification period. Retention of fish collected in bar screen and travelling screen bins in operating units is presently targeted to occur for one weekly 24-hour period from May 1 to October 31 (when the FDS is installed as a mitigation measure) and one weekly 48-hour period the remainder of the year (when the FDS is typically removed).

Fish collected in bins during the sampling periods are identified, counted and weighed to calculate impingement numbers, biomass and rate of biomass impinged per unit volume of intake water used by the CCW pumps. Table 3 displays the sampling effort in 2019 and compares it with the previous years. Results indicate that the fraction of time sampled in 2019 is comparable to that of the FDS compliance verification period, as is intended.

Table 3: Comparison of impingement monitoring effort during different monitoring years and periods since 2003.

Period	Year	# Bins Sampled	Total In-Service Bin Hours sampled	Fraction of time sampled[3]
Pre-FDS	2003 - 2004	574	32,236	46%
FDS Performance Evaluation	2006[1]	234	25,420	36%
	2010	1,505	37,904	54%
	2011	1,456	38,541	55%
	2012	1,181	29,415	42%
Compliance Verification[2]	2013	400	14,711	21%
	2014	353	12,178	17%
	2015	281	9,516	14%
	2016	338	12,012	17%
	2017	327	11,808	17%
Fisheries Act Authorization Monitoring	2018	354	11,495	16%
	2019	353	12,439	18%

Notes:
[1] Monitoring in 2006 encompassed spring, summer and fall only.
[2] In addition to the weekly sampling, OPG committed to undertake event based sampling if a fish run occurred between the regularly scheduled sampling events.
[3] Based on a full year of service for the 8 bin locations.

3.2 Unit Operating Status and Intake Volume

Table 4 provides the number of days that condenser cooling water (CCW) pumps were not operating at a specific Unit in 2019. PNGS Unit 2 and Unit 3 are in a safe storage state and the CCW pumps are not used, as these Units are not generating power, nor are the CCW pumps providing water for other purposes. When operating, each Unit normally has two CCW pumps running. Total CCW intake volume in 2019 was 5.27 billion cubic metres.

Table 4: CCW operating status in 2019.

Unit	Days with no CCW pumps operating
1	0
2	365
3	365
4	0
5	104
6	1
7	95
8	1

3.3 Data Quality Management

OPG undertakes data quality management of the fish impingement monitoring program at various steps during the program design, data collection, data entry, data analysis and results reporting process. Impingement monitoring followed OPG approved procedures, standards, guides and manuals.

Fish were identified and enumerated by staff that are trained in identification of Ontario fish species. Photos of impinged fish that are measured and weighed are taken and archived to assist in subsequent species verification, if an identification is uncertain. The identification of species listed in Schedule 1 of the Species at Risk Act (SARA) is verified by the Royal Ontario Museum (ROM) or other qualified third party. The identification of uncommon species was checked and verified by OPG biologists, and in some cases by ROM staff as well.

Field results were entered into an impingement database. Entered data was peer checked by an independent reviewer for input errors. Potential omissions, errors and outliers in each data field were flagged and investigated. The total number of samples for each month at each monitoring location was reviewed. In the unlikely instance where no samples were collected in a month but the CCW pumps were operational, (for example, due to the prolonged maintenance of an intake screen system), impingement was estimated using data collected from other Units.

3.3.1 Atypical Impingement Volumes that were Potential Data Outliers

Once all entered data was validated, queries in the database that are designed to calculate impinged numbers and biomass for each bin sampled during routine monitoring were run. The total count and total biomass in each bin for each monitoring event was reviewed and compared against historic (2010-2018) rates, standardized to a 24 hour collection period, to flag potential outliers. Each potential outlier was investigated and if it was determined to be a valid outlier, that sampling event for that bin was excluded from the data that was used to extrapolate the monthly value. The impingement number and biomass for that date for that specific bin was then added to

the extrapolated monthly value and the values recalculated to determine the total monthly result (see Appendix A for more details).

Fifteen of 353 bins sampled had impingement numbers or biomass estimates that exceeded the mean ± 3 standard deviation thresholds used to identify outliers at the bin level (Table 5). A close evaluation of data from other bins on days prior to or following the sample date, suggested that impingement rates were also elevated; therefore, the bins were assumed representative of the week (i.e. not outliers).

Table 5: Individual bins identified as having count or biomass estimates that were potential data outliers.

Date	Bin Location	Calculated 24 hr Count	Calculated 24 hr Biomass (gm)	2010-2018 Bin Outlier Threshold	
				24 hr Count	24 hr Weight
28-Jan-19	56 BS	106	86,010	90	17,882
28-Jan-19	78 BS	106	95,176	357	10,845
10-Jun-19	12 TS	219	5,755	421	5,214
17-Jun-19	12 TS	605	4,296	421	5,214
17-Jun-19	34 TS	643	6,169	549	6,509
11-Nov-19	78 TS	26,802	134,456	18,591	160,196
18-Nov-19	34 BS	232	2,120	120	10,663
18-Nov-19	56 TS	64,771	241,719	54,182	343,765
18-Nov-19	78 TS	65,529	235,961	18,591	160,196
25-Nov-19	34 BS	272	2,392	120	10,663
25-Nov-19	78 TS	48,541	243,662	18,591	160,196
2-Dec-19	12 BS	3,394	33,838	92	3,622
2-Dec-19	34 BS	3,986	53,569	120	10,663
2-Dec-19	78 TS	24,689	163,438	18,591	160,196
16-Dec-19	12 BS	94	502	92	3,622

3.4 Impingement Estimate

The formulas used to calculate monthly impingement and extrapolate it over the year are provided in Appendix B.

4.0 2019 FISH IMPINGEMENT

4.1 All Species and Life Stages

Figure 4 and Table 6 provide the biomass of fish impinged in 2019. The quantity of fish impinged is provided in Table 7, and the rate of biomass impinged per unit volume of intake water used by the CCW pumps is provided in Table 8. All estimates are for all species and life stages of fish impinged. For clarity, OPG notes that the Authorization value is based on Age-1 equivalent impingement and entrainment estimates for 23 modelled species only. These species are denoted with an asterisk (*) beside the species name in Table 6 and Table 7.

The combined biomass of all species and ages impinged in 2019 was 15,114.5 kg, a rate equivalent to 2.87 kg per million cubic metres of station intake volume. The FDS was installed on schedule and impingement rates during the period the FDS was installed were within the anticipated range, except for the month of June (Figure 4). On several occasions from early to mid June, dead fish (Alewife) were observed floating along the shoreline, in Frenchman's Bay and on the Lake bottom on the outside of the FDS prior to the exceedance period in June. It is unclear as to what caused the fish deaths (Patrick 2020), dead fish floating over the FDS mesh may have contributed to the elevated impingement rates observed.

Before FDS installation and after FDS removal, impingement rates can be sporadic and highly variable. During these periods, impingement rates are more influenced by several variables beyond the control of OPG. These factors include (but are not limited to) total fish biomass in the lake, weather, coastal processes, water temperature fluctuations, mass seasonal movements or sporadic impingement events. During the period the FDS was not installed in 2019, the monthly impingement rates were relatively acceptable from February to April, but were considerably higher than projected in January and November to December. It is worth noting that since the monthly impingement rates are extrapolated from weekly estimates, the bins identified in Table 5 are substantial contributors to monthly and cumulative annual impingement.

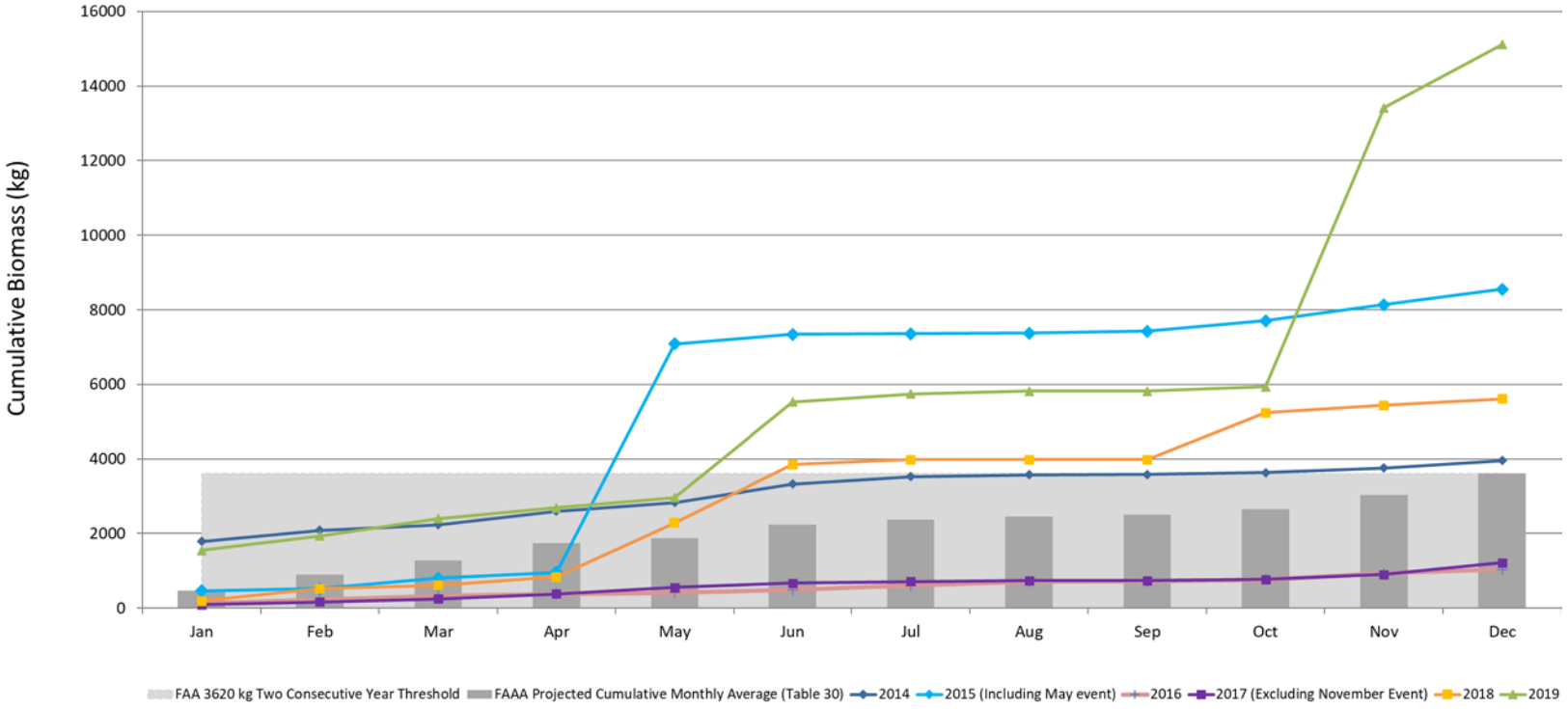
The high impingement in January is indicative of unusually cold conditions in the lake and not attributed to PNGS operations. A polar vortex caused lake temperatures to plunge below 2°C prior to the January 28 sampling event and frazzle ice was also reported in the intake forebay. Primarily, adult Gizzard Shad were impinged during this period, this species is known to be susceptible to "cold shock" at or below 2°C (Patrick, 2020). Die-offs of Gizzard Shad near power plants is a relatively common occurrence in the Great Lakes and other waterbodies within the region (Patrick, 2020).

Elevated rates of impingement throughout several weeks of November-December also appear to be influenced by low water temperatures and not as a result of PNGS operations (Patrick, 2020). Land Ocean Biophysical Observatory (LOBO) data shows temperatures declining from 12 °C on November 2nd to 2.6 °C by the 19th. It appears the unusually cold temperatures may have forced near shore fish movement and induced cold shock and/or stupor (reduced fish swimming ability) significantly increasing impingement risk. There were multiple species of fish (Alewife, Gizzard Shad and to lesser extent White Perch, Northern Pike and other species) impinged over multiple days during this period. Temperatures remained below 3°C (close to lower threshold for thermally sensitive fish) in November for an extended period. Due to limited data, there is some degree of uncertainty on the lower temperature thresholds for the impinged fish, including specific acclimation temperatures.

Consistent with the 2018 impingement report, Figure 4 and Table 8 exclude the 2017 impingement event. In 2017, an additional 24,000 kg of Alewife were impinged during a November event that OPG reported to CNSC and DFO. A report investigating the factors contributing to the event was subsequently submitted to CNSC and Fisheries and Oceans Canada (DFO). CNSC staff accepted OPG's conclusions that the impingement event was an unusual occurrence, that likely could not have been anticipated or mitigated, and warranted no corrective action. CNSC staff also accepted that it is likely that the environmental conditions at the time of event caused the impingement event as indicated by OPG (CNSC, 2018). As a result, Figure 4 and Table 8 have been adjusted to reflect the impingement biomass and rate precluding the event.

Impingement is also influenced by trends in lake-wide abundance of various fish species. Fish populations are monitored by the Lake Ontario Management Unit of the Ontario Ministry of Natural Resources and Forestry. Their most recent annual report (for 2018) is available online at http://glfc.org/lakecom/loc/mgmt_unit/. A comparison of impingement rates to species population trends is beyond the scope of this report.

Figure 4: Annual cumulative biomass (kg) of fish of all species and ages impinged from 2013-2019.



Notes:

1. The Fisheries Act Authorization two consecutive year threshold requires consultation with DFO if >3619 kg of fish of all species and ages are impinged in two consecutive years, commencing in 2018.

2. The cumulative biomass includes data extrapolated from routine impingement monitoring, and an impingement event occuring in May 2015, which was attributable to a breach in the FDS.

Table 6: Monthly biomass and annual fish impinged (kg) at Pickering Nuclear Generating Station in 2019.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total (kg)
Alewife*	0.05			2.45	98.72	2,351.57	179.79	55.77	0.70	8.78	7,202.96	1,293.25	11,194.0
American Brook Lamprey												0.03	0.03
American Eel*	8.90	4.07									3.69	42.17	58.8
Atlantic Salmon*			3.35	5.50									8.85
Black Bullhead*			3.12									0.87	4.0
Bluegill*		0.09											0.09
Brown Bullhead*	5.76	3.08	4.16	1.83	8.27			3.57			0.99		27.7
Brown Trout		16.55											16.55
Carp/Gold Fish		0.72			5.10								5.8
Channel Catfish												1.62	1.62
Chinook Salmon*			0.06	54.46							16.05	0.09	70.7
Common Carp*	24.63		21.62	40.03		2.86				66.31	0.31	16.10	171.85
Emerald Shiner*	0.14	0.67	0.77	0.02	0.10							0.03	1.7
Freshwater Drum*											1.35		1.35
Gizzard Shad*	1,485.28	288.35	339.35	122.70	34.16	2.21	0.00	0.00	0.00	34.94	149.27	251.24	2,707.5
Gold Fish	0.80	0.13		5.70									6.64
Golden Shiner	0.03												0.0
Lake Trout*											22.70		22.70
Largemouth Bass*						0.16	0.34		0.34			1.37	2.2
Logperch					0.13								0.13
Longnose Gar											1.53		1.5
Northern Pike*	12.78	34.70	3.72	2.59							45.06	44.12	142.97
Pumpkinseed		0.07	0.17	0.04							0.51	0.01	0.8
Rainbow Smelt*	0.57	1.93	10.78	10.89	0.32	0.60				0.97	0.97		27.04
Rainbow Trout*											8.98		9.0
Rock Bass		1.13	0.83			0.18	0.04		0.58				2.75
Round Goby	2.92	10.16	13.71	24.47	126.77	198.03	38.50	12.19	2.52	2.44	14.28	4.95	450.9
Smallmouth Bass*		4.31		3.42		0.07					0.62	1.23	9.66
Three-spine Stickleback*	0.12	7.87	45.12	5.75	1.90	0.00	0.13	0.08	0.01		0.03	0.01	61.0
Unid	0.76												0.76
Unid - Salmonids		5.38									4.93		10.3
Walleye				9.85								6.67	16.52
White Bass*	5.51	10.67										1.63	17.8
White Perch*		1.27									0.75	34.37	36.38
White Sucker*	1.11	0.46	10.12	2.47		4.27	0.11		0.17		3.22	0.00	21.9
Yellow Perch*			1.39	0.63			0.62			0.19			2.82
Total (kg)	**1.5**	**0.4**	**0.5**	**0.3**	**0.3**	**2.6**	**0.2**	**0.1**	**0.0**	**0.1**	**7.5**	**1.7**	**15,114.5**

Table 7: Number of fish impinged at Pickering Nuclear Generating Station in 2019.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Alewife*	4			253	8,263	176,489	9,650	4,533	292	1,530	1,768,137	181,133	2,150,283
American Brook Lamprey												3	3
American Eel*	8	5									4	26	42
Atlantic Salmon*			4	22									26
Black Bullhead*		4	8									3	15
Bluegill*		25											25
Brown Bullhead*	23	27	23	11	46			51			8		189
Brown Trout		5											5
Carp/Gold Fish		5			34								39
Channel Catfish												7	7
Chinook Salmon*			4	11							4	3	22
Common Carp*	8		4	11		8				8	18	6	63
Emerald Shiner*	81	319	203	4	34							3	645
Freshwater Drum*											4		4
Gizzard Shad*	1,757	307	374	195	44	8				34	4,212	546	7,476
Gold Fish	4	5		15									23
Golden Shiner	4												4
Lake Trout*											4		4
Largemouth Bass*						22	61		8			3	94
Logperch					24								24
Longnose Gar											4		4
Northern Pike*	12	28	4	4							24	21	92
Pumpkinseed		23	125	10							36	3	198
Rainbow Smelt*	35	142	1,142	1,046	67	74				117	213	3	2,840
Rainbow Trout*											4		4
Rock Bass		9	4			7	8		15				43
Round Goby	69	494	560	904	8,500	11,747	2,089	2,583	690	782	2,306	240	30,966
Smallmouth Bass*		5		7		7					18	3	41
Three-spine Stickleback*	85	4,864	30,060	4,175	1,275		57	51	27		36	10	40,639
Unid	4		15										19
Unid - Salmonids		4									4		8
Walleye				7								3	11
White Bass*	8	13										3	24
White Perch*		9									4	28	42
White Sucker*	8	29	42	12		8	15		8		8		129
Yellow Perch*			23	27			62			34			146
Total	**2,108**	**6,321**	**32,592**	**6,714**	**18,287**	**188,370**	**11,943**	**7,218**	**1,039**	**2,505**	**1,775,050**	**182,050**	**2,234,198**

Table 8: Impinged biomass, intake volume and impingement rate by volume.

Year	Annual Biomass (kg)	Annual Station Flow (billion m^3)	Annual Rate (kg/million m^3)
2003/2004	18,214	4.19	4.35
2010	4,617	4.88	0.95
2011	4,012	4.77	0.84
2012	1,706	4.94	0.35
2013	2,926	4.86	0.60
2014	3,953	4.82	0.82
2015[1]	8,553	5.07	1.69
2016	1,035	4.70	0.22
2017	1,217	5.05	0.24
2018	5,616	4.88	1.15
2019	15,114	5.27	2.87

Note: [1] 6,000 kg of impingement in 2015 was attributable to a single event in May 2015 caused by an opening in the net seam. Excluding this event, the impingement rate in 2015 was 2,553 kg or 0.50 kg/million m^3 of station intake volume.

4.2 Species Impinged in 2019 to be Included in Age-1 Equivalency Estimates

The Authorization value is based on the modeled Age-1 equivalent biomass for 23 species which were used in the FAAA modeling. In 2019, 22 of the 23 species were impinged. Round Whitefish was not observed in impingement monitoring in 2019. The combined biomass impinged for the 22 species was 14,600 kg, representing 97% of the total biomass impinged.

4.3 Regulated and Other Aquatic Invasive Fish and Mussel Species

One regulated invasive species, Round Goby (450 kg) was impinged in 2019. Round Goby is an invasive species listed in Part 2 of SOR/2015-121 Aquatic Invasive Species Regulations and is a Species Subject to Prohibitions and Controls. The Aquatic Invasive Species Regulations also applies to Grass Carp, Bighead Carp, Silver Carp, Black Carp, Zebra Mussel, Quagga Mussel, any species of the Snakehead family, Ruffe, Rudd, and Tubenose Goby. Zebra Mussel and Quagga Mussel are impinged consistently, but similar to Round Goby these species are not included in estimates of serious harm to fish due to impingement.

Though Round Goby is included in impingement estimates for all species and age classes, DFO agreed in their review of the FAAA and in the Authorization that they are not included in estimates of Age-1 equivalent losses.

4.4 Species at Risk Act Schedule 1 Fish Species

There were no SARA Schedule 1 fish species observed impinged in 2019.

4.5 Endangered Species Act Species at Risk in Ontario List fish species

American Eel is a species listed as Endangered in the Species at Risk in Ontario (SARO) List of the Endangered Species Act (ESA). During 2019, OPG held permits for species protection or recovery issued under the authority of clause 17(2)(b) of the ESA. Impinged American Eel are reported to MNRF as a condition of the permits. In 2019 OPG voluntarily collected additional information on impinged individuals to assist in recovery efforts for the species.

Twelve (12) American Eel, with a combined biomass of 17.2 kg, were documented during impingement counts in 2019. All were observed when the FDS was removed. The extrapolated number of impinged American Eel was 42 individuals with an estimated combined biomass of 58.8 kg for 2019. Two additional American Eel were impinged outside the normal sampling period.

4.6 Northern Pike

In 2008, the CNSC requested that OPG implement measures to verify there is no population level impact on Northern Pike (CNSC 2008). Although effective at deterring all but the smallest of Northern Pike while installed, the FDS was unable to achieve a reduction in Northern Pike impingement during the FDS performance validation period, as impingement of this species occurs primarily in the winter period when the FDS is not installed.

In 2019, OPG documented 21 Northern Pike during impingement monitoring. The annualized estimate of impingement in 2019 was 92 individuals with a combined biomass of 143 kg. Table 9 provides a summary of Northern Pike impingement since 2010.

OPG participates in a Northern Pike tag monitoring program conducted by the Toronto Region Conservation Authority. During impingement monitoring, Northern Pike are scanned to determine if the fish contain a tagging device. There were no tagged Northern Pike impinged in 2019, and only one tagged individual has been confirmed as impinged since monitoring of tags began in 2010.

Table 9: Number and biomass in Northern Pike impinged in 2010-2019.

Year	Annual Number	Annual Biomass (kg)
2010	50	51
2011	46	120
2012	46	133
2013	58	188
2014	36	112
2015	27	70
2016	12	31
2017	33	21
2018	67	106
2019	92	143

4.7 Episodic Fish Kill Events

There were no episodic fish kill events in 2019.

5.0 IMPINGEMENT TRENDS

5.1 Comparison with FAA Impingement Predictions

OPG's FAAA provided annual, all ages, biomass of impinged fish in 2003/2004 and from 2010 to 2016. FAAA estimates were used to define an annual all ages impingement threshold of 3,619 kg in each of two consecutive years of impingement monitoring during the Authorization period. Condition 3.2.1.1 of the FAA states that if this threshold is exceeded, communications with DFO should be held to discuss the root causes, with the potential need for subsequent adaptive management. This commitment was included as a condition of the Authorization.

The impingement estimates provided in 2018 and in this report (2019) indicate that PNGS exceeded 3,619 kg of all ages impingement for two consecutive years. Based on preliminary impingement estimates for 2019, OPG previously provided verbal notification to DFO on June 10th, and written notification to DFO and CNSC on July 30, 2019 (OPG 2019b). In parallel and subsequent to these notifications, OPG initiated an internal evaluation of the underlying causes contributing to the elevated impingement rates. OPG subsequently retained a consultant to further evaluate and assess periods of elevated impingement in 2018 and 2019 and prepare a technical report. The consultant concluded that none of the exceedances appear to be caused by PNGS operations (Patrick, 2020).

5.2 Trends

The 2019 impingement rate was 2.87 kg/million cubic metres of CCW intake volume compared to the five-year mean of 0.82 kg/million cubic metres of CCW intake volume.

The impingement estimate for the year was influenced by above average impingement rates in June and winter months. The elevated impingement in June was unexpected, as impingement is typically low when the FDS is installed.

The high impingement in the winter months appears to be strongly influenced by weather, particularly cold water temperatures effecting fish mobility, distribution and allegedly causing mortality or stupor from cold shock.

The species with the largest all ages biomass impinged were Alewife (11,194 kg; 74.1% of total biomass), and Gizzard Shad (2,707.5 kg, 17.9% of total biomass). Round Goby contributed 3.0%, Common Carp 1.1% and Northern Pike 0.9% of the total biomass, all other species contributed less than 1% each. Gizzard Shad and Alewife were also the top two species in the 2013 to 2018 period, with the exception of 2014, where Common Carp were the second most abundant, followed by Alewife.

6.0 UNCERTAINTY

Uncertainty is a factor common to all scientific studies. The following are the primary factors that contribute to uncertainty in these impingement estimates:

- There is uncertainty associated with the performance of the FDS, numbers and species of fish that may be present in the forebay prior to FDS installation, and the number of additional fish that may enter the forebay if performance is affected by natural causes, tears or small holes.

- There is a lag effect between the period that fish enter the forebay and the time they may be impinged. Some large fish with strong swimming capabilities may never be impinged and could leave the forebay after the FDS is removed. The lag effect and how this affects monthly impingement numbers and biomass varies between species and life stages.

- There is uncertainty associated with the identification of fish sampled from the bins (physical counting, length/weight measurements, subsamples and identification), largely due to the physical condition of the fish after being impinged. To mitigate the physical condition of the fish, bins are exchanged prior to weekly monitoring. To mitigate misidentification, sampling practices have been proceduralized and monitoring is undertaken by qualified individuals that have completed the Royal Ontario Museum (ROM) fish identification course. Photos are taken of collected fishes which aid in validation. Misidentification may result in small errors associated with the individual species data reported in Tables 6 and 7.

- There is uncertainty associated with missing or incomplete data from field forms. This has been minimized by self checks, peer checks and follow up communications. If necessary, missing values for certain parameters (e.g. fish length, weight) can be estimated using descriptive statistics calculated or interpreted from available data, as described in Section 3.4

- There is uncertainty in extrapolating data for non-sampled time periods. There is also high natural variability from season to season. This uncertainty has been reduced by extrapolating data within each month, and appropriate flagging, verification and treatment of outliers in the database and associated number and biomass calculations.

- There is high natural variability from day to day, which is largely influenced by environmental factors and movement of fishes through the zone affected by the PNGS intake and CCW system. The variability associated with this is real and cannot be reduced through increased sampling effort. Typically, impingement rates are more stable when the FDS is installed as the FDS deters migration of many species and life stages into the intake forebay. However, Monte Carlo simulations on the 2011 data indicated that reducing the sampling frequency from five to one day per week would have minimal impact on the 95% confidence intervals.

7.0 CONCLUSION

This report documents outcomes of impingement mitigation measures and impingement estimates for the 2019 calendar year, and is submitted to satisfy both condition 3.1 and condition 3.2.1 of the Authorization.

The primary measure to avoid or mitigate fish impingement at PNGS is the FDS. The installation completion dates comply with condition 2.1.1.1, and the removal date complies with condition 2.1.1.2 of the Authorization, respectively.

Impingement monitoring was conducted throughout the calendar year. Fish collected in bins during the sampling periods are identified, counted and weighed to calculate impingement numbers, biomass and rates. Over 2019, 353 bins were assessed during routine impingement monitoring in Units 1, 4, 5, 6, 7 and 8 combined.

All ages impingement in 2019 was 15,114.5 kg or 2.87 kg/million cubic meters of CCW intake volume. The impingement estimate for the year was heavily influenced by above average impingement rates in January, June, November and December. A total of 35 taxa, identifiable to the species level and an estimated 2,234,198 fish were impinged in 2019. Approximately 8,496 kg of Alewife were estimated to have been impinged in November and December alone, accounting for 56% of the total estimated impingement for 2019. This elevated fish impingement was attributed primarily to weather and environmental influences and not PNGS operations.

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Appendix A: Management of Bin Outliers in Fish Impingement Database

Background

The fish impingement program at Pickering collects a nominal daily composite sample each week. These samples are used to estimate a total monthly impingement in each bar screen and travelling screen bin located in each operating unit using linear extrapolation as follows:

$$\text{EQN 1: Monthly Impingement for Bin Location 1} = \frac{[S1 + S2 + S3 + S4\ ] \times \text{Monthly Flow}}{\text{Flow1} + \text{Flow2} + \text{Flow3} + \text{Flow4}}$$

Where S1 to S4 is the number and biomass of fish impinged on each sample day 1
Flow1 to Flow 4 is the volume of water that passed through the screen on that sample day
Monthly Flow is the total volume of water that passed though the screen in the month.

Note: For simplicity, the formula illustrated is based on four weekly samples in a month. There are eight bin sampling locations, and impingement at each location is quite different. The above calculation is repeated at each of the eight bin locations and is summed to provide a Total Monthly impingement estimate as per Appendix B.

This extrapolation method assumes that the samples collected in each of the four week are also representative of the unsampled days. This assumption is valid in most instances; however, occasionally a sample is not representative of the month and if used would produce an erroneous result if used directly in the monthly extrapolation provided in Appendix B. It is therefore justified to treat the non-representative sample differently, as follows:

$$\text{EQN 2: Monthly Impingement for Bin Location 1} = \frac{[\ S1 + S2 + S3] \times \text{Monthly Flow}}{\text{Flow1} + \text{Flow2} + \text{Flow3}} + S4$$

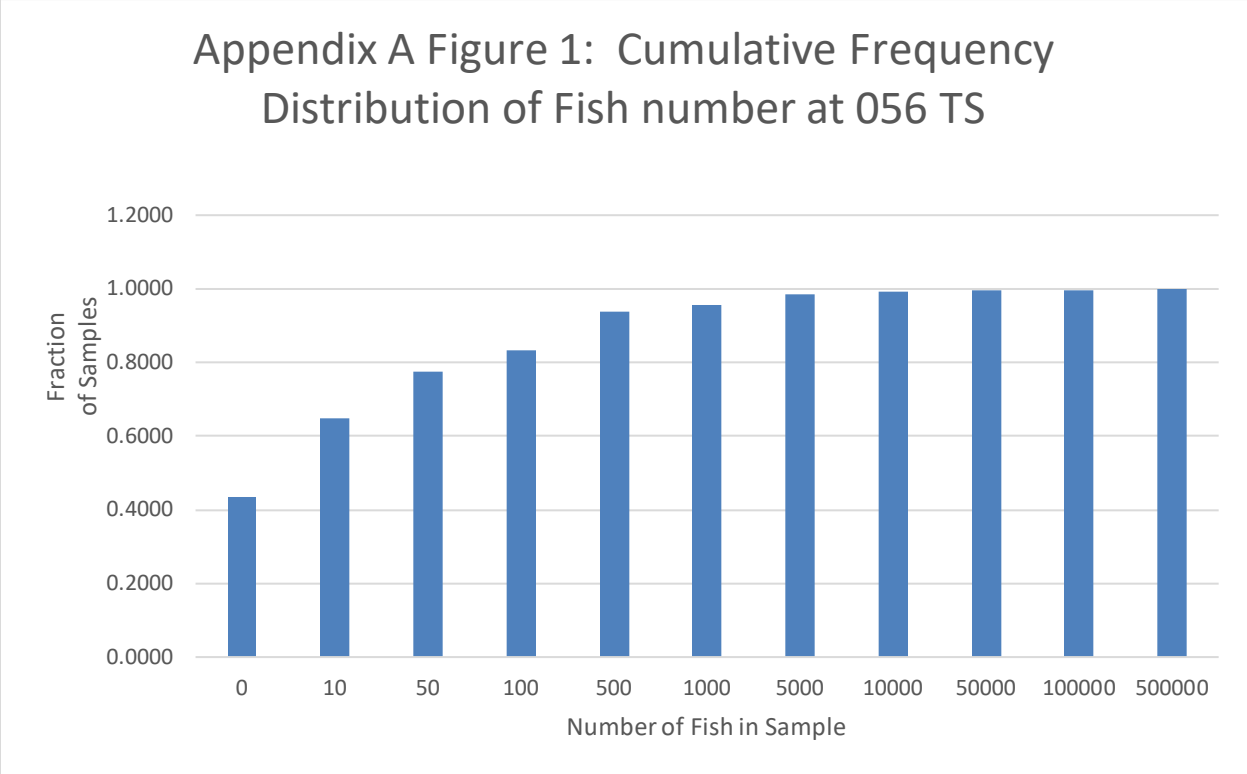
Where S4 is the non-representative sample.

The above formula uses the 3 representative samples to extrapolate the monthly total and then adds the non-representative sample as a single un-extrapolated value. This is consistent with the method OPG has previously used to incorporate an impingement event (whether or not that occurred on a scheduled or un-scheduled sampling day) into the monthly impingement value.

CSA Governance on Outliers

OPG follows the guidance provided in the N288 series of environmental standards. Outlier management is discussed in N288.4 (Environmental Monitoring Program), N288.5 (Effluent Monitoring Program), N288.6 (Environmental Risk Assessment) and N288.8 (Action Levels). N288.4 and N288.5 pertain to data collection, while N288.6 and N288.8 pertain to the use of data. These standards justify the treatment outliers differently that other data, provided there is supporting evidence that the outlier is truly an atypical result.

To illustrate, 2010 to 2018 bin data for the Unit 056 traveling screen, standardized to a 24 hour collection period, is shown in Appendix A Figure 1. Over 40% of the samples contained no fish, less than 5% contained more than 1,000 fish, and less than 1% contained more than 10,000 fish. So, in general we would not expect samples containing thousands of fish to occur more that once in a month and therefore it would be inappropriate to include such a sample in the data used to extrapolate the monthly impingement as it would produce a result which would significantly overestimate the impingement number or impingement biomass.



There is no single rule for the treatment of outliers that has been adopted by the scientific community. Many guidance documents suggest using the Mean+ 3 Standard Deviations as a rule of thumb to identify outliers. This corresponds to the 99.7th percentile, or a frequency of occurrence of 3 times in 1000 samples. This is approximately one day per year.

To develop the upper outlier threshold for each bin, data from 2010 to 2018 was used. The total number of fish per bin and total weight of fish per bin was standardized to a 24 hour period and M+3SD was calculated. The cumulative sample size for individual bins ranged from 600 to 800 per location, which was more that adequate to detect an occurrence of 3 in a 1000 samples.

Bin Location	Sample Size	24 hr Count Outlier Total number of fish in a bin	24 hr Weight Outlier Total weight (gm) of fish in a bin)
12 BS	785	92	3,622
12 TS	677	421	5,214
34 BS	781	120	10,663
34 TS	619	549	6,508
56 BS	839	90	17,882
56 TS	707	54,182	343,765
78 BS	832	357	10,845
78 TS	696	18,591	160,196

Justification required

The 99.7th percentile represents a frequency of approximately 1 day per year when you would expect that value to occur by chance. Therefore, it is reasonable to exclude samples exceeding the 99.7th percentile from the monthly extrapolation in EQN 1(where it would represent several occurrences in the month) and treat is as a single occurrence as in EQN 2 (where it would represent one occurrence in the month). The evidence necessary to support this visual observation of the bins on the days following the sample date to verify that large number of fish are not present.

Appendix B: Estimation of Annual Impingement

The following formulas were used calculate monthly impinged biomass for each species:

Monthly annualized biomass impinged for species x =

$$\sum_{Locn=1\ to\ 8} \left[\left(\sum_{Bin=1}^{j} \sum_{Fish=1}^{i} Measured\ Fish\ Weigth \right) * \frac{Total\ Flow}{Sampled\ \ Flow} \right]$$

Where:

Fish = Record of individual fish in bin_j

i = Total number of fish of species x in bin_j

Bin = Record of bin sampled at a specific bin location

j = Number of bins sampled at single bin location in one month

Locn = one of 8 screenhouse bin locations

Total Flow = Total monthly condenser cooling water and reactor building service water flow at the bin location

$= \sum_{Day=1}^{\#\ Days\ in\ Month} \text{Hourly Flow}_{day,locn} * 24\ \text{hr}$

Sampled Flow = Total flow at the bin location for the sampled time periods

$= \sum_{bin=1j} \text{Hourly Flow}_{day,locn} * \#\ \text{Hours bin j was in Service}_{day,locn}$