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Fish Impingement Sampling at Darlington Nuclear Generating Station

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EXECUTIVE SUMMARY

Darlington Nuclear Generating Station (DNGS) was the first Ontario Power Generation (OPG) generating station where fish protection issues were considered in the decision making process for both design and shoreline location of the intake. The porous intake concept was developed to circumvent the problems of the velocity cap intake which had been used at OPG's Nanticoke coal-fuelled generating station as well as at the Bruce Nuclear Generating Station (now operated by Bruce Power). It incorporated features in its design to prevent entrapment of large schools of fish. For instance, flow near the intake was made heterogeneous and designed so that velocities did not exceed the swimming capacities of large schooling species such as alewife and rainbow smelt. Studies also focused on the offshore location of the intake where fish distribution and abundance were lower than in inshore locations. Earlier studies conducted in the nineties suggested that the intake design met design requirements and impinged few fish (Wismer 1997a).

Following the results of the 2006-07 DNGS impingement study (SENES 2009a), it was recommended that an additional year of impingement data be collected to validate the data collected in 2006-07 and to determine whether Unit 4 could be used as a surrogate for the entire station in future monitoring studies.

Recent impingement sampling at DNGS was conducted over a one-year period from May 4, 2010 to April 26, 2011, with a qualified statistician assisting with the sampling design. The estimated annual impingement at DNGS was 274,931 (2362 kg) fish. The estimated counts and biomass are higher than totals reported from 2006-07 sampling (26,020 fish or 839 kg). However, some of this difference was attributed to the presence of round goby which accounted for over 50% of the total impingement in 2010-11. In 2006-07, goby only represented about 8.5% of total impingement. In addition, new more efficient travelling screens were installed in 2010-11 and changes in the lake population dynamics of alewife (increased numbers of age-1) may account for these increases. In recent sampling, a total of 13 species were identified of which round goby and alewife contributed approximately 55% and 42% of the total, respectively. In 2006-07, eight species were impinged.

A comparison of impingement at DNGS was made to other power plants on the Great Lakes. The comparison was particularly relevant with Pickering Nuclear Generating Station (PNGS) since impingement was conducted during the same year (2010-11), and each facility is only approximately 35 km apart. The results provide evidence that DNGS impinged fewer fish relative to other locations on the Great Lakes, which is consistent with earlier data reported by Wismer (1997a) and in the DEER report (1997). This is important since many of these power plants already have some fish protection system in place. For example, impingement levels at DNGS (2362 kg) were still considerably lower than that at PNGS (4617 kg) which had a fish

protection system in place (barrier net) which was estimated to be approximately 80% effective (OPG 2011). A total of 13 fish species were identified impinged at DNGS compared to 41 species at PNGS. It must be noted that the electrical output of DNGS (3512 MW) is also 12% higher than PNGS (3100 MW).

This impingement report also provided an evaluation of the biological liability of fish that were impinged at DNGS in 2010-11. Lost fishery yield was relatively small (89 kg) and consisted almost exclusively of rainbow smelt (almost 98%). Lost fishery yield for all other species combined amounted to less than 2 kg. The number of equivalent age 1 fish that could have resulted from impinged fish was estimated to be 4,242,050 with round goby being the predominant species (91% or 3,860,403 age 1 equivalents) and alewife only comprising 1.3% (56,515 age 1 equivalents). The total future production foregone was estimated to be 905.47 kg, with alewife, rainbow smelt and round goby comprising 99% of the biomass. The production foregone of alewife and rainbow smelt are negligible when considering the biomass of each species available in Lake Ontario. For example, in 2006, MNR’s Lake Ontario Management Unit (LOMU) estimated an alewife biomass in Lake Ontario of 1650 MT. In 2009, the alewife population in Lake Ontario was 134 million year one- and older fish which translated to an estimated biomass of 5298 MT.

When considering recent commercial harvest estimates (suckers, brown bullhead, yellow perch, sunfish), losses in terms of economic value were considered negligible.

Results of the 2010-11 impingement data supported the use of Unit 4 as a surrogate (conservative estimate) for the other units (Units 1-3). However, due to existing data gaps, occasional sampling at a much lower intensity at Units 1-3 is still recommended. This is to ensure that any unforeseen systematic changes are not missed. Future impingement sampling should consider using Unit 4 (which impinges the most fish) as a surrogate for the entire station as a cost saving measure. Results from Unit 4 could be multiplied by four to provide an overall estimate of impingement.

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1.0 INTRODUCTION

Darlington Nuclear Generating Station (DNGS) was the first Ontario Power Generation (OPG) generating station where fish protection issues were considered in the decision making process for both design and shoreline location of the intake. The porous intake concept was developed to circumvent the problems of the velocity cap intake which had been used at OPG's Nanticoke coal-fuelled generating station as well as at the Bruce Nuclear Generating Station (now operated by Bruce Power). It incorporated features in its design to prevent entrapment of large schools of fish. For instance, flow near the intake was made heterogeneous and designed so that velocities did not exceed the swimming capacities of large schooling species such as alewife and rainbow smelt. Studies also focused on the offshore location of the intake where fish distribution and abundance were lower than in inshore locations. Earlier studies conducted in the nineties suggested that the intake design met design requirements and impinged few fish (Wismer 1997a).

Impingement sampling was conducted in 2006-7 which is summarized in SENES (2009a). The 2009a SENES report recommended that additional impingement data should be collected with an increased sampling frequency during periods when fish densities are expected to be highest. Further sampling was required to:

1. Validate recently collected impingement data, with a view to decrease the frequency of future impingement studies.
2. Determine whether one Unit (e.g. Unit 4) could be used as a "reference location" for estimating impingement for the entire station in future studies.

The overall objective of this study was to conduct a quantitative impingement and biological liability study to assess annual impingement at the DNGS intake pumphouses (Units 1 to 4) over the spring, summer, fall and winter periods. The work was initiated in May 2010 after the Vacuum Building Outage. There were several Tasks as follows:

Task 1: Conduct Statistically Robust Impingement Sampling over a 12-month period. A statistical analysis of earlier collected data was done to determine the number and occurrence of sampling events. Results of this 2010-11 DNGS impingement study were also compared to the results from earlier conducted in the 90's (ESG 2011) and in 2006-07 (SENES 2009a). A statistical analysis of the 2010-11 results was also conducted to determine whether one Unit (Unit 4) can be used for extrapolation to the others for an annual impingement determination in future studies.

Task 2: Determine the Biological Liability Losses Associated with Impingement. Studies focused on extrapolating losses of impingement at DNGS to numbers or production of older fish, and subsequent losses in prey biomass to predators. Methodology used the Production Foregone Model and the Equivalent Adult Model consistent with USEPA methodology (Dey 2002, EPRI 2004a). The production foregone model expresses impingement losses in terms of the reduction in prey biomass available to predators. The Equivalent Adult Model expresses impingement losses in terms of fish which would have survived to some given future age (i.e. age of equivalence).

Task 3: Discuss Losses in Context with other Great Lakes Facilities.
Some information on impingement losses at other Great Lakes facilities was prepared in the earlier reports (SENES 2009a, SENES and Golder 2009) but were expanded to also include other power plants on the Great Lakes. Many of these power plants used for comparison already have some fish protection system in place. In particular, impingement results were compared to concurrently collected impingement results during 2010 at PNGS which is a surface draw intake approximately 35 km west of DNGS. During the impingement collection period, a barrier net was in place as a fish protection system which has been estimated to be approximately 80% effective (OPG 2011).

Task 4: Assess Significance of Loss as it relates to Conservation and/or Harvest.
Fish biomass losses in impingement were estimated for selected target species of commercial interest. These results were compared to recent harvest estimates for each species by both commercial and recreational fishermen in Lake Ontario as might be available from fisheries management agencies in both Canada and the US.

2.0 METHODS

2.1 TASK 1: IMPINGEMENT SAMPLING

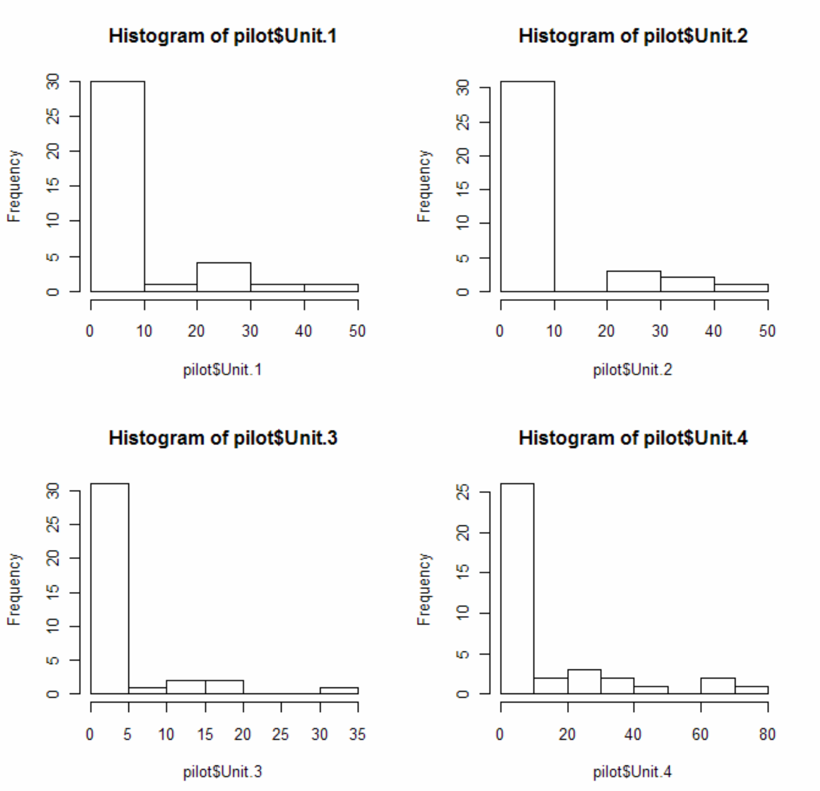
2.1.1 Sampling Design

Background

A qualified statistician was consulted to develop the sampling design for the DNGS 2010-11 impingement sampling campaign. Statistical analysis was conducted on data collected from the 2006-07 DNGS impingement sampling campaign.

An analysis of the 2006-7 impingement results showed that the data were highly skewed (SENES 2009a). There were a large number of zero observations and a few large observations (Figure 2.1). Count data were typically skewed, but in this case the excessive number of zeros suggested that the population was clustered. In other words, impingement did not occur randomly but tended to be clumped as a result of large schools being impinged.

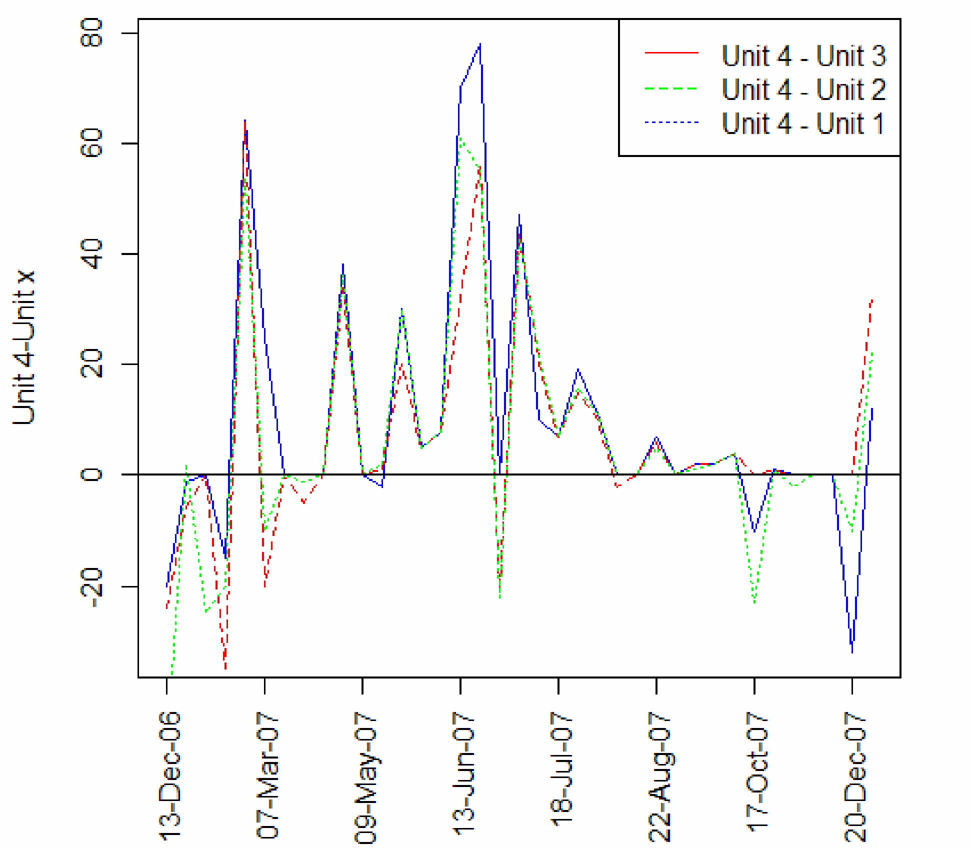
Figure 2.1 Histogram of Raw Observations from the 2006-2007 Impingement Sampling



Independent vs. Paired Tests

The objective was to determine whether Unit 4 could be used as a surrogate for all other units (1, 2 and 3). Results from Unit 4 could be multiplied by four to provide an overall estimate of impingement for the entire station. One approach could consider generating an annual estimate for each of the 4 units separately and comparing the estimates to each other using appropriate statistical tests. However, this strategy ignores any information about the timing of sample. If the samples are collected at all 4 units simultaneously or at least during the same day, then it is likely that they are correlated with each other. A paired test would take advantage of this correlation. This would entail taking the difference between Unit 4 and each of the other units and testing whether or not this difference was greater than zero. Using paired methods can greatly increase the power especially when the correlation between paired data is strong (Devore 1995). Figure 2.2 shows the observed difference between Unit 4 and the other 3 Units for all of the earlier impingement (2006-2007) data.

Figure 2.2 Illustration of the Difference Between Unit 4 and the Other Units for all of the Raw Data



Positive numbers indicate sampling occasions where Unit 4 was greater than the other units. Based on these results, most impingement occurs at Unit 4.

Sampling Plan

The following are general findings from a simulation study completed by EPRI (2004b):

- Systematic sampling was shown to be as good as random sampling for impingement monitoring;
- Substantial variability in impingement abundance was observed:
    - Between years;
    - Between seasons;
    - Between days.
- A recommendation was using higher intensity monitoring during periods of higher impingement;
- Greater bias and lower precision were found with monthly and bi-weekly designs compared to weekly designs.

These findings are consistent with sampling theory:

- More effort should be placed in strata with: greater variability internally or greater size (Cochran 1977).

2010 -11 DNGS Impingement Sampling Program

Prior to commencing 2010-11 sampling at DNGS, an issue was that multiple year consecutive data was not available to compare months which have the greatest abundance/variability. Furthermore, the 2006-07 results suggested that DNGS likely behaves differently than other stations such as PNGS, as relatively large observations are seen from December through March. This meant that recent impingement studies may not be usable to determine which months to invest the most sampling effort. In addition, the 2006-07 data cannot simply just be used because: 1) the year to year variability may be large and 2) the sampling intensity during December to March was less effort (biweekly) and therefore does not provide a good understanding of the impingement pattern during these months. Preliminary data indicate that Unit 4 may generally have greater abundance during the middle months (e.g. May-August), but during the winter months the other units often had greater levels of impingement (Figure 2.2). However, this would need to be confirmed through an increase in sampling effort during the winter months. Given this uncertainty, a suggestion would be to increase the sampling intensity across all months to help determine the local temporal pattern of impingement. This increased intensity may be reduced or reallocated once the pattern at this station has been identified.

The other benefit to increasing the sampling intensity to a minimum of weekly is that the analyses are simplified. Because the sampling intensity varies by month and it is expected that different months will differ in terms of impingement, all of the observations cannot be treated equally. In the original proposal (SENES 2009b) 8-10 samples were proposed for some months and only 2 samples in other months. Treating all of these observations as independent samples from the entire year would not be valid. One would expect the observations to be close together in time to be more correlated with each other than those further apart in time. This is consistent with the EPRI (2004b) findings that impingement varies seasonally. Treating all points equally in this case is a form of pseudo-replication (Hurlbert 1984). The original proposed sampling design (SENES 2009b) can be thought of as a form of ‘sub-sampling’ or ‘two-stage’ sampling. First, the two-week blocks are sampled and in some cases extra samples are taken within the two-week block. The additional samples improve the estimate of the two-week block, but cannot be weighted equally with samples from less intensively sampled blocks. In other words, one should not just average all 64 points (original design in RFP, SENES 2009b). Instead one should first find the bi-weekly average and then average those, leaving fewer bi-weekly observations. Thus, an additional 8 sampling events were proposed so that the ‘week’ becomes the smallest common unit. One would then find weekly estimates first and then average those (or total them). This design would have 52 weekly observations rather than fewer bi-weekly observations (around 21), increasing the degrees of freedom (and hence power) for any statistical tests employed to compare among units.

In summary, optimal allocation of effort within a stratified sampling design requires estimates of the abundance and variability within each of the strata (Cochran 1977). Without this knowledge it is better to spread the effort more equally to obtain these estimates, which can then be used to optimize the design. Therefore, an additional 8 impingement events were suggested (Table 2.1).

Table 2.1 Sampling Design for the 2010-11 DNGS Impingement Sampling Campaign

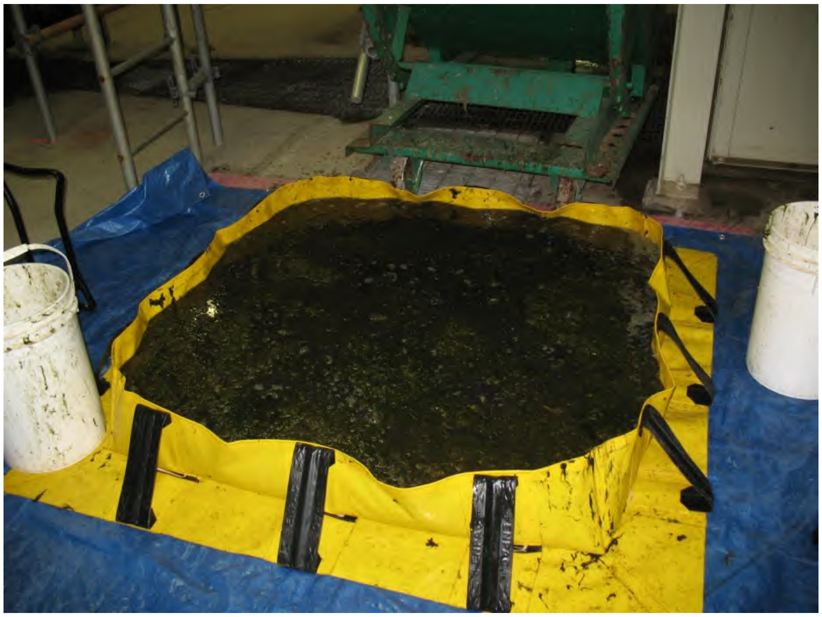
Date	Sampling Frequency	Number of Samples per Month
May 2010	Twice/week	8
June 2010	Twice/week	9
July 2010	Twice/week	9
August 2010	Once/week	5
September 2010	Once/week	4
October 2010	Once/week	4
November 2010	Once/week	4
December 2010	Once/week	4
January 2011	Once/week	4
February 2011	Twice/week	8
March 2011	Twice/week	9
April 2011	Once/week	4
Total		**72**

2.1.2 Sampling Methodology

Impingement sampling was conducted between May 2010 to April 2011 with the frequency of sampling being either once per week or twice per week depending on the month (see Table 2.1). In total, 72 sampling events were carried out. Sampling was conducted on all four Units when available. During the 2010-11 sampling campaign, new, efficient travelling screens were installed at all Units. Unit 2 was the first to be equipped with the new screens (already in place when sampling began in May 2010). The last Unit to be equipped with new travelling screens was Unit 1 (March 2011). The sampling design followed the guidance of the Impingement Abundance Monitoring Technical Support Document (EPRI 2004b).

A containment berm (0.3 m^3) was used to collect impingement bin contents from each Unit (Figure 2.3). A rake or shovel was used to transfer the bin contents into the berm. The contents were then mixed as thoroughly as possible to distribute fish evenly throughout sample and minimize bias. In many cases, subsampling was undertaken as there was excessive sample in the bins. Subsampling, when it occurred, was usually about 25% of the sample. All fish collected were separated by species and condition (i.e., live, recently dead or long dead).

Figure 2.3 Impingement Bin Contents in a Containment Berm



For each bin, meristics (length, weight, injuries, presence of tags, general fish health) were collected for up to 30 species for each species. This samples size was considered large enough to be statistically meaningful for analysis (standard practice). It is too time consuming to process all fish. Fork length measurements were obtained using a standard ruler and weight measurements were obtained using weighing scales.

All information collected were recorded on a datasheet and then inputted into an Excel file. QA/QC was conducted on data transfer between data sheets and the Excel file to ensure accuracy. QA/QC species ID was also conducted using Scott Gibson, MNR's Aquatic Species at Risk Specialist, on species collected to ensure proper identification. All staff had fish ID courses (MNR, OPG (given by Scott Gibson of MNR) and/or SENES (also given by Scott Gibson of MNR)). Qualified staff are very important in collecting proper impingement sampling which was identified earlier by Wismer (1997b). Photographs were also taken throughout the duration of sampling.

2.2 TASK 2: DETERMINATION OF BIOLOGICAL LIABILITY LOSSES ASSOCIATED WITH IMPINGEMENT

Estimates of the annual impingement losses from cooling water withdrawals, such as DNGS, do not provide reliable measures of the potential for adverse environmental impact and do not lend themselves to direct monetization of the potential economic value these losses represent. To address this problem and to allow combining of loss estimates across multiple life stages, one commonly used approach is to invoke one or more of the Equivalent Loss Models. This was the approach used by the United States Environmental Protection Agency (USEPA 2004) for National Benefits Valuation of the Phase II rulemaking. These models are all based on standard biological life tables and are used to convert estimates of impingement benefits to equivalent benefits at other life stages that are more amenable to impact assessment and economic valuation. Equivalent Loss Models are discussed in detail in Dey (2002) and EPRI (2004a).

The purpose of this task is to estimate the equivalent losses using impingement monitoring data collected at DNGS from May 2010 through April 2011. These equivalent loss estimates were calculated using the Equivalent Adult Model (EAM), the Equivalent Yield Model (EYM) and the Production Foregone Model (PFM). The EAM was used to provide estimates of the number of Age 1 individuals that could have resulted from juvenile and adults impinged at DNGS. The EYM provides a measure of the potential additional fishery yield that could have been harvested by commercial or recreational fishermen had these individuals not been impinged at DNGS. The PFM provides a measure of the potential additional biomass production that could have resulted had these individuals not been impinged at DNGS. This biomass production could be used by the ecosystem to support survival and growth at higher trophic levels. For this study, equivalent loss estimates were generated for the following 14 target taxa:

- Alewife
- Brown bullhead
- Emerald shiner
- Pumpkinseed
- Rainbow smelt
- Round goby
- Slimy sculpin
- Smallmouth bass
- Spoonhead sculpin
- Threespine stickleback
- Unidentified sculpin
- Unidentified sunfish
- White sucker
- Yellow perch

These 14 taxa including unidentified species were selected based on the availability of the necessary biological information for calculating equivalent loss at DNGS. Of the taxa impinged at DNGS, the only species not included as part of this analysis was the American eel.

2.2.1 Impingement Loss

Estimates of monthly impingement were calculated using biological monitoring data collected at DNGS from May 2010 through April 2011. During this study, impingement collections were made at up to 4 units at DNGS on each sampling event. Generally these collections were for a full 24-hour period. The number of sampling events at an individual unit at DNGS on a monthly basis is provided in Table 2.2.

Table 2.2 Total Number of 24-hr Impingement Collections by Month and Unit at Darlington Nuclear Generating Station, May 2010 - April 2011

Month	Unit 1	Unit 2	Unit 3	Unit 4	Total
May 2010		8	8		16
June 2010		9	9		18
July 2010		8	9	5	22
Aug. 2010		5	5	5	15
Sept. 2010		3	4	3	10
Oct. 2010		4	2	4	10
Nov. 2010		3		4	7
Dec. 2010				4	4
Jan. 2011				4	4
Feb. 2011		5	8	8	21
Mar. 2011	2	9	8	9	28
Apr. 2011	4	4	4	4	16
Total	6	58	57	50	171

Counts of the number of fish impinged by species and unit on each sample date at DNGS were used. With these data, estimates of the average daily impingement rate for a unit at DNGS for each month and species were calculated as follows:

$$AIR_{ms} = \frac{\sum_{u=1}^{4} \sum_{i=1}^{J_{mu}} \left(CT_{msiu} \times \frac{8}{P_{miu}} \right)}{\sum_{u=1}^{4} J_{mu}}$$

where:

AIR_{ms} = Adjusted daily mean impingement rate for species (s) at DNGS in month (m)

CT_{msiu} = Impingement count for species (s) at unit (u) on collection date (i) at DNGS in month (m)

P_{miu} = Number of pumps operating at unit (u) on collection date (i) at DNGS in month (m)

J_{mu} = Number of collection date (i) at unit (u) at DNGS in month (m).

Using these impingement rates, total impingement at DNGS for species (s) in month (m) was estimated as follows:

$$NI_{ms} = AIR_{ms} \times \sum_{u=1}^{4} \sum_{d=1}^{N_{mu}} \left(\frac{P_{mdu}}{3} \right)$$

where:

NI_{ms} = Total impingement of species (s) at DNGS in month (m)

P_{mdu} = Total number of pumps operating at unit (u) at DNGS on day (d) of month (m)

N_{mu} = Number of days of operation at unit (u) at DNGS in month (m)

The total number of pumps operating at each unit on each day over the period May 2010 - April 2011 were provided by OPG. Estimates of the monthly and annual impingement loss for each fish taxon are provided in Results and Discussion section (Section 3.0).

Estimates of the weight of each taxon of fish impinged for each month were then calculated by multiplying the estimated number impinged (NI_{ms}) by the mean weight of individuals impinged that were weighed in each month. These weight estimates are provided in the Results and Discussion section (Section 3.0).

2.2.2 Model Descriptions

2.2.2.1 Equivalent Age 1 Modeling

The measure "equivalent Age 1" provides an estimate of the number of individuals of each selected taxon entering Age 1 that could have resulted from the total number of impinged in the absence of compensatory changes in total mortality. This number is calculated using the Equivalent Adult Model (EAM), which combines estimates of impingement loss together with estimates of survival for all stages up to any specified age (Dey 2002, EPRI 2004a). Using the EAM, the number of equivalent adults for each selected taxon was estimated as follows:

$$EA = \sum_{j=1}^{n_l} \left(NE_j S_{j \rightarrow A} \right)$$

where:

EA = Number of equivalent Age 1 individuals

NE_j = Number of each Age ($_j$) lost to impingement at Age 1

$S_{j \rightarrow A}$ = Total survival from Age ($_j$) to Age 1[1]

$_nI$ = Number of Ages ($_j$) impinged at DNGS.

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[1] For individuals impinged that were Age 1 or older, then this survival becomes the inverse of the survival from Age 1 to the age of impingement.

In this assessment, the EAM was applied to each of the 14 selected taxa.

2.2.2.2 Equivalent Yield Model

The measure "yield to the fishery" is defined as the total yield (in weight) that could have accrued to a commercial or recreational fishery from those individuals lost to impingement in the absence of compensatory changes in total mortality. This yield is calculated using the Equivalent Yield Model (EYM), which integrates Baranov's catch equation (Ricker 1975) with estimates of the mean weight by age (Dey 2002, EPRI 2004a). Using the EYM, the equivalent yield for each selected was estimated as follows:

$$EY = \sum_{i=1}^{n_f} \left[\sum_{j=1}^{n_l} \left(NI_j S_{j \to i} \right) A_i W_i \frac{V_i F_i}{Z_i} \right]$$

where:
EY = Equivalent yield to fishery
NL_j = Number of each age ($_j$) lost annually to impingement at DNGS
$S_{j \to i}$ = Total survival from time period or life stage ($_j$) to age ($_i$)
nj = Number of ages ($_j$) impinged at DNGS
V_i = Vulnerability of age ($_i$) to fishing
F_{ci} = Instantaneous rate of capture by fishery for age ($_i$)
Z_i = Instantaneous total mortality rate for age ($_i$)
A_i = Total mortality rate for age ($_i$) = $1\text{-}e^{-Zi}$
W_i = Average weight for individual of age ($_i$) captured in the fishery
nf = Maximum number of ages ($_i$) vulnerable to fishery.

The EYM results in an estimate of yield defined in the same units used to describe the average weight of the individuals and integrates yield across all ages. In this assessment, the EYM was applied to the seven selected taxa that support commercial or recreational fishing; rainbow smelt, brown bullhead, pumpkinseed, smallmouth bass, unidentified sunfish, white sucker, and yellow perch.

2.2.2.3 Production Foregone

The future biomass production that could have resulted from taxa lost to impingement at DNGS was calculated using the Production Foregone Model (PFM) (Dey 2002, EPRI 2004a). Using the PFM, potential biomass production was estimated for each of the selected taxa as follows:

$$P_i = \sum_{i=1}^{L} \frac{\sum_{j=1}^{n_l} \left(NI_j S_{j \to i} \right) G_i W_i \left(e^{(G_i - Z_i)} - 1 \right)}{G_i - Z_i}$$

and the total production foregone (P) can be found by summing over all the age categories that are entrained:

$$P = \sum_{i=1}^{m} P_i$$

where:

P = Total production foregone
P_i = Production foregone for individuals lost to impingement at DNGS in age ($_i$)
G_i = Instantaneous growth rate in weight for age ($_i$)
NL_j = Number in each time period or life stage ($_j$) lost to impingement at DNGS
$S_{j \to i}$ = Total survival from time period or life stage ($_j$) to age ($_i$)
nj = Number of time periods or life stages ($_j$) impinged at DNGS
W_i = Average weight of individuals in age ($_i$)
Z_i = Average instantaneous mortality rate for age ($_i$)
m = Total number of life stages or ages impinged at DNGS
L = Final age.

The PFM was applied to each of the selected taxa, since they all serve as food for other aquatic organisms during at least part of their life cycle.

Both the EYM and PFM are consistent with the equivalent loss procedures used in USEPA (2004) for determining the national economic benefits of the Phase II rule. Estimation of the biological input parameters for each of the 14 selected taxa is described below.

2.2.3 Model Inputs

In addition to the monthly estimates of impingement numbers and weights discussed above, a variety of other inputs were required for this modeling effort. Each of these is discussed below.

2.2.3.1 Assignment of Age Categories for Impinged Individuals

One of the necessities of equivalent loss calculation is that the direct measures of impingement loss must be assigned to individual age categories as defined in the equivalent Age 1, production foregone and equivalent yield models. For this assessment, age was assigned using length information for each Target Species obtained from the impingement monitoring conducted at

DNGS, together with estimates of length at age for these same species obtained from the scientific literature and from an analysis of the length frequency patterns for each species. Details are provided in Appendix A.

2.2.3.2 Life Table Information

Biological input parameters for the Production Foregone and Equivalent Yield models include life stage durations, instantaneous natural and fishing mortality rates, and the fraction vulnerable to the fishery for each life stage and age, as well as mean weights at the beginning of each life stage and age for each Target Species. Each of these model inputs were determined as described below.

2.2.3.2.1 Age Durations

Estimates of impingement on a monthly basis were developed for this assessment. Consequently, the duration of each month was set as 30.4 days, the average monthly duration across the entire year. However, it is important to recognize that fish do not become vulnerable to impingement until they are approximately 1 inch (2.54 cm) long and typically 1 to 2 months of age on a traditional 3/8-inch mesh traveling screen. Hence, the number of months remaining in the first year of life is normally less than 12. The number of whole months of impingement vulnerability during Age 0 was determined by dividing the total time between the median date of initial impingement vulnerability and the end of the first year of life by the average month duration (30.4 days). Any remainder was assigned as the duration of the first month of impingement vulnerability. Median date of initial impingement vulnerability for each target species, shown in Table 2.3, was determined using best professional judgment.

Table 2.3 Median Dates of Initial Impingement Vulnerability

Taxon	Median Month of Initial Impingement Vulnerability
Alewife	September
Pumpkinseed and unidentified sunfish	September
Emerald shiner	September
Rainbow smelt	August
Round goby	September
Slimy, spoonhead and unidentified sculpins	October
Smallmouth bass	August
Brown bullhead	September
Threespine stickleback	September
White sucker	July
Yellow perch	June

In this assessment, we assumed that all individuals impinged in each age category were at the median age for that category. The median age is the age at which half of the individuals in that age category were older than the median age while the remaining half were younger. Median age for each age category was calculated as:

$$d_i = \frac{\ln 2 - \ln(1+e^{-Z_i t_i})}{Z_i}$$

where:

d_i = median age of age category (i)

t_i = Duration (days) for age category (i).

2.2.3.3 Natural Mortality Rates

In this assessment natural mortality refers to any source of death other than through fishing or impingement. In aquatic ecosystems, the ultimate cause of death, especially in the early stages of fish, is principally through predation. For calculation of production foregone, it was assumed that all natural mortality is a result of being consumed by predators.

A range (maximum, most probable, and minimum) of instantaneous natural mortality rates for each target species was obtained from the following sources:

Alewife – Most probable daily instantaneous natural mortality rates were obtained from EPRI (2005) Table 4-23. Maximum and minimum values were assumed to be 25 percent higher and 25 percent lower than the most probable value, respectively.

Brown bullhead – Most probable daily instantaneous natural mortality rates were obtained from EPRI (In preparation). Maximum and minimum values were assumed to be 25 percent higher and 25 percent lower than the most probable value, respectively.

Emerald shiner – Most probable daily instantaneous natural mortality rates were obtained from EPRI (In preparation). Maximum and minimum values were assumed to be 25 percent higher and 25 percent lower than the most probable value, respectively.

Pumpkinseed and unidentified sunfish – Most probable daily instantaneous natural mortality rates were obtained from EPRI (In preparation). Maximum and minimum values were assumed to be 25 percent higher and 25 percent lower than the most probable value, respectively.

Rainbow smelt – Maximum and minimum daily instantaneous natural mortality rates were obtained from EPRI (2005) Table 4-37 and the most probable value was assumed to be the midpoint between the maximum and minimum values.

Round goby – Most probable daily instantaneous natural mortality rates were obtained from EPRI (In preparation). Maximum and minimum values were assumed to be 25 percent higher and 25 percent lower than the most probable value, respectively.

Slimy, spoonhead and unidentified sculpins – Most probable daily instantaneous natural mortality rates were obtained from EPRI (In preparation). Maximum and minimum values were assumed to be 25 percent higher and 25 percent lower than the most probable value, respectively.

Smallmouth bass – Most probable daily instantaneous natural mortality rates were obtained from EPRI (In preparation). Maximum and minimum values were assumed to be 25 percent higher and 25 percent lower than the most probable value, respectively.

Threespine stickleback – Most probable daily instantaneous natural mortality rates were obtained from EPRI (In preparation). Maximum and minimum values were assumed to be 25 percent higher and 25 percent lower than the most probable value, respectively.

White sucker — Most probable daily natural mortality rates were obtained from EPRI (In preparation) for shorthead redhorse as a surrogate. Maximum and minimum values were assumed to be 25 percent higher and 25 percent lower than the most probable value, respectively.

Yellow perch – Maximum and minimum daily instantaneous natural mortality rates were obtained from EPRI (2005) Table 4-39 and the most probable value was assumed to be the midpoint between the maximum and minimum values.

The most probable values were used to provide the best estimates of equivalent loss, while the maximum and minimum values were considered in the uncertainty analysis.

2.2.3.4 Fishing Mortality Rates

Fishing mortality refers to the death of individuals as a result of commercial, recreational and/or subsistence fishing. In this assessment, fishing mortality was assumed to apply only to those seven target taxa subject to fishing (pumpkinseed, unidentified sunfish, brown bullhead, rainbow smelt, smallmouth bass, white sucker, and yellow perch). The other seven taxa, alewife, emerald shiner, round goby, slimy sculpin, spottail shiner, unidentified sculpins and threespine stickleback, were assumed not to be harvested by fishermen.

A range (maximum, most probable, and minimum) of instantaneous fishing mortality rates for the seven target taxa subject to fishing were selected as follows:

Pumpkinseed and unidentified sunfish – Most probable daily instantaneous fishing mortality rates were obtained from EPRI (In preparation). Maximum and minimum values were assumed to be 25 percent higher and 25 percent lower than the most probable value, respectively.

Brown bullhead– Most probable daily fishing mortality rates were obtained from EPRI (In preparation). Maximum and minimum values were assumed to be 25 percent higher and 25 percent lower than the most probable value, respectively.

Rainbow smelt – Most probable daily instantaneous fishing mortality rates were assumed to be one-half of the natural mortality rate, which was obtained from EPRI (2005). Maximum and minimum values were assumed to be 25 percent higher and 25 percent lower than the most probable value, respectively.

Smallmouth bass – Most probable daily instantaneous fishing mortality rates were assumed to be one-half of the total annual mortality rate, which was obtained from EPRI (In preparation), and equal to the natural mortality rate. Maximum and minimum values were assumed to be 25 percent higher and 25 percent lower than the most probable value, respectively.

White sucker – Most probable daily fishing mortality rates were obtained from EPRI (In preparation) for shorthead redhorse as a surrogate. Maximum and minimum values were assumed to be 25 percent higher and 25 percent lower than the most probable value, respectively.

Yellow perch – Most probable daily instantaneous fishing mortality rates were assumed to be one-half of the total annual mortality rate obtained from EPRI (2005) Table 4-39, and equal to the natural mortality rate. Maximum and minimum values were assumed to be 25 percent higher and 25 percent lower than the most probable value, respectively.

As with natural mortality, the most probable values were used to provide the best estimates of equivalent loss, while the maximum and minimum values were considered in the uncertainty analysis. See Appendix B for more details on uncertainty analysis.

2.2.3.5 Fishing Vulnerability Rates

Fishing vulnerability rates refer to the fraction of each age at a size vulnerable to be harvested by anglers. For the maximum and minimum fishing vulnerability rates used in this assessment, individuals were assumed to be not vulnerable (rate = 0) up to a set age and completely vulnerable (rate = 1) above that age. The ages of complete vulnerability were estimated using best professional judgment based on length at age information from the scientific literature and current fishing regulations. Resulting estimates are shown in Table 2.4.

Table 2.4 Age at Initial Fishing Vulnerability by Species

Species	Age at Initial Fishing Vulnerability (Years)	
	Earliest	Latest
Pumpkinseed and unidentified sunfish	3	7
Brown bullhead	2	3
Rainbow smelt	2	3
Smallmouth bass	4	7
White sucker	1	2
Yellow perch	2	4

The maximum vulnerability was assigned using the earliest age whereas the minimum vulnerability was assigned using the latest age. The most probable values were assigned assuming that half of the population became vulnerable at the age of maximum initial vulnerability while the remaining half became vulnerable at the age of minimum initial vulnerability. These most probable values were used to provide the best estimates of equivalent loss, while the maximum and minimum values were considered in the uncertainty analysis.

2.2.3.6 Weight at Beginning of Age

This input parameter refers to the average weight of individuals as they enter each age category. These weights are then used to determine the average weight of harvested individuals for calculation of equivalent fishery yield and to determine the daily instantaneous growth rate used for calculation of production foregone.

A range (maximum, most probable, and minimum) of estimated weights at the beginning of each age were obtained for each target species from the following sources:

Alewife – Maximum and minimum mean weights were obtained from EPRI (2005) Table 4-23, and the most probable value was assumed to be the average of the maximum and minimum weights. For all other life stages or ages, maximum and minimum values were assumed to be 20 percent higher and 20 percent lower than the most probable value, respectively.

Pumpkinseed and unidentified sunfish – Most probable mean weights (g) at the beginning of each age were obtained from EPRI (In preparation). Maximum and minimum values were assumed to be 20 percent higher and 20 percent lower than the most probable value, respectively.

Brown bullhead – Most probable mean weights (g) at the beginning of each age were obtained from EPRI (In preparation). Maximum and minimum values were assumed to be 20 percent higher and 20 percent lower than the most probable value, respectively.

Emerald shiner – Most probable mean weights (g) at the beginning of each age were obtained from EPRI (In preparation). Maximum and minimum values were assumed to be 20 percent higher and 20 percent lower than the most probable value, respectively.

Rainbow smelt – Most probable mean weights (g) of eggs, larvae, entrainable juveniles were obtained from EPRI (2005) Table 4-37. Maximum and minimum values for the egg through age-0 juvenile life stages were assumed to be 20 percent higher and 20 percent lower than the most probable value, respectively. For age-1 and older fish, the maximum and minimum mean weights at the beginning of each age were obtained from EPRI (2005) Table 4-37, and the most probable value was assumed to be the average of the maximum and minimum weights.

Round goby – Most probable mean weights (g) at the beginning of each age were obtained from EPRI (In preparation). Maximum and minimum values were assumed to be 20 percent higher and 20 percent lower than the most probable value, respectively.

Slimy, spoonhead and unidentified sculpins – Most probable mean weights (g) at the beginning of each age were obtained from EPRI (In preparation). Maximum and minimum values were assumed to be 20 percent higher and 20 percent lower than the most probable value, respectively.

Smallmouth bass – Most probable mean weights (g) at the beginning of each age were obtained from EPRI (In preparation). Maximum and minimum values were assumed to be 20 percent higher and 20 percent lower than the most probable value, respectively.

Threespine stickleback – Most probable mean weights (g) at the beginning of each age were obtained from EPRI (In preparation). Maximum and minimum values were assumed to be 20 percent higher and 20 percent lower than the most probable value, respectively.

White sucker – Most probable mean weights (g) at the beginning of each age were obtained from EPRI (In preparation) for shorthead redhorse. Maximum and minimum values were assumed to be 20 percent higher and 20 percent lower than the most probable value, respectively.

Yellow perch – Most probable mean weights (g) of eggs, larvae, entrainable juveniles were obtained from EPRI (2005) Table 4-39. Maximum and minimum values for the egg through age-0 juvenile life stages were assumed to be 20 percent higher and 20 percent lower than the most probable value, respectively. For age-1 and older fish, the maximum and minimum mean weights at the beginning of each age were obtained from EPRI (2005) Table 4-39, and the most probable value was assumed to be the average of the maximum and minimum weights.

For all species, weights at the beginning of each month within an age were interpolated using an instantaneous growth rate based on the weights at the beginning and end of that age. The most probable values were used to provide the best estimates of equivalent loss, while the maximum and minimum values were considered in the uncertainty analysis.

2.2.3.7 Definition of Age 1

The EA1M defines equivalent losses in terms of numbers of Age 1. However, the term “Age 1” can be defined in many terms. For this assessment, we defined “Age 1” as the time of first annulus completion.

3.0 RESULTS AND DISCUSSION

3.1 IMPINGEMENT SAMPLING (2010-11)

3.1.1 Collections Uncorrected for Station Operation (i.e., Raw Data)

Table 3.1 shows species collected by month and counts. Table 3.2 shows the overall “raw” counts (recently dead + long dead) for each species and the percentage impinged in relation to all species. Note that the counts in Tables 3.1 and 3.2 are not annual estimates but rather raw counts based on the 72 sampling events. Figures 3.1 to 3.5 are a sample of the fish collected during the May 2010 – April 2011 impingement period. Raw data counts can be found in Appendix C.

A total of 40,572 fish consisting of 13 identified species were impinged. Approximately 54% (21,985 goby) of the fish were the invasive round goby. Alewife comprised 42% of the fish impinged (16,874 alewife). All other fish species (brown bullhead, emerald shiner, pumpkinseed, rainbow smelt, slimy sculpin, spoonhead sculpin, smallmouth bass, threespine stickleback, white sucker, yellow perch and American eel), as well as some unidentified sculpin (*Cottus* species) (likely slimy sculpin), a sunfish species (possibly longear sunfish but could not be confirmed by Scott Gibson of MNR), and other unidentifiable fish (too decayed for positive identification) comprised the remaining 4% impinged. One adult American eel, which is a species of special concern according to the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and an endangered species listed under SARO (Species at Risk Ontario), was impinged at Unit 4. American eel currently has no SARA (*Species at Risk Act*) status. Both OPG and MNR were contacted immediately following the collection of the impinged American eel on February 22, 2011.

Table 3.1 Fish Impingement at DNGS (May 2010 – April 2011)

Month	Fish Species	Count (not an annual estimate)	Percent Impinged (%)	Total Counts (not an annual estimate)*
May 2010	Alewife	71	1.4	5210
	Rainbow Smelt	174	3.3	
	Round Goby	**4853**	**93.1**	
	Spoonhead Sculpin	62	1.2	
	Unidentified	50	1.0	
June 2010	Alewife	600	21.0	2863
	Rainbow Smelt	121	4.2	
	Round Goby	**1856**	**64.8**	
	Spoonhead Sculpin	50	1.7	
	Unidentified	236	8.2	
July 2010	Alewife	11353	69.4	16354
	Pumpkinseed	6	0.0	
	Rainbow Smelt	204	1.2	
	Round Goby	**4632**	**28.3**	
	Spoonhead Sculpin	48	0.3	
	White Sucker	6	0.0	
	Unidentified	105	0.6	
August 2010	Alewife	535	26.9	1991
	Rainbow Smelt	109	5.5	
	Round Goby	**1329**	**66.8**	
	Smallmouth Bass	1	0.05	
	Spoonhead Sculpin	5	0.3	
	Unidentified	12	0.6	
September 2010	Alewife	206	69.8	295
	Rainbow Smelt	1	0.3	
	Round Goby	**76**	**25.8**	
	Unidentified	12	4.1	
October 2010	Alewife	311	52.0	598
	Rainbow Smelt	7	1.2	
	Round Goby	**280**	**46.8**	
November 2010	Alewife	85	21.9	388
	Rainbow Smelt	15	3.9	
	Round Goby	**285**	**73.5**	
	Unidentified	3	0.8	

Table 3.1 (Cont'd) Fish Impingement at DNGS (May 2010 – April 2011)

Month	Fish Species	Count (not an annual estimate)	Percent Impinged (%)	Total Counts (not an annual estimate)*
December 2010	Alewife	3594	79.2	4540
	Emerald Shiner	2	0.0	
	Pumpkinseed	2	0.0	
	Rainbow Smelt	36	0.8	
	Round Goby	**890**	**19.6**	
	Unidentified	16	0.4	
January 2011	Alewife	108	12.4	868
	Rainbow Smelt	6	0.7	
	Round Goby	**708**	**81.6**	
	Unidentified	46	5.3	
February 2011	Alewife	5	0.3	1453
	American Eel	1	0.1	
	Cottus sp.	20	1.4	
	Emerald Shiner	1	0.1	
	Rainbow Smelt	6	0.4	
	Round Goby	**1215**	**83.6**	
	Slimy Sculpin	3	0.2	
	Spoonhead Sculpin	34	2.3	
	Sunfish species	1	0.1	
	Threespine Stickleback	1	0.1	
	White Sucker	1	0.1	
	Yellow Perch	1	0.1	
	Unidentified	164	11.3	
March 2011	Alewife	4	0.2	2397
	Brown Bullhead	1	0.0	
	Cottus sp.	1	0.0	
	Emerald Shiner	5	0.21	
	Rainbow Smelt	6	0.3	
	Round Goby	**2280**	**95.1**	
	Slimy Sculpin	15	0.6	
	Spoonhead Sculpin	22	0.9	
	Unidentified	63	2.6	
April 2011	Alewife	2	0.1	3615
	Rainbow Smelt	7	0.2	
	Round Goby	**3581**	**99.1**	
	Slimy Sculpin	6	0.2	
	Spoonhead Sculpin	13	0.4	
	Yellow Perch	1	0.0	
	Unidentified	5	0.1	

*Raw data only. Annual estimates are presented later in this report.
Note: counts include all fish, regardless of fish condition.
Cottus sp. : likely slimy sculpin

Table 3.2 Percent Composition of Fish Impinged at DNGS (May 2010 to April 2011)

Fish Species	Number Impinged (not an annual estimate)*	Percentage (%)
Alewife	16,874	41.6
American Eel	1	0.0
Brown Bullhead	1	0.0
Cottus sp.	21	0.1
Emerald Shiner	8	0.0
Pumpkinseed	8	0.0
Rainbow Smelt	692	1.7
Round Goby	**21,985**	**54.2**
Slimy Sculpin	24	0.1
Smallmouth Bass	1	0.0
Spoonhead Sculpin	234	0.6
Sunfish species	1	0.0
Threespine Stickleback	1	0.0
White Sucker	7	0.0
Yellow Perch	2	0.0
Unidentified	712	1.8
Totals	40,572	100.0

* Raw data only. Annual estimates are presented later in this report.
Note: Count includes all fish, regardless of fish condition.
Cottus sp. : likely slimy sculpin

Figure 3.1 Round Goby, Unit 3, February 1, 2011

Figure 3.2 Alewife, Unit 2, June 4, 2010

Figure 3.3 Rainbow Smelt, Unit 3, May 18, 2010

Figure 3.4 Spoonhead Sculpin, Unit 2, May 4, 2010

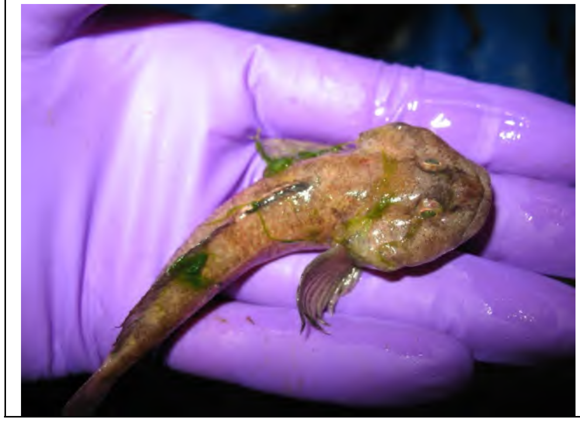


Figure 3.5 American Eel, Unit 4, February 22, 2011

3.1.2 Annualized Impingement Estimates

Raw data counts were annualized taking into account pump operation and bin in and out service times (data provided by OPG). Results were expressed as both numbers and biomass. It was assumed that all fish deaths occurred in the lake at the intake.

Raw data counts of alewife sampled at Unit 2 (9960 fish) on July 2, 2010 were excluded when calculating annual impingement estimates. The mortality of alewife on July 2, 2010 was attributed to a naturally occurring upwelling event. This was based on visual inspection of fish that were collected, and measured temperatures in the field. Fish impinged were hemorrhaging around the gills and fins, which was an abnormal observation based on other fish collection periods. Alewife year class strength is related to temperature (Walsh and Connerton 2011), and it is believed that naturally occurring seiche events can have an impact on alewife condition. Fish that became weak or died during the upwelling event (i.e. cold shock) would be very susceptible to impingement whereas normally they would display an avoidance response. An upwelling event occurred in the lake near PNGS around July 2, based on temperature data collected at the site (SENES 2011). The water temperature fell from 15.7°C on June 28, 2010, to 11.0°C and 7.8°C on June 29 and June 30, 2010, respectively (SENES 2010). This same event occurred at DNGS.

When the raw data counts of numbers impinged were annualized, the annual impingement of fish was estimated at 274,931 (Table 3.3). Excluding round goby, which comprised 55% of the fish impinged annually, total impingement was estimated at 123,421 for all other species. Most of this impingement was attributed to alewife (115,465 of 123,421 fish, or 94%), and the majority of these alewife were impinged in the month of December (86,950 of 115,465 alewife, or 75% of all alewife impinged). It was suspected that there was an upwelling event based on fish collection data on December 7; however, objective data was not available to support this belief and therefore these fish were counted as impinged. The high numbers of round goby impinged are likely because they are feeding on zebra mussels (Lederer et al. 2008) that have attached to the porous veneer intake structure. Large numbers of goby have been observed on the intake structure by OPG divers who are involved in "mussel" removal on the intake surface. Round goby are a recent invasive species (first noted impinged at DNGS in 2006-07) and the current porous veneer intake structure was not designed to protect goby, a benthic species. Note that no information is given on fish grouped as "unidentifiable" in the raw data, as they were decayed fish.

In terms of biomass, annual impingement losses were estimated at 2362 kg (Table 3.4). Round goby comprised 55.4% of the biomass (1307.8 kg) lost, followed by alewife which comprised 42.1% of the biomass (994.1 kg) lost. This estimate of alewife loss in 2010-11 is similar to that recorded in 2006-07 (720.7 kg (conservative)). Rainbow smelt, spoonhead sculpin, American eel, white sucker and unidentified sculpin (Unid Cottus) (likely slimy sculpin) comprised the remainder of the 2.5% of biomass lost to impingement. Biomass losses from all other species were negligible relative to the above mentioned species.

Table 3.3 Estimates of Total Annual Impingement (Counts), May 2010 – April 2011

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Total (%)
Alewife	3,240	26	17	11	550	3,926	8,225	4,280	2,142	4,176	1,921	86,950	115,465	42.0
American eel	0	5	0	0	0	0	0	0	0	0	0	0	5	0.0
Brown bullhead	0	0	4	0	0	0	0	0	0	0	0	0	4	0.0
Emerald shiner	0	5	21	0	0	0	0	0	0	0	0	60	86	0.0
Pumpkinseed	0	0	0	0	0	0	34	0	0	0	0	72	106	0.0
Rainbow smelt	180	31	27	43	1,349	829	1,150	872	10	94	339	933	5,857	2.1
Round goby	21,240	5,238	8,924	21,410	23,576	10,920	24,513	9,216	728	3,169	4,317	18,261	151,510	55.1
Slimy sculpin	0	16	63	34	0	0	0	0	0	0	0	0	113	0.0
Smallmouth bass	0	0	0	0	0	0	0	8	0	0	0	0	8	0.0
Spoonhead sculpin	0	256	94	83	481	325	276	40	0	0	0	0	1,555	0.6
Threespine stickleback	0	5	0	0	0	0	0	0	0	0	0	0	5	0.0
Unid Cottus	0	157	4	0	0	0	0	0	0	0	0	0	161	0.1
Unid sunfish	0	5	0	0	0	0	0	0	0	0	0	0	5	0.0
White sucker	0	5	0	0	0	0	34	0	0	0	0	0	39	0.0
Yellow perch	0	5	0	6	0	0	0	0	0	0	0	0	11	0.0
Total	24,660	5,755	9,154	21,587	25,955	16,000	34,232	14,416	2,881	7,439	6,577	106,276	274,931	100.0

Unid = unidentified
Note: Individual estimates may not add to totals due to rounding.
Unid Cottus – likely slimy sculpin

Table 3.4 Estimates of Total Annual Impingement (Biomass), May 2010 – April 2011

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Total (%)
Alewife	29.20	0.27	0.10	0.02	4.28	36.16	33.61	31.02	4.11	11.57	9.85	833.92	994	42.1
American eel	0.00	7.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7	0.3
Brown bullhead	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0.0
Emerald shiner	0.00	0.01	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0	0.0
Pumpkinseed	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00	0.00	0.00	0.22	0	0.0
Rainbow smelt	1.50	0.22	0.12	0.47	8.97	4.21	5.99	5.06	0.10	1.22	1.56	3.98	33	1.4
Round goby	164.69	41.59	70.55	192.68	217.77	117.62	219.65	92.21	5.27	28.75	41.77	115.29	1,308	55.4
Slimy sculpin	0.00	0.12	0.62	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1	0.0
Smallmouth bass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0	0.0
Spoonhead sculpin	0.00	2.84	1.03	0.78	3.71	2.02	2.31	0.34	0.00	0.00	0.00	0.00	13	0.6
Threespine stickleback	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0.0
Unid Cottus	0.00	1.71	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2	0.1
Unid sunfish	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0.0
White sucker	0.00	2.02	0.00	0.00	0.00	0.00	0.34	0.00	0.00	0.00	0.00	0.00	2	0.1
Yellow perch	0.00	0.14	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0	0.0
Total	195.39	56.45	72.52	194.34	234.74	160.02	262.16	128.72	9.49	41.55	53.18	953.68	2,362.24	100.0

Unid = unidentified

Note: Individual estimates may not add to totals due to rounding.

Unid Cottus – likely slimy sculpin

Compared to 2006-7 sampling at DNGS, the numbers and biomass of fish impinged in 2010-11 are higher. For 2006-7, estimated annual impingement was 14,119 (437 kg) to 26,024 (893 kg) fish, with the higher estimate being conservative (assuming all Units impinged similar amounts as Unit 4). There are several reasons why recent impingement numbers and biomass in 2010-11 are higher than those observed in 2006-7:

- **Increased Numbers of Invasive Round Goby:** Round goby are an invasive species which represented approximately 8.5% of the fish impinged in 2006-07 at DNGS. Approximately 55% of the fish impinged (counts and biomass) during the 2010-11 sampling were round goby (Tables 3.3 and 3.4). At times, round goby comprised a large proportion of the fish impinged for the month. For example, in May 2010, January 2011, February 2011 and March 2011, round goby comprised 93%, 82%, 86% and 95% of the fish impinged, respectively, based solely on the sampling events (i.e., not annualized, raw data). In April 2011, round goby comprised 99% of the fish impinged (see Table 3.2);
- **Increased Number of Sampling Events:** During 2006-7, sampling was weekly from May 1 to August 31 period, and biweekly in September 5 to March 23. Although these estimates were consistent with previous OPG sampling initiatives they were less robust than US counterparts who performed more rigorous sampling as part of the United States Environmental Protection Agency (USEPA) 316b requirements (SENES 2009a). Still, these estimates are considered adequate in providing preliminary assessments. In 2010-11, there was a marked increase in the number of sampling events to either twice a week (May, June, July, February, March) or weekly (January, April, August, September, October, November, December). An increase in sampling events provides more accurate impingement numbers, although the numbers may not be necessarily higher;
- **Increase in Number of Age-1 Alewife in Lake Ontario:** There appears to be a recent increase in the numbers of age-1 alewife in Lake Ontario. For example, in 2006 MNR's Lake Ontario Management Unit (LOMU) estimated an alewife biomass in Lake Ontario of 1650 MT. In 2009, the alewife population in Lake Ontario was 134 million year one- and older fish which translated to an estimated biomass of 5298 MT (MNR 2010). On the US side, there has been a recent marked increase in the number of age-1 alewife in 2010 (defined as less than 11 cm in length) based on a relatively large year class in 2009, the third largest in 15 years (Walsh and Connerton 2011). Previous years, there had been declines. Based on measured data for May, June and July 2010, the percentage of age-1 alewife (less than 11.0 cm fork length) was 94% (Table 3.5), which is typically high (e.g., see Walsh and Connerton 2011). The larger numbers impinged during this period likely reflect the larger number of fish in Lake Ontario of age-1 equivalence.

Table 3.5 Age-1 Alewife Impinged at DNGS, May-July 2010

Month	No. Age-1 Alewife Measured (Fork Length < 11cm)	Total No. of Alewife Measured	% of Age-1 Alewife
May 2010	22	24	92
June 2010	62	74	84
July 2010	189	193	98
Totals	273	291	94

- **More Efficient Travelling Screens:** New more efficient travelling screens were installed at all 4 Units. A performance engineer at DNGS has indicated that it is too early to evaluate the efficiency of the new screens as only two of the units were completed for the 2010 algae season. The algae ingress was also mild last year. The engineer, however, did indicate that the efficiency of trash removal with the new screens is improved compared to the old system (i.e., these new screens appear to be better collectors of debris and fish).
- **Mortality Possibly due to Naturally Occurring Upwelling Events:** Three quarters (75%) of the annual alewife impingement (counts) in 2010-11 occurred in December 2010 (86,950 of 115,465 alewife). Sampling occurred on 4 dates at two Units (Units 2 and 4) in December 2010 and 84% of alewife collected (based on raw data) were collected on December 7, 2010 at Unit 4. Similar to July 2, 2010, we believe that an external influence such as an upwelling may have caused a mass die off of alewife or caused them to be moribund and these alewife subsequently entered the intake structure. However, since we do not have any temperature data to confirm an upwelling, the December data were included in the analysis.

3.1.3 Comparison of 2010-11 Losses with Earlier Estimates and Prediction of Future Impingement Losses

DNGS condenser cooling water (CCW) intake performance is summarized in Wismer (1997a) and includes impingement monitoring at DNGS from 1993 to 1996. These data were subsequently highlighted in the Darlington Ecological Effects Review (DEER) (ESG 2001) to assess impingement losses, and are summarized in Table 3.6. These estimates were not adjusted for station flow, and may be underestimated due to identification and processing errors (Wismer 1997b). Estimated annual weights were 232 kg in 1993, 555 kg in 1994, 368 kg in 1995 and 164 kg in 1996. In 1993 and 1994 impingement estimates were underestimated due to fish bypassing the screening system and ending up in the sump for later disposal. For example, in 1994 the highest relative impingement estimate would be considerably higher, if an estimated 1,300 kg of alewife (based on gross weight in sump with likely other material such as debris and mussels, and fish not counted) is included. Based on fish impinged on the travelling screens, total estimated impingement summed over the four-year period was 1,319 kg (relative numbers and not corrected for flow). Of this, 791 kg (59.9% by weight) was alewife, 229 kg (17.3%) was shiners and 113 kg (8.6%) was smelt. Sucker, probably mostly white sucker, losses totalled 99 kg (7.5%) over the four years and whitefish, likely including both round and lake whitefish, accounted for 38 kg (2.9%). All other species individually comprised only fractions of a percent of total impingement by weight, representing the incidental loss of a few individuals. Other species impinged are given in Table 3.6.

Table 3.6 DNGS Impingement Loss Estimates

Year	Biomass (Kg)	Species Impinged
1993 1994 1995 1996	232 555* 368 164	• Alewife, Shiners, Smelt, Sucker, Walleye, Whitefish, Carp, Salmon, Lake Trout, Rainbow Trout, Gizzard Shad, Brown Trout, Bass, Eel (assumed American Eel), Yellow Perch, Catfish, Sunfish, Others (not speciated)
Dec 2006- Dec 2007	437- 893** (375.4 - 720.7 kg alewife)	• Alewife, Longnose Sucker, Pink Salmon, Rainbow Smelt, Round Goby, Spoonhead Sculpin, Threespine Stickleback, White Sucker
May 2010 – April 2011	2362 (994.1 kg alewife)	• Round Goby, Alewife, Rainbow Smelt, Sculpin (Spoonhead and Slimy), Pumpkinseed, Emerald Shiner, Yellow Perch, Threespine Stickleback, White Sucker, American Eel, Brown Bullhead, Sunfish.

* Does not include 1300 kg of alewife/debris in sump in June 1994.

** Upper biomass range (893 kg) is based on Unit 4 results (assumes other Units impinge similar amounts as Unit 4 which is a conservative estimate). 2006-7 data corrected for station flow.

Additional impingement sampling at DNGS was conducted over approximately a one-year period from December 13, 2006 to January 9, 2008 (2006-2007 adjusted for station flow) (SENES 2009a). Sampling was typically weekly during the May to August period, and biweekly from September to April. This sampling regime was less robust than most recent United States Environmental Protection Agency (USEPA) 316b studies (usually twice weekly during periods when fish densities are highest), but was considered adequate to show relative rates of impingement and composition of species impinged for EA purposes. Biomass estimates for data collected in 2006-07 are given in Table 3.6. Annual impingement was estimated to be approximately 14,119 fish (437.5 kg). Of this total, alewife contributed 375.4 kg. This biomass estimate is within the range from most years reported in the DEER report (1993, 1995, 1996, but not compared to 1994 results which had significantly higher impingement when including fish which bypassed the screens). Still, the 2006-7 impingement results may still be underestimated due to issues not sampling some Units during critical impingement periods. However, Unit 4, which is the last Unit in the forebay, had the highest impingement during the 2006-7 sampling (6,505 fish) as well as the least missed sampling dates during critical impingement periods. Typically, Unit 4 impinges more fish as fish become weakened, and move to the end of the forebay. If we assume the other Units impinge as many fish as Unit 4, then an estimated impingement would involve 26,020 fish/yr (i.e. 6505 x 4) which is likely a conservative estimate. Similarly, station biomass estimates were extrapolated based on Unit 4 data (which also had the highest values) and were estimated to be approximately 893 kg (720.7 kg alewife) (Table 3.6). An estimated range of impingement at DNGS could possibly vary from approximately 14,119 (437 kg) to 26,020 (839 kg) fish/yr. In 2006-07 sampling, a total of only 8 species were collected of which alewife and round goby contributed approximately 85.9 and 8.5% of the total, respectively. Round goby is a VEC indicator species (Table 3.6) which was not reported earlier in the DEER Report (ESG 2001, 1993-1996 data sets). Although round goby is a demersal species densities tend to be higher in the nearshore environment in the spring and summer than at the 10 m depth where the intake is located. Fall migration occurs to deeper depths. During this migration period, goby will likely become in contact with the intake structure. However, they have excellent swimming speed capabilities (sustained speeds for short periods up to 85 cm/s, Pennuto 2009), and should be able to avoid the low intake velocities of the intake structure.

Based on 2010-11 sampling, an estimated total of 274,931 fish (2,362 kg) were lost to impingement. This estimate is higher than those for previous years (Table 3.6) and more than 2.5 times higher than estimates from 2006-07. However, as mentioned previously, several factors can explain this increase. This difference was partly attributed to the presence of round goby which recently invaded Lake Ontario in the early 2000's (few were impinged in 2006) but accounted for over 50% of the total impingement in 2010-11. In addition, new more efficient travelling screens were installed in 2010-11 and changes in the lake population dynamics of alewife (increased numbers of age-1) can account for these increases. In recent sampling, a total of 13 species were identified impinged of which round goby and alewife contributed approximately 55% and 42% of the total, respectively.

When excluding round goby, which were not impinged in earlier studies (1993-96) and less than 8.5% of species impinged in more recent studies (2006-07), the annual impingement in 2010-11 would be estimated at 123,421 fish (1054 kg) (approximately 94% alewife). This estimate is not far off from the conservative estimate of 893 kg of fish lost to impingement in 2006-07, especially considering the installation of the new travelling screens which have been observed to be better collectors of debris and fish.

The 2010-11 annual estimate of 274,931 fish (2362 kg) lost to impingement may also be a conservative estimate. As previously mentioned, of the 115,465 alewife impinged, approximately three-quarters (75%) were impinged in the month of December, most of which were impinged on one sampling event (December 7, 2010). Thus, it is possible that an external factor (possibly an upwelling event) played a role in the weakening/death and subsequent impingement of these alewife. However, unlike the July 2 upwelling event, objective data is not available to support this belief and as such was counted as impinged.

3.1.4 Recommendations for Frequency of Future Impingement Studies

Following DNGS impingement sampling in 2006-07, the question arose as to whether Unit 4 could be used as a surrogate (conservative estimate) of impingement for the station. Data collected in 2006-07 suggested that Unit 4 had greater impingement than the other units. Results from Unit 4 could potentially be multiplied by four to provide an overall estimate of impingement.

This question was explored for two different scenarios:

1. Using all data for all species. Since all long dead species are also counted, this option is very conservative.
2. Using all data except long dead goby. Round goby made up the bulk of the long dead numbers so removing them gives a more realistic but less conservative estimate.

Note that for both scenarios, alewife data collected on July 2, 2010 at Unit 2 was removed prior to analysis as an upwelling event likely caused the death of these fish.

3.1.5 Exploratory Analysis

Based on data collected over the May 2010 to April 2011 period, Figures 3.6 and 3.7 show the weekly average 24-hr impingement across all species by Unit (depicted as 2011 weekly estimates for simplicity) for all species for scenario 1 (conservative) and scenario 2. Note that in May/June (approximately weeks 20-30), there were very high levels of impingement at Unit 2. However, no data were available for Unit 4. Sampling at Unit 4 only commenced in mid-July 2010. An option would be to use the maximum estimate observed in a given period as a surrogate for the other 4 Units. Also, for various reasons, no data were collected at Units 1-3 in December 2010 and January 2011 (except for one sample in December 2010 at Unit 2), thus, it is unclear if Unit 4 would have had greater or less impingement. Data from the 2006-07 impingement study showed that Unit 4 had less impingement during those months (Figure 3.8).

Figure 3.6 2011 Weekly Average 24hr Impingement (across all Species) by Unit (including all Long Dead Species)

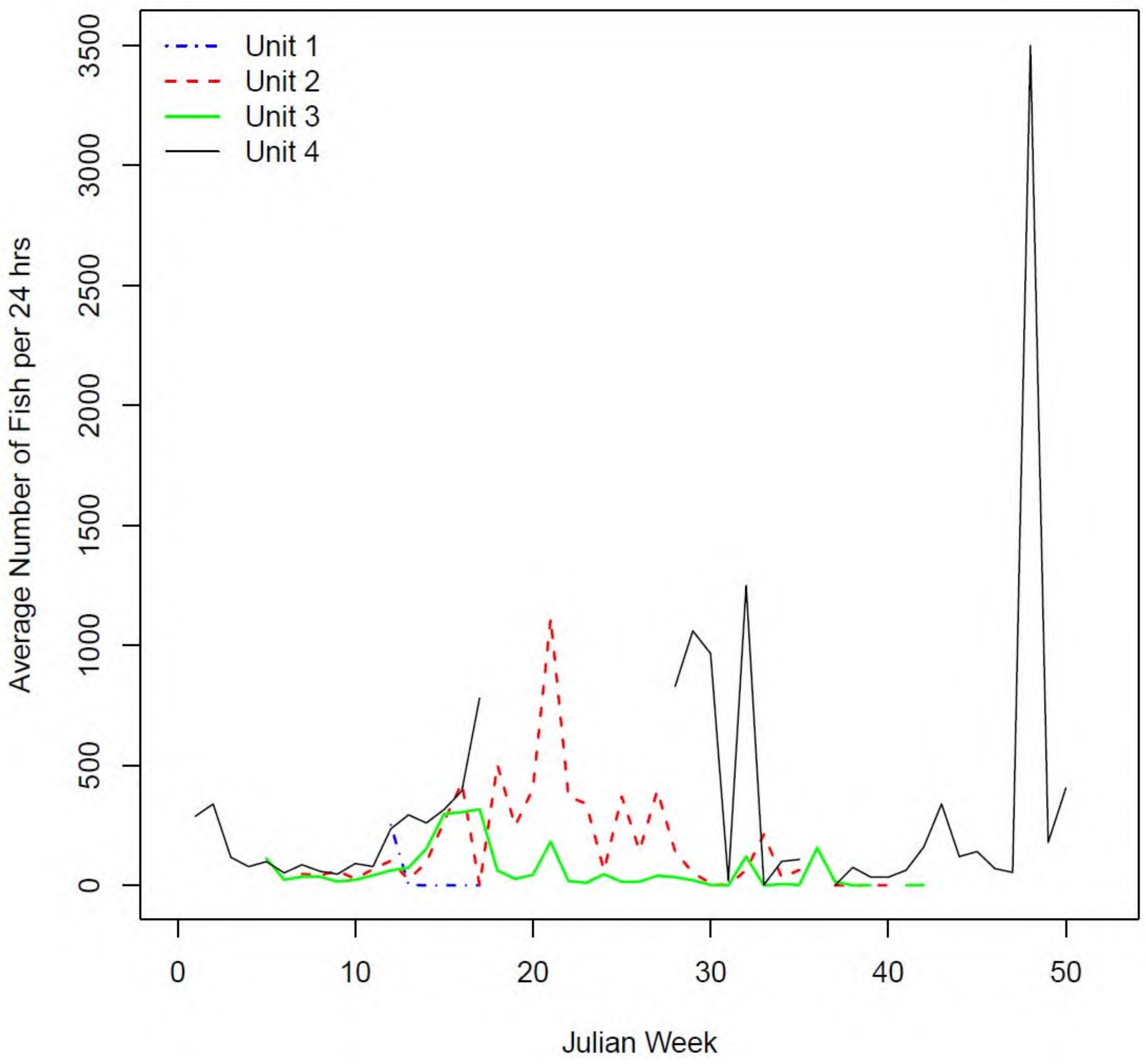


Figure 3.7 2011 weekly average 24hr impingement (across all species) by Unit (Excluding all Long Dead Round Goby)

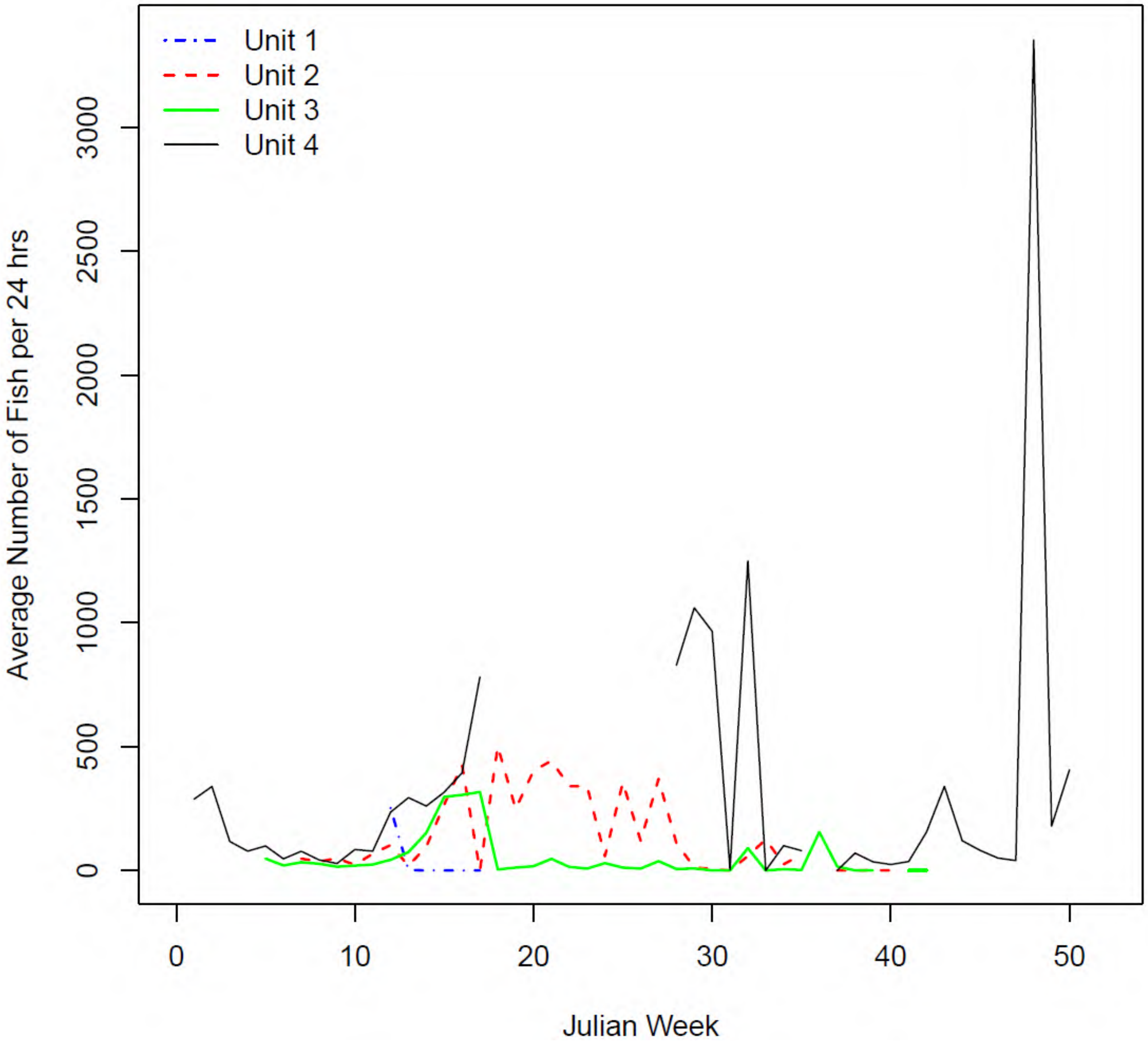
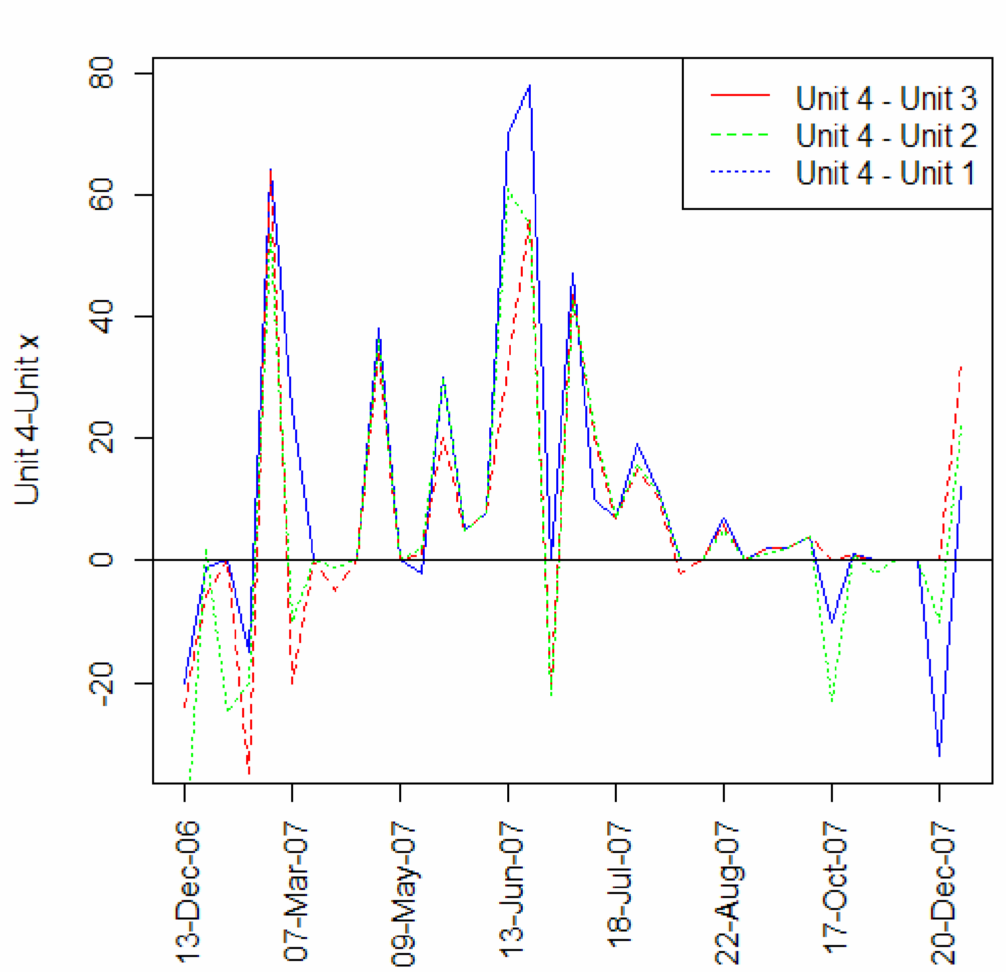


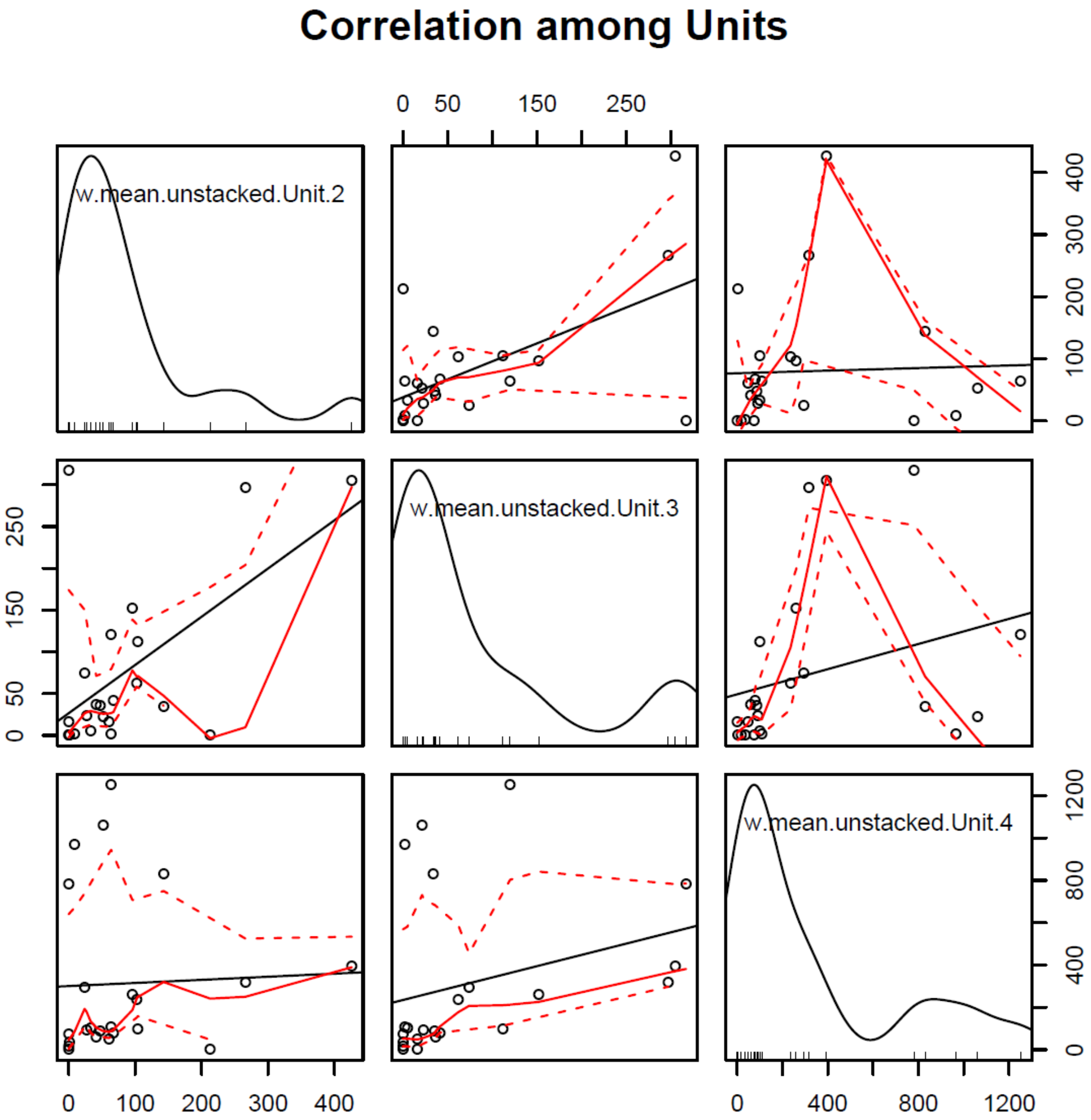
Figure 3.8 Illustration of the Difference Between Unit 4 and the Other Units for all of the Raw Data (2006-07)



Note: Positive numbers indicate sampling occasions where Unit 4 was greater than the other units.

Figure 3.9 shows correlation plots for Units 2, 3 and 4 using all available data. Unit 1 was not evaluated as there were insufficient data. Observed correlations were very weak, but it still makes sense that broad seasonal/environmental changes should be observed across all Units. Unfortunately there are large data gaps that reduce the number of weeks where correlation among Units may be observed.

Figure 3.9 Correlation Plots for Units 2, 3, and 4 using all available data



Note: There are insufficient data to evaluate Unit 1.

Comparing Unit 4 to Units 1-3

The null hypothesis that impingement at Unit 4 does not differ from the other Units was tested against the alternative that Unit 4 has greater impingement than the other Units.

Paired t-test

A paired t-test was chosen for use to take advantage of the correlation across Units within a week. First, the weekly mean 24hr impingement was calculated. The difference between Unit 4 and Unit 1-3, respectively, was then taken. This difference was then analyzed to determine whether or not there was evidence that it was greater than zero. If the difference was found to be greater than zero, this indicates that impingement at Unit 4 is greater than the other units. Results for a two-sample t-test are shown as well.

Assumptions:

- Assumes the pairs are independent samples. This is not necessarily valid as it is possible the pairs are correlated over time. Here we also have some clustering, the pairs were not taken at random from the year. Some parts of the year have more data than others.
- Assumes the differences are normally distributed. This may not be valid for Units 2 and 3 as they look quite skewed. However, when the number of pairs is large, the CLT validates the test regardless of the distribution (Devore 1995).
- Several transformations of the data were evaluated and it was found that a natural log transformation normalized the data quite well. Where zeros occurred they were first increased to 1 to avoid any impossible values. In this case, this adjustment was a reasonable approach as there were not very many zeros and the other numbers were quite large (i.e., 1 was not big relative to the other data). Both the paired test and the two-sample test using the log transformed data had consistent results with those shown here. Other approaches are possible but not shown as all results are consistent.
- No assumption of equal variance was required for the paired t-test as we are looking at the difference among pairs rather than two separate datasets.

Results:

- T-tests on paired data (i.e., is the difference >0), found that Unit 4 had significantly greater impingement than each of Units 1, 2, and 3 (Tables 3.7 and 3.8).
- Two-sample t-tests which ignore the correlation among paired samples but have greater degrees of freedom also find that Unit 4 has significantly greater impingement than each of Units 1, 2, and 3 (Tables 3.9 and 3.10).
- Given the high seasonal variability observed in the data (Figures 3.6 and 3.7) and the expectation that there should be some correlation among units within a time period even though it is not particularly strong in this dataset (Figure 3.9), it still makes sense to pair them in this case and in future comparisons.

Table 3.7 Paired T-Test Results using all Available Data (Conservative Estimate)

Comparison	Test Statistic	Degrees Freedom	P-value
U4 vs U1	3.20	5	0.0120
U4 vs U2	2.37	25	0.0128
U4 vs U3	3.25	25	0.0016

Table 3.8 Paired T-Test Results using all Data except Long Dead Round Goby

Comparison	Test Statistic	Degrees Freedom	P-value
U4 vs U1	3.20	5	0.012
U4 vs U2	2.44	25	0.011
U4 vs U3	3.22	25	0.002

Table 3.9 Two Sample T-Test Results using all Available Data (Conservative Estimate)

Comparison	Test Statistic	Degrees Freedom	P-value
U4 vs U1	2.79	42.3	0.004
U4 vs U2	1.69	48.7	0.049
U4 vs U3	2.80	39.7	0.004

Table 3.10 Two Sample T-Test Results using all Data except Long Dead Round Goby

Comparison	Test statistic	Degrees Freedom	P-value
U4 vs U1	2.76	42.0	0.004
U4 vs U2	1.99	43.9	0.026
U4 vs U3	2.91	39.7	0.003

Conclusions

The results of the available data support the use of Unit 4 as a conservative estimate for the other units. However there are several important limitations to the data that should be noted:

- Unit 1 – Despite the significant result, the Unit 1 samples only represent a very short window of 6 weeks not sampled at random from the year. It is assumed that the results show a similar trend for the rest of the year.
- Unit 4 was not sampled for May and June 2010, two potentially important months. During this period Unit 2 in particular had large occurrences of impingement. If Unit 4 cannot be sampled for any reason (e.g., safety, mechanical), a long term strategy could be

to sample all other active units during this period and use the maximum of these (e.g., Unit 2 with this example).

- Only Unit 4 was measured for December 2010 and January 2011, so it cannot be assessed whether or not impingement is greater at Unit 4 than the other units for this period. In 2009 (Figure 3.3), Unit 4 actually had less impingement than the other units during the December-January period.

If Unit 4 is generally used as a surrogate (once the concerns above have been addressed), consideration to continue some limited level of sampling at the other units (e.g., random spot checks at much lower intensity) into the future is recommended to make sure that any unforeseen systematic changes are not missed.

3.2 COMPARISON TO OTHER GREAT LAKES FACILITIES

A comparison of impingement at DNGS to other power plants on the Great Lakes is given in Table 3.11. These estimates are for general comparison only since impingement collection methodologies may vary based on the study objective. The results provide evidence that DNGS impinges fewer fish relative to other locations on the Great Lakes which is consistent with earlier data reported by Wismer (1997a) and the DEER report (1997).

The results shown in Table 3.11 suggest that there is considerable variability in the number of organisms impinged. Variation depends on intake location (Great Lake), intake type (submerged or surface), and intake flow rate. It is noteworthy that the number of species impinged at DNGS is considerably lower than all other plants. There were only 13 fish identified species impinged (and two groups identified to family level) in 2010-11. As stated above, the number of fish impinged is also low relative to the other locations even with DNGS having the highest intake flow rate of its counterparts.

Perhaps the most realistic comparisons with DNGS are the D.C. Cook Plant and the J.H. Campbell Plant, both of which are large plants and have submerged intakes but are located on Lake Michigan rather than on Lake Ontario. These power plants also have fish protection systems in place (Cook has an acoustic system to address impingement, and Unit 3 at the Campbell Plant has a 3/8 inch wedge wire screen intake to address both entrainment and impingement).

Another interesting comparison is with the J.A. FitzPatrick Plant directly across from DNGS on Lake Ontario which also has a submerged intake. FitzPatrick also has an acoustic system which was installed to directly reduce alewife impingement similar to the porous veneer at DNGS (Ross *et al*. 1993). Alewife impingement at FitzPatrick was 16,796 (2004 estimate) similar to that at DNGS (12,139) in 2006-7. A large number of stickle-back were impinged at FitzPatrick, and it is likely that they do not respond well to an acoustical deterrent (e.g., Maes *et al.* 2004).

In comparison to 2010 annual impingement at Pickering Nuclear Generating Station (PNGS), annual impingement at DNGS is lower. PNGS is located on Lake Ontario approximately 35 km west of DNGS. PNGS uses a surface intake system and in 2010, a Fish Diversion System (FDS) Barrier Net was installed during the ice free period (April to November) as a fish protection measure. It was estimated that PNGS achieved approximately a 78% reduction in impinged fish biomass in 2010 (4617 kg) compared to the baseline data in 2003/04 when no fish protection measures were in place (18,214 kg) (OPG 2011) (see Table 3.12). The FDS barrier net was found to be from 75% (spring season) to 100% (fall season) effective (weighted arithmetic mean) based on hydroacoustic assessments (SENES 2011). A total of 304,593 fish were impinged at PNGS compared to the slightly lower count of 274,931 fish at DNGS in 2010-11 (Table 3.12). However, in terms of biomass, impingement losses at DNGS is approximately half that of PNGS (2362 kg vs. 4617 kg, respectively). At DNGS, 13 species and 2 groups identified to family level were impinged. At PNGS, 41 species were impinged, as well as 5 groups identified to family level. It must be noted that the electrical output of DNGS (3512 MW) is also 12% higher than PNGS (3100 MW). These results suggest that the performance of the porous veneer intake structure exceeds 80% impingement reduction at a minimum.

Table 3.11 Comparison of Impingement Estimated Losses at Different Plants on the Great Lakes

Plant	Location	MWe (gross)	Flow m^3/s	Intake Type	Fish Protection System in Place	Annual Impingement		
						No. of Species	Dominant Species Impingement	No. Impinged
DNGS	Lake Ontario	3740	150	Submerged	Porous veneer intake structure	8 (2006-7)	Alewife Round goby	14,119-26,020 (2006-7)
						13 (2010-11)		274,931 (2010-11)
D.C. Cook[1]	Lake Michigan	2,191	106-145	Submerged	Acoustic system (Ross *et al*. 1993)	50	Yellow perch Alewife spottail shiner	1,386,023 (2005-6)
J. H. Campbell[2]	Lake Michigan	1,200	Units 1-2 (13.1)	Surface	None	50	Alewife Gizzard shad	491,717 (2005-6)
			Unit 3 (17.5)	Submerged	Wedge wire screen (3/8" opening)	N.A. (screen size too small to capture fish)	N.A.	No impingement.
Bay Shore[3]	Lake Erie (Maumee Bay)	631	35.5	Surface	None	55	Emerald shiner Gizzard shad White perch	46,030,066 (2005-6)
J.A. FitzPatrick[4]	Lake Ontario	886	26.1	Submerged	Acoustic system (Ross *et al*. 1993)	54	Stickleback (201,563) Alewife (16,796)	230,534 (2004)
Ludington	Lake Michigan	1872	2.6	Surface	Barrier net (Consumers Energy 2010)	N/A	Alewife and salmonid species	89.3% reduction (alewife >5" - 94.5%; alewife <5" - 82%; salmon >5" - 77.4%) for period net installed (2010).
Port Washington[5]	Lake Michigan	1150	36	Surface	None (in 2004 but porous dike installed in 2009)	36	Alewife Gizzard Shad Threespine Stickleback	1,122,518 (2004)
Pickering Nuclear[6]	Lake Ontario	3100	A-64 B-150	Surface	None	34	Alewife	686,448 (2003/04)
					Barrier net (SENES 2011, OPG 2011)	41	Alewife (258,189)	304,593 (2010)

Notes:

1. Data obtained from Normandeau 2007 (Report R-20452)
2. Data obtained from GLEC 2007 (Report 1765-00)
3. Data obtained from Ager *et al.*, 2007 (Report 11206-005-RA-0001-R00)
4. Data obtained from 2004 SPDES Biological Monitoring Report James A. FitzPatrick Nuclear Power Plant (Permit No. NY 0020109, Section 10, CP-04.03). May 2005.
5. Data obtained from EA Engineering, Science, and Technology (2005)
6. Data obtained from OPG 2011

Table 3.12 Comparison of Annual Impingement Losses at DNGS (2010-11) and PNGS (2003-04 and 2010)

Station	Year	Type of Intake	# of Species	Count	Biomass (kg)
Pickering Nuclear	2003/04	Surface (no fish protection)	34	686,448	18,214
	2010	Surface (barrier net in place)	41	304,593 (5% round goby)	4617
Darlington Nuclear	2010-11	Submerged (porous veneer)	13	274,931 (55% round goby)	2362

3.3 BIOLOGICAL LIABILITY LOSSES ASSOCIATED WITH IMPINGEMENT

Using the methodology and input parameters described in Section 2.0, estimates of the three measures of equivalent loss from impingement at DNGS are provided for each selected taxa in Table 3.13. Estimates of the total number of equivalent Age 1 were dominated by round goby which together accounted for more than 90 percent of the total estimate (3,860,403 out of 4,242,050 equivalent Age 1). The reason that the number of Age 1 equivalents is greater than the estimate of total impingement for this species can be attributed to the fact that most impinged were judged to be Age 2+ or Age 3+. The total number of equivalent Age 1 alewife was estimated at 56,515, or only one percent of the total estimate. To determine that total biomass lost from impingement at DNGS, estimates of the future production foregone were added to the weight of the annual estimated weight impinged for each species. The total biomass lost was estimated at 3,260.22 kg. This lost biomass was roughly evenly split between alewife (1570.79 kg) and round goby (1515.12 kg). Together, these two taxa accounted for almost 95 percent of the total biomass lost from impingement at DNGS (48.1% for alewife and 46.5% for round goby). Most of the total biomass lost across all species was attributable to the weight of fish at the time of impingement. Lost fishery yield was relatively small (89 kg) and consisted almost exclusively of rainbow smelt (almost 98%). Lost fishery yield for all other species combined amounted to less than 2 kg. The total estimated future production foregone was 905.47 kg, with alewife (576.65 kg), round goby (207.27 kg) and rainbow smelt (111.93 kg) comprising 99% of the total estimate. For comparative purposes, production foregone for the 2006-7 period was estimated to range from 229 to 422 kg (SENES 2009a). Production foregone estimates for each species will be discussed further in Section 3.4.

Table 3.13 Estimates of Annual Equivalent Loss from Impingement at the Darlington Nuclear Generating Station, May 2010 – April 2011

Taxa	Number of Equivalent Age 1+	Total Annual Impingement Weight (kg)	Total Future Production Foregone (kg)	Total Biomass Lost (kg)	Lost Fishery Yield (kg)
Alewife	56,515	994.14	576.65	1,570.79	N/A
Brown bullhead	7	0.01	0.60	0.61	0.21
Emerald shiner	1,006	0.32	0.09	0.41	N/A
Pumpkinseed	132	0.49	2.59	3.09	0.75
Rainbow smelt	20,114	33.42	111.93	145.35	87.30
Round goby	3,860,403	1,307.85	207.27	1,515.12	N/A
Slimy sculpin	26,573	1.08	0.09	1.17	N/A
Smallmouth bass	0	0.08	0.04	0.12	0.01
Spoonhead sculpin	237,962	13.02	2.44	15.46	N/A
Threespine stickleback	20	0.01	0.00	0.01	N/A
Unid sculpin	39,281	1.75	0.13	1.88	N/A
Unid sunfish	8	0.04	0.14	0.18	0.04
White sucker	21	2.35	2.57	4.92	0.56
Yellow perch	10	0.18	0.93	1.11	0.35
Total	4,242,050	2,354.75	905.47	3,260.22	89.22

Unid = unidentified
N/A = not applicable
Unid sculpin – likely slimy sculpin

3.4 COMPARISON OF 2010-11 DNGS IMPINGEMENT LOSSES TO LAKE ONTARIO FISH POPULATIONS

Round Goby

Round goby invaded Lake Ontario in the 1990s and first appeared in DNGS impingement samples during the 2006-07 sampling campaign, comprising approximately 8.5% of fish impinged that year (SENES 2009a, SENES and Golder 2009). In 2010-11, approximately 55% of the fish impinged were round goby (based on annual estimated counts and biomass). According to the MNR (2011), round goby abundance has remained high and stable or increased over the last three years. The total future production foregone for round goby was estimated to be 207.27 kg (approximately 23% of total future production foregone) (Table 3.13). As mentioned previously, the current porous veneer intake structure at DNGS was not designed to protect goby as they are only a recent invasive species.

Alewife

The numbers of alewife impinged in 2010-11 (115,465 fish; 994.1 kg) (and previously in 2006-07) are very low relative to the population estimate for Lake Ontario. In 2009, the population estimate was 134 million yearling-and-older fish, translating into an estimated biomass of 5298 metric tonnes (MT) (MNR 2010). Since 2006, adult alewife (11 cm fork length or greater) numbers have decreased in the US waters of Lake Ontario (Walsh and Connerton 2011). Furthermore, there has been a marked increase in the number of age-1 alewife (fork length less than 11 cm) in 2010 based on a relatively large year class in 2009, the third largest in 15 years. It is assumed that the same applies for alewife in the Canadian waters of Lake Ontario. The estimated number of equivalent age-1 was 56,515 alewife (Table 3.13). The total estimated future production foregone was 576.65 kg (64% of total estimated future production foregone) (Table 3.13). This amount is negligible (0.01%) when considering the estimated biomass of alewife in Lake Ontario in 2009 was 5298 MT (MNR 2010).

Rainbow Smelt

Based on 2010-11 data, annual impingement losses of rainbow smelt are estimated to be 5857 individuals (33.4 kg), which is low relative to the smelt population in Lake Ontario. In 2009, the population estimate for smelt in Lake Ontario in 2009 was 311 million yearling-and-older fish, translating into a biomass of 1714 MT. The abundance of rainbow smelt remains at low levels since the early 2000s even though there was a modest increase in the population of yearling-and-older rainbow smelt (MNR 2010). The total future production foregone of rainbow smelt from DNGS in 2010-11 was estimated to be 111.93 kg (Table 3.14). This amount is insignificant (<0.01%) when compared to the smelt biomass of 1714 MT in Lake Ontario. The lost fishery yield for smelt from impingement at DNGS was estimated to be 87.30 kg (Table 3.13). Again, this amount is insignificant when considering the biomass of smelt in Lake Ontario (1714 MT in 2009).

Sculpin

Sculpin losses totalled 1829 individuals (approximately 15.9 kg) in 2010-11. Of these individuals, 113 (1.1 kg) were slimy sculpins. Available data for slimy sculpin shows that its abundance in the US waters of Lake Ontario has been on the decline since 2002 (Weidel *et al.* 2011). The average catch using trawl nets was 10 slimy sculpin per minute for the period of 2004-2010. This trend is expected to be similar for slimy sculpin in the Canadian waters of Lake Ontario. The estimated future production foregone for sculpins (spoonhead and slimy) was 2.66 kg (0.3% of total future production foregone) (Table 3.13).

American Eel

As mentioned, American eel is considered endangered under Ontario's *Endangered Species Act* (ESA) and a species of Special Concern according to COSEWIC. An estimated 5 American eels (7.5 kg) were impinged at DNGS in 2010-11. OPG stocked eels into the upper St. Lawrence River and the Bay of Quinte and preliminary results suggest that these eels are surviving, growing and dispersing from stocked sites. The province of Ontario is working with other management agencies and stakeholders to promote the safe passage of eels around hydro dams (MNR 2010).

Panfish

Approximately 111 panfish (106 pumpkinseed (0.5 kg) and 5 sunfish species (0.09 kg)) were impinged in 2010-11. At the Bay of Quinte, panfish abundance has increased. For example, at Big Bay, Bay of Quinte, the mean catch per gillnet for pumpkinseed was 23.9, 27.3 for bluegill and 3.2 for black crappie for the period of 2001-2010. For the period of 1992-2000, the mean catch per gillnet for pumpkinseed, bluegill and black crappie was 26.1, 3.8 and 0.7, respectively. Panfish are also common in other Lake Ontario embayments and nearshore areas (MNR 2011). The numbers of panfish impinged at DNGS over the course of one year is thus low when compared to the numbers being collected in gillnets since gillnets are only set for a short period of time (e.g., 24 hours). Based on 2010-11 impingement data at DNGS, future production foregone for panfish was estimated to be 2.73 kg and estimated fishery yield loss was 0.79 kg (Table 3.13).

Yellow Perch

An estimated 11 yellow perch (0.2 kg) were lost to impingement in 2010-11. Despite yellow perch being one of the most common species in the nearshore areas, their current abundance is low to moderate when compared to past levels (MNR 2011). For example, at Big Bay, Bay of Quinte, the mean catch per gillnet set for yellow perch was 912.2 for the period 1992-2000 and 705.7 for the period 2001-2010. At Northeastern Lake Ontario, the mean catch per gillnet set was 96.5 in 1992-2000 and 36.5 in 2001-2010. The total future production foregone of yellow perch was estimated to be less than 1 kg (Table 3.13). In terms of lost fishery yield, the biomass lost is 0.35 kg (Table 3.13).

Threespine Stickleback

Few threespine stickleback were impinged at DNGS in 2010-11 (estimated 5 individuals or 0.0 kg) and thus further discussion is not included. Threespine stickleback did not contribute (0% of total) to the total future production foregone due to impingement at DNGS (Table 3.13).

3.5 SIGNIFICANCE OF LOSS AS IT RELATES TO CONSERVATION AND/OR HARVEST

Of the fish species impinged at DNGS in 2010-11, only suckers (white sucker), brown bullhead, sunfish (pumpkinseed and unidentified) and yellow perch have been reported in commercial harvest numbers on Lake Ontario.

The sucker fishery on Lake Ontario is small and of minor economic importance representing a total yearly value ranging from $485 to $1157 between 2005 and 2010 (Table 3.14).

An estimated 39 white sucker were impinged at DNGS during 2010-11. Based on an average weight of 587.4 g for white sucker (assuming all fish reached adult stage), the total estimated weight of impinged suckers at DNGS during 2010-11 would have been 22.9 kg (50.4 lb) which based on the data, is a conservative estimate. Compared to the most recent commercial Lake Ontario fish harvest numbers available, the 2010-11 sucker impingement at DNGS represented no more than 1.1% of the annual commercial harvest between 2005 and 2010 (Table 3.15). In Western Lake Ontario, where data is available, 2010-11 sucker impingement numbers represent an increasing proportion of the total sucker harvest as sucker harvests have been declining in that area since 2001. In terms of economic value, the estimated sucker impingement numbers represent a value of between $5.04 and $5.57 annually depending on the yearly price for sucker.

Table 3.14 Commercial Harvest of Suckers from the Lake Ontario Fishery, 2005-2010

Year	Fish Species	Harvest (lb)		Price/lb	Value of Catch	
		Western Lake Ontario	All of Lake Ontario		Western Lake Ontario	All of Lake Ontario
2010	White Sucker	0	7017	$0.11	$0	$751
2009	Suckers	0	7923	$0.10	$0	$824
2008	Suckers	0	4772	$0.10	$0	$481
2007	Suckers	224	4613	$0.11	$24.64	$485
2006	Suckers	1110	8057	$0.10	$111	$837
2005	Suckers	424	11569	$0.10	$42.40	$1,156.90

Source: Source: 2005 = MNR 2006; 2006 = MNR 2007; 2007 = MNR 2009a; 2008 = MNR 2009b; 2009 = MNR 2010; 2010 = MNR 2011

Table 3.15 Sucker Impingement Loss (LB) as a Proportion of the Commercial Sucker Harvest in Lake Ontario, 2005-2010

Year	% of Commercial Catch		Loss of Potential Commercial Value
	Western Lake Ontario	All of Lake Ontario	
2010	*	0.7%	$5.57
2009	*	0.6%	$5.04
2008	*	1.1%	$5.04
2007	22.5%	1.1%	$5.57
2006	4.5%	0.6%	$5.04
2005	11.9%	0.4%	$5.04

* No commercial sucker catch

The brown bullhead fishery on Lake Ontario represents a total yearly value ranging from $2952 to $32,575 between 2005 and 2010 (Table 3.16).

An estimated four (4) brown bullhead were impinged at DNGS during 2010-11. Based on an average weight of 610 g[2] for brown bullhead (assuming all fish reached adult stage), the total estimated weight of impinged brown bullhead at DNGS during 2010-11 would have been 2.4 kg (5.3 lb) which based on the data, is a conservative estimate. Compared to the most recent commercial Lake Ontario fish harvest numbers available, the 2010-11 brown bullhead impingement at DNGS represented less than 0.1% of the annual commercial harvest between 2005 and 2010 (Table 3.17). In Western Lake Ontario, where data is available, 2010-11 brown bullhead impingement numbers represent a negligible proportion of total brown bullhead harvest (2005-2007) but represented approximately half of the harvest in 2008. In terms of economic value, the estimated brown bullhead impingement numbers represent a value of between $1.50 and $2.23 annually depending on the yearly price for brown bullhead.

Table 3.16 Commercial Harvest of Brown Bullhead from the Lake Ontario Fishery, 2005-2010

Year	Fish Species	Harvest (lb)		Price/lb	Value of Catch	
		Western Lake Ontario	All of Lake Ontario		Western Lake Ontario	All of Lake Ontario
2010	Brown Bullhead	0	10,506	$0.28	$0	$2952
2009	Brown Bullhead	0	14,040	$0.30	$0	$4271
2008	Brown Bullhead	10	32,567	$0.30	$3	$9802
2007	Brown Bullhead	2698	37,463	$0.31	$836.38	$11,614
2006	Brown Bullhead	3699	77,955	$0.42	$1553.58	$32,575
2005	Brown Bullhead	5558	81,765	$0.37	$2056.46	$30,253

Source: 2005 = MNR 2006; 2006 = MNR 2007; 2007 = MNR 2009a; 2008 = MNR 2009b; 2009 = MNR 2010; 2010 = MNR 2011

Table 3.17 Brown Bullhead Impingement Loss (LB) as a Proportion of the Commercial Brown Bullhead Harvest in Lake Ontario, 2005-2010

Year	% of Commercial Catch		Loss of Potential Commercial Value
	Western Lake Ontario	All of Lake Ontario	
2010	*	0.05%	$1.50
2009	*	0.04%	$1.59
2008	53.0%	0.02%	$1.59
2007	0.2%	0.01%	$1.64
2006	0.1%	0.00%	$2.23
2005	0.1%	0.00%	$1.96

*No commercial brown bullhead catch

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[2] Data from the Ontario Freshwater Fishes Life History Database: http://www.fishdb.ca/home.htm.

The sunfish fishery on Lake Ontario represents a total yearly value ranging from $29,686 to $106,858 between 2005 and 2010 (Table 3.18). Sunfish include species such as pumpkinseed and bluegill and these form a significant component of the commercial fishery in terms of dollar value (2nd only to yellow perch) (MNR 2011).

An estimated 119 sunfish (106 pumpkinseed, 5 unidentified sunfish and 8 smallmouth bass) were impinged at DNGS during 2010-11. Based on an average weight of 1300 g[3] for smallmouth bass (assuming all fish reached adult stage) and 250 g[4] for pumpkinseed (assuming all fish reached adult stage and the 5 unidentified sunfish are also pumpkinseed), the total estimated weight of impinged sunfish at DNGS during 2010-11 would have been 38.2 kg (84.0 lb) which based on the data, is a conservative estimate. Compared to the most recent commercial Lake Ontario fish harvest numbers available, the 2010-11 sunfish impingement at DNGS represented no more than 0.2% of the annual commercial harvest between 2005 and 2010 (Table 3.19). In Western Lake Ontario, where data is available, 2010-11 sunfish impingement numbers represent more than 100% of the total sunfish harvest in Western Lake Ontario for 2005, 2007 and 2008. In terms of economic value, the estimated sunfish impingement numbers represent a value of between $53.76 and $102.48 annually depending on the yearly price for sunfish.

Table 3.18 Commercial Harvest of Sunfish from the Lake Ontario Fishery, 2005-2010

Year	Fish Species	Harvest (lb)		Price/lb	Value of Catch	
		Western Lake Ontario	All of Lake Ontario		Western Lake Ontario	All of Lake Ontario
2010	Sunfish	0	87,509	$1.22	$0	$106,858
2009	Sunfish	0	45,483	$1.17	$0	$53,006
2008	Sunfish	5	37,886	$0.82	$4.10	$30,975
2007	Sunfish	30	38,214	$0.79	$23.70	$30,271
2006	Sunfish	116	46,597	$0.64	$74.24	$29,686
2005	Sunfish	62	51,323	$1.07	$66.34	$54,916

Source: 2005 = MNR 2006; 2006 = MNR 2007; 2007 = MNR 2009a; 2008 = MNR 2009b; 2009 = MNR 2010; 2010 = MNR 2011

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[3] Data from the Ontario Freshwater Fishes Life History Database: http://www.fishdb.ca/home.htm.
[4] Data from the Ontario Freshwater Fishes Life History Database: http://www.fishdb.ca/home.htm.

Table 3.19 Sunfish Impingement Loss (LB) as a Proportion of the Commercial Sunfish Harvest in Lake Ontario, 2005-2010

Year	% of Commercial Catch		Loss of Potential Commercial Value
	Western Lake Ontario	All of Lake Ontario	
2010	*	0.1%	$102.48
2009	*	0.2%	$98.28
2008	1680%	0.2%	$68.88
2007	280%	0.2%	$66.36
2006	72.4%	0.2%	$53.76
2005	135.5%	0.2%	$89.88

*No commercial sunfish catch

The yellow perch fishery on Lake Ontario represents a total yearly value ranging from $96,336 to $330,889 between 2005 and 2010 (Table 3.20). Yellow perch are the most valuable species in the commercial fishery (MNR 2011).

An estimated eleven (11) yellow perch were impinged at DNGS during 2010-11. Based on an average weight of 300 g[5] for yellow perch (assuming all fish reached adult stage), the total estimated weight of impinged yellow perch at DNGS during 2010-11 would have been 3.3 kg (7.3 lb) which based on the data, is a conservative estimate. Compared to the most recent commercial Lake Ontario fish harvest numbers available, the 2010-11 yellow perch impingement at DNGS represented 0% of the annual commercial harvest between 2005 and 2010 (Table 3.21). In Western Lake Ontario, where data is available, 2010-11 yellow perch impingement numbers represent a less than 10% of total yellow perch harvest for the years 2005-07. For 2008, recent impingement numbers represent more than 100% of the total yellow perch harvest in Western Lake Ontario. In terms of economic value, the estimated yellow perch impingement numbers represent a value of between $6.28 and $12.56 annually depending on the yearly price for yellow perch.

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[5] Data from the Ontario Freshwater Fishes Life History Database: http://www.fishdb.ca/home.htm.

Table 3.20 Commercial Harvest of Yellow Perch from the Lake Ontario Fishery, 2005-2010

Year	Fish Species	Harvest (lb)		Price/lb	Value of Catch	
		Western Lake Ontario	All of Lake Ontario		Western Lake Ontario	All of Lake Ontario
2010	Yellow Perch	0	140,207	$1.72	$0	$241,320
2009	Yellow Perch	0	131,180	$1.43	$0	$188,003
2008	Yellow Perch	6	112,591	$0.86	$5.16	$96,336
2007	Yellow Perch	336	195,122	$1.42	$477.12	$277,041
2006	Yellow Perch	546	222,609	$1.49	$813.54	$330,889
2005	Yellow Perch	96	99,461	$1.38	$132.48	$137,256

Source: 2005 = MNR 2006; 2006 = MNR 2007; 2007 = MNR 2009a; 2008 = MNR 2009b; 2009 = MNR 2010; 2010 = MNR 2011

Table 3.21 Yellow Perch Impingement Loss (LB) as a Proportion of the Commercial Yellow Perch Harvest in Lake Ontario, 2005-2010

Year	% of Commercial Catch		Loss of Potential Commercial Value
	Western Lake Ontario	All of Lake Ontario	
2010	*	0.0%	$12.56
2009	*	0.0%	$10.44
2008	121.7%	0.0%	$6.28
2007	2.2%	0.0%	$10.37
2006	1.3%	0.0%	$10.88
2005	7.6%	0.0%	$10.07

*No commercial yellow perch catch

The total commercial harvest of all fish species in Lake Ontario in 2010 was 418,804 lbs (189.966 kg), translating into an economic value of $491,089 (MNR 2011). The losses of white sucker, brown bullhead, sunfish and yellow perch at DNGS in 2010-11 amounted to approximately 147 lbs (66.8 kg). Using the upper range economic value for each species, the total fisheries loss due to impingement at DNGS in 2010-11 was $122.84. This economic loss is negligible, and translates into 0.025% of the total economic value of the Lake Ontario commercial harvest in 2010.

4.0 CONCLUSIONS AND RECOMMENDATIONS

Recent impingement sampling at DNGS was conducted over a one-year period from May 4, 2010 to April 26, 2011, with a qualified statistician assisting with the sampling design. The estimated annual impingement at DNGS was 274,931 (2362 kg) fish. The estimated counts and biomass are higher than totals reported from 2006-07 sampling (26,020 fish or 839 kg). However, some of this difference was attributed to the presence of round goby which accounted for over 50% of the total impingement in 2010-11. In 2006-07, goby only represented about 8.5% of total impingement. In addition, new more efficient travelling screens were installed in 2010-11 and changes in the lake population dynamics of alewife (increased numbers of age-1) may account for these increases. In recent sampling, a total of 13 species were identified of which round goby and alewife contributed approximately 55% and 42% of the total, respectively. In 2006-07, eight species were impinged.

A comparison of impingement at DNGS was made to other power plants on the Great Lakes. The comparison was particularly relevant with Pickering Nuclear Generating Station (PNGS) since impingement was conducted during the same year (2010-11), and each facility is only approximately 35 km apart. The results provide evidence that DNGS impinged fewer fish relative to other locations on the Great Lakes, which is consistent with earlier data reported by Wismer (1997a) and in the DEER report (1997). This is important since many of these power plants already have some fish protection system in place. For example, impingement levels at DNGS (2362 kg) were still considerably lower than that at PNGS (4617 kg) which had a fish protection system in place (barrier net) which was estimated to be approximately 80% effective (OPG 2011). A total of 13 fish species were identified impinged at DNGS compared to 41 species at PNGS. It must be noted that the electrical output of DNGS (3512 MW) is also 12% higher than PNGS (3100 MW).

This report also provided an evaluation of the biological liability of fish that were impinged at DNGS in 2010-11. Lost fishery yield was relatively small (89 kg) and consisted almost exclusively of rainbow smelt (almost 98%). Lost fishery yield for all other species combined amounted to less than 2 kg. The number of equivalent age 1 fish that could have resulted from impinged fish was estimated to be 4,242,050 with round goby being the predominant species (91% or 3,860,403 age 1 equivalents) and alewife only comprising 1.3% (56,515 age 1 equivalents). The total future production foregone was estimated to be 905.47 kg, with alewife, rainbow smelt and round goby comprising 99% of the biomass. The production foregone of alewife and rainbow smelt are negligible when considering the biomass of each species available in Lake Ontario. For example, in 2006 MNR’s Lake Ontario Management Unit (LOMU) estimated an alewife biomass in Lake Ontario of 1650 MT. In 2009, the alewife population in Lake Ontario was 134 million year one- and older fish which translated to an estimated biomass of 5298 MT.

When considering recent commercial harvest estimates (suckers, brown bullhead, yellow perch, sunfish), losses in terms of economic value were considered negligible.

Results of the 2010-11 impingement data supported the use of Unit 4 as a surrogate (conservative estimate) for the other units (Units 1-3). However, due to existing data gaps, occasional sampling at a much lower intensity at Units 1-3 is still recommended. This is to ensure that any unforeseen systematic changes are not missed. Future impingement sampling should consider using Unit 4 (which impinges the most fish) as a surrogate for the entire station as a cost saving measure. Results from Unit 4 could be multiplied by four to provide an overall estimate of impingement.

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APPENDIX A

AGE ASSIGNMENT

APPENDIX A: AGE ASSIGNMENT

Ages were assigned by evaluating monthly impingement length-frequency information by species obtained from measurements of impinged fish provided by SENES. Length cut-offs by age for each species were based on information from available scientific studies as described below. With year-round length-frequency data at DNGS, ages were advanced +1 year during the month of annulus formation or spawning. For each of the targeted species, estimates of the percent impingement by age during each month were used to assignment monthly estimates of impingement to each age.

Alewife

Length-at-age results reported for Lake Ontario alewife (O'Gorman *et al*. 1997) were supplemented with age-length data from a Lake Michigan study (Madenjian *et al.* 2003), which indicated slower growth of fish in the former lake, likely due to diet.

Rainbow smelt

Aging data from DNGS impingement studies as well as for rainbow smelt of Lake Ontario (Walsh and Maloy 2008) were used to assign ages. The ages assigned using sectioned fin rays were used from the latter reference as they were shown to exhibit less bias than for ages assigned using otoliths.

Round goby

Age-length data from the Detroit River given in MacInnis and Corkum (2000) were referred to, but based on the sizes and ages observed at the Lake Ontario DNGS, growth was assumed to be greater at the latter site. In addition, the former gave lengths as standard lengths, which were converted to total lengths based on a formula found in FISHBASE (for round goby, TL = SL/0.848).

Sculpins:

No age-length information was found for spoonhead sculpin, but based on reported maximum sizes for it (~134 mm; Delisle and Van Vliet 1968) and slimy sculpin (~120 mm; McPhail and Lindsey 1970), growth rate was assumed to be relatively similar for these two fishes. Some sculpin were not identified to species in the DNGS impingement dataset, so these specimens could be either of these two sculpins. Average lengths at age for southern Lake Michigan slimy sculpin reported by Rottiers (1965) and given in Becker (1983) were used to assign ages to DNGS sculpins. An aggregated sculpin species monthly age-length table was prepared.

Other species

Ages of brown bullhead, pumpkinseed, and unidentified sunfish were estimated from information provided in Scott and Crossman (1973) and yellow perch from Becker (1983). Age and growth of Lake Erie emerald shiner reported by Flittner (1964) were used.

The other two species were more problematic due to a lack of regional information in the case of threespine stickleback and the relatively wide range of growth that occurs in adult white sucker. Based on age and growth and longevity information published by Jones and Hynes (1950) in England, Greenbank and Nelson (1959) in Alaska, and Reimchen (1990) in British Columbia, threespine stickleback from widely disparate areas appeared to exhibit similar age and growth characteristics, so their results were used.

Long life and slow growth, which depends upon location and many other environmental variables, characterizes many white sucker populations (Beamish 1973). Age and growth information given in Beamish (1973), Chen and Harvey (1995), and Vondracek (1977) were used to estimate the age of the 30-39 cm white sucker taken in the impingement sampling. Because the latter aged white sucker from a Great Lakes population (Green Bay, Lake Michigan), an age of 2+ was assigned to the one white sucker that was measured during the impingement sampling. Given results from the other two references, this age was plausible.

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APPENDIX B

UNCERTAINTY ANALYSIS

APPENDIX B: UNCERTAINTY ANALYSIS

EPA's Phase II §316(b) Rule requires that a facility seeking a site-specific determination based on benefits valuation also submit "an analysis of the effects of significant sources of uncertainty on the results of the study" [§125.95(b)(6)(iii)(C)]. Uncertainty refers to the lack of knowledge about measures and components that go into each element of the benefits valuation procedures. Under Phase II, the purpose of the uncertainty analysis is to make transparent all the underlying sources of uncertainty in the calculation of economic value such that the appropriate regulatory authority can independently determine whether the results have sufficient precision and accuracy to meet regulatory needs (USEPA 2004) and form sufficient basis for sound regulatory decisions. Since equivalent loss estimates form the basis upon which economic valuation is conducted, the purpose of this appendix is to evaluate the effects of uncertainty in key input parameters on the estimates of equivalent loss for DNGS.

USEPA (2000) identified the following minimum requirements applicable to most uncertainty analyses related to environmental regulations:

- To present the outcomes or conclusions based on expected or most plausible values;
- To provide descriptions of all known key assumptions, biases, and omissions;
- To perform sensitivity analysis on key assumptions; and
- To justify the assumptions used in the sensitivity analysis.

Uncertainty arises in assessments from three general sources: natural variation, uncertainty in model structure, and uncertainty in model parameters.

APPROACH

Key input parameters addressed in this section include:

- Natural mortality rate,
- Fishing mortality rate,
- Age of recruitment to the fishery, and
- Mean weight at beginning of each stage.

Two other key input parameters, annual impingement and age composition, were not addressed in this uncertainty analysis as reliable information on the uncertainty was unavailable from the historical studies.

Uncertainty for this assessment was addressed by two means. First, a sensitivity analysis was conducted on individual input parameters. Second, a Monte Carlo analysis was conducted to determine the likely overall uncertainty in the estimates of annual equivalent loss resulting from the current levels of uncertainty. The results of each of these analyses are provided below.

Sensitivity Analysis

A sensitivity analysis was conducted individually on each of the four input parameters listed above. Calculations of annual equivalent loss were made using the extreme values (i.e., maximum and minimum) for each parameter while holding all other parameters constant at their most probable values. The purpose of this sensitivity analysis was to determine the parameters for which the current levels of uncertainty have the greatest effect on each of the estimates.

Monte Carlo Analysis

Monte Carlo analysis was used to assess the overall uncertainty in the estimates of total annual equivalent loss based on the current levels of uncertainty in each of the four input parameters. For each of these parameters, random values were selected from a triangular distribution, wherein the maximum and minimum values for the distribution were set to the maximum and minimum values for each parameter described earlier and the mode of the distribution was set to the mid-point used as the best estimate for each parameter. Values for each parameter were randomly selected separately for each taxa and life stage and the Monte Carlo analysis was run using 1,000 iterations to define the resulting frequency distribution in annual estimates of equivalent loss measures.

RESULTS

The results of the sensitivity analysis demonstrate that model results for all Age 1 equivalents was most sensitive to uncertainty in estimates of natural mortality rates (Figure B-1). However for the other two model results, lost fishery yield and lost biomass were sensitive to both natural mortality rates and mean weight at the beginning of each stage. Compared to these two inputs, the effects of the other two input, fishing mortality rate and age of fishery vulnerability were relatively minor.

Results of the Monte Carlo analysis for each measure of equivalent loss are illustrated in Figure B-2. Overall, uncertainty in the estimates of lost fishery yield and lost biomass was relatively small compared to that of lost yield. Median difference was < 1 percent less than the most probable estimate for both lost fishery yield and lost biomass. Approximately, less than 10 percent of the Monte Carlo estimates of lost fishery yield and lost biomass were greater than 2 - 4 percent of the most probable estimate. Median difference for Age 1 equivalents was just 1 percent greater than the most probable while there was < 10 percent chance that the number of Age 1 equivalents was more than 11 percent greater than the most probable estimate.

Figure B-1 Estimate of the Range of Effects of Uncertainty in Each Input Parameter on Estimates of Annual Equivalent Loss at the Darlington Nuclear Generating Station

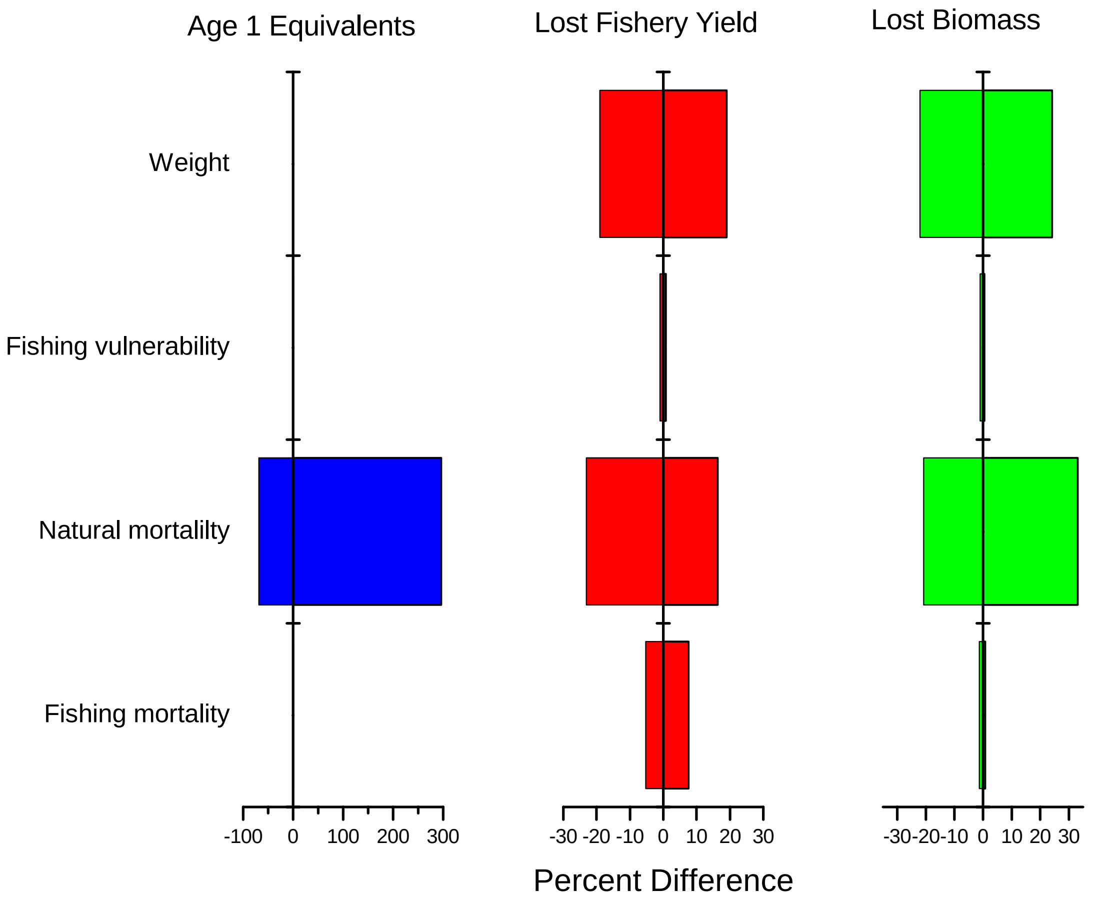

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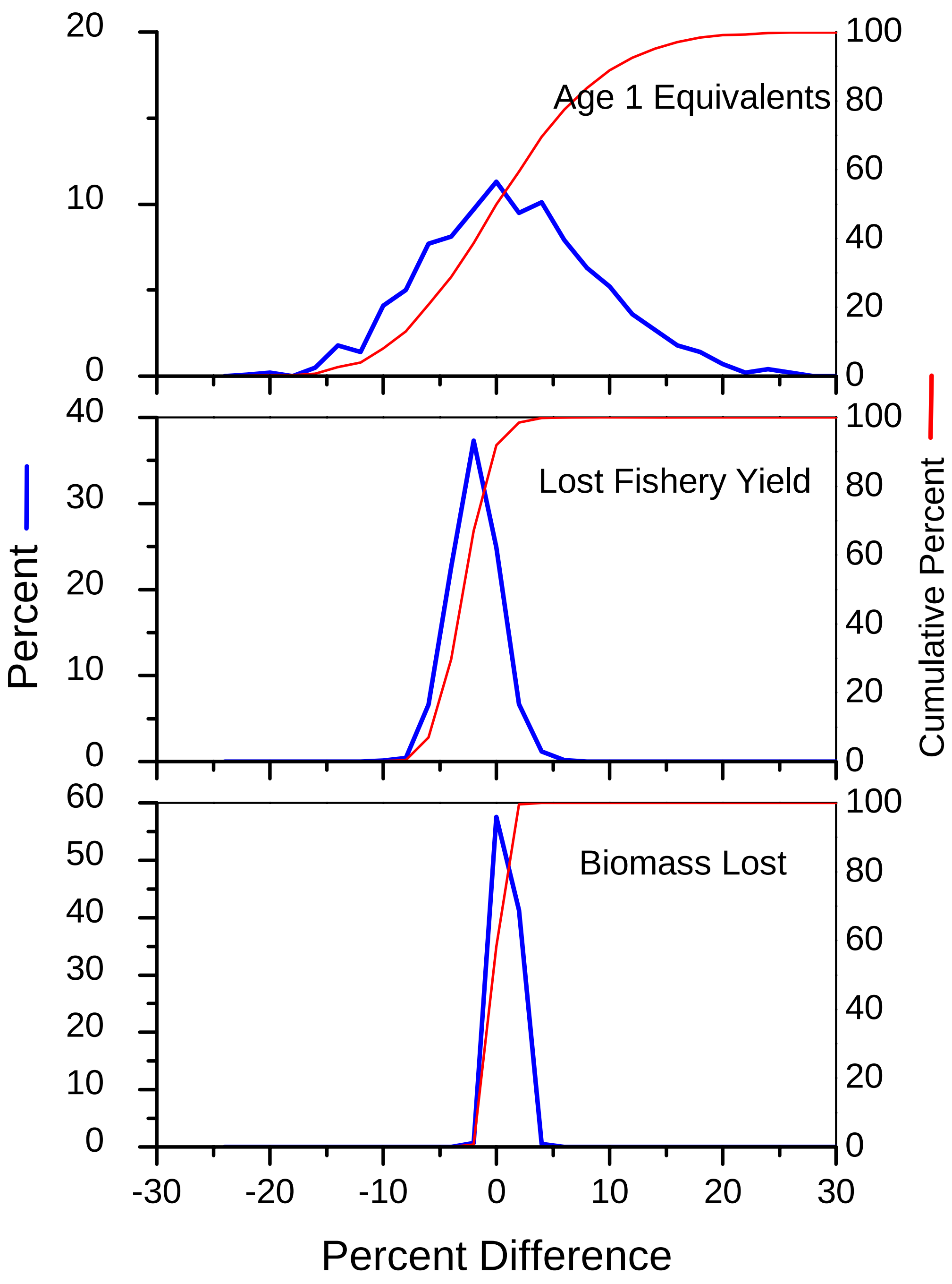
Figure B-2 Results of Monte Carlo Analysis of Uncertainty in Key Input Parameters on Estimates of Annual Equivalent Loss at the Darlington Nuclear Generating Station



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APPENDIX C

RAW DATA COLLECTED AT DNGS, MAY 4, 2010 – APRIL 26, 2011

Darlington Nuclear Generating Station																
Impingement Counts per 24-hour sampling event																
		Rainbow smelt	Spoonhead sculpin	Round goby	Alewife	White sucker	Pumpkinseed	Smallmouth bass	Emerald shiner	Cottus sp	Slimy sculpin	Threespine stickleback	American eel	Yellow perch	Unid sunfish	Brown bullhead
Date	Unit	RD	RD	Recent dead	RD	RD	RD	RD	RD	RD	RD	RD	RD	RD	RD	RD
5/4/2010	2	7	8	527	0	0	0	0	0	0	0	0	0	0	0	0
5/4/2010	3	4	0	1	0	0	0	0	0	0	0	0	0	0	0	0
5/7/2010	2	3	7	451	0	0	0	0	0	0	0	0	0	0	0	0
5/7/2010	3	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0
5/11/2010	2	9	6	312	1	0	0	0	0	0	0	0	0	0	0	0
5/11/2010	3	5	1	1	0	0	0	0	0	0	0	0	0	0	0	0
5/14/2010	2	7	2	160	0	0	0	0	0	0	0	0	0	0	0	0
5/14/2010	3	1	0	14	1	0	0	0	0	0	0	0	0	0	0	0
5/18/2010	2	13	6	297	0	0	0	0	0	0	0	0	0	0	0	0
5/18/2010	3	12	0	12	0	0	0	0	0	0	0	0	0	0	0	0
5/21/2010	2	18	4	465	1	0	0	0	0	0	0	0	0	0	0	0
5/21/2010	3	5	0	5	0	0	0	0	0	0	0	0	0	0	0	0
5/25/2010	2	7	17	732	5	0	0	0	0	0	0	0	0	0	0	0
5/25/2010	3	25	1	6	4	0	0	0	0	0	0	0	0	0	0	0
5/28/2010	2	30	10	40	45	0	0	0	0	0	0	0	0	0	0	0
5/28/2010	3	26	0	18	14	0	0	0	0	0	0	0	0	0	0	0
6/2/2010	2	30	0	240	10	0	0	0	0	0	0	0	0	0	0	0
6/2/2010	3	8	2	10	4	0	0	0	0	0	0	0	0	0	0	0
6/4/2010	2	0	0	380	20	0	0	0	0	0	0	0	0	0	0	0
6/4/2010	3	2	0	2	1	0	0	0	0	0	0	0	0	0	0	0
6/8/2010	2	40	40	430	20	0	0	0	0	0	0	0	0	0	0	0
6/8/2010	3	0	0	3	2	0	0	0	0	0	0	0	0	0	0	0
6/11/2010	2	0	0	50	100	0	0	0	0	0	0	0	0	0	0	0
6/11/2010	3	2	0	6	2	0	0	0	0	0	0	0	0	0	0	0
6/15/2010	2	5	0	60	15	0	0	0	0	0	0	0	0	0	0	0
6/15/2010	3	5	0	20	0	0	0	0	0	0	0	0	0	0	0	0
6/18/2010	2	5	0	15	15	0	0	0	0	0	0	0	0	0	0	0
6/18/2010	3	6	2	20	6	0	0	0	0	0	0	0	0	0	0	0
6/22/2010	2	5	0	60	350	0	0	0	0	0	0	0	0	0	0	0
6/22/2010	3	3	1	4	15	0	0	0	0	0	0	0	0	0	0	0
6/25/2010	2	10	0	245	40	0	0	0	0	0	0	0	0	0	0	0
6/25/2010	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6/29/2010	2	0	5	105	0	0	0	0	0	0	0	0	0	0	0	0
6/29/2010	3	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0
7/2/2010	2	20	0	110	9960	0	0	0	0	0	0	0	0	0	0	0
7/2/2010	3	1	0	3	3	0	0	0	0	0	0	0	0	0	0	0
7/6/2010	2	4	12	48	480	0	0	0	0	0	0	0	0	0	0	0
7/6/2010	3	8	0	2	0	0	0	0	0	0	0	0	0	0	0	0
7/9/2010	2	25	0	75	95	0	0	0	0	0	0	0	0	0	0	0
7/9/2010	3	5	0	15	45	0	0	0	0	0	0	0	0	0	0	0
7/13/2010	2	0	5	86	19	0	0	0	0	0	0	0	0	0	0	0
7/13/2010	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Darlington Nuclear Generating Station

Impingement Counts per 24-hour sampling event

		Rainbow smelt	Spoonhead sculpin	Round goby	Alewife	White sucker	Pumpkinseed	Smallmouth bass	Emerald shiner	Cottus sp	Slimy sculpin	Threespine stickleback	American eel	Yellow perch	Unid sunfish	Brown bullhead
Date	Unit	RD	RD	Recent dead	RD	RD	RD	RD	RD	RD	RD	RD	RD	RD	RD	RD
7/16/2010	3	0	8	4	0	0	0	0	0	0	0	0	0	0	0	0
7/16/2010	4	17	17	689	94	6	6	0	0	0	0	0	0	0	0	0
7/20/2010	2	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0
7/20/2010	3	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0
7/20/2010	4	47	7	1007	280	0	0	0	0	0	0	0	0	0	0	0
7/23/2010	2	2	0	2	6	0	0	0	0	0	0	0	0	0	0	0
7/23/2010	3	0	0	2	4	0	0	0	0	0	0	0	0	0	0	0
7/23/2010	4	30	0	540	210	0	0	0	0	0	0	0	0	0	0	0
7/27/2010	2	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0
7/27/2010	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7/27/2010	4	10	0	660	45	0	0	0	0	0	0	0	0	0	0	0
7/30/2010	2	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0
7/30/2010	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7/30/2010	4	35	0	1082	100	0	0	0	0	0	0	0	0	0	0	0
8/3/2010	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8/3/2010	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8/3/2010	4	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0
8/10/2010	2	0	0	34	24	0	0	0	0	0	0	0	0	0	0	0
8/10/2010	3	10	5	15	60	0	0	0	0	0	0	0	0	0	0	0
8/10/2010	4	65	0	785	400	0	0	0	0	0	0	0	0	0	0	0
8/17/2010	2	0	0	125	0	0	0	0	0	0	0	0	0	0	0	0
8/17/2010	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8/17/2010	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8/24/2010	2	0	0	25	0	0	0	0	0	0	0	0	0	0	0	0
8/24/2010	3	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0
8/24/2010	4	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0
8/31/2010	2	2	0	56	6	0	0	0	0	0	0	0	0	0	0	0
8/31/2010	3	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
8/31/2010	4	32	0	12	36	0	0	0	0	0	0	0	0	0	0	0
9/10/2010	3	0	0	0	155	0	0	0	0	0	0	0	0	0	0	0
9/14/2010	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9/14/2010	3	1	0	0	15	0	0	0	0	0	0	0	0	0	0	0
9/14/2010	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9/21/2010	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9/21/2010	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9/21/2010	4	0	0	45	25	0	0	0	0	0	0	0	0	0	0	0
9/28/2010	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
9/28/2010	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9/28/2010	4	0	0	25	10	0	0	0	0	0	0	0	0	0	0	0
10/5/2010	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10/5/2010	4	2	0	2	20	0	0	0	0	0	0	0	0	0	0	0
10/15/2010	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Darlington Nuclear Generating Station																
Impingement Counts per 24-hour sampling event																
		Rainbow smelt	Spoonhead sculpin	Round goby	Alewife	White sucker	Pumpkinseed	Smallmouth bass	Emerald shiner	Cottus sp	Slimy sculpin	Threespine stickleback	American eel	Yellow perch	Unid sunfish	Brown bullhead
Date	Unit	RD	RD	Recent dead	RD	RD	RD	RD	RD	RD	RD	RD	RD	RD	RD	RD
10/15/2010	4	0	0	30	6	0	0	0	0	0	0	0	0	0	0	0
10/19/2010	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10/19/2010	4	5	0	0	150	0	0	0	0	0	0	0	0	0	0	0
10/26/2010	4	0	0	204	135	0	0	0	0	0	0	0	0	0	0	0
11/2/2010	4	2	0	86	32	0	0	0	0	0	0	0	0	0	0	0
11/9/2010	4	0	0	54	27	0	0	0	0	0	0	0	0	0	0	0
11/16/2010	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11/16/2010	4	5	0	35	10	0	0	0	0	0	0	0	0	0	0	0
11/23/2010	4	8	0	16	16	0	0	0	0	0	0	0	0	0	0	0
12/7/2010	2	1	0	5	0	0	0	0	0	0	0	0	0	0	0	0
12/7/2010	4	23	0	85	3246	0	0	0	0	0	0	0	0	0	0	0
12/14/2010	4	6	0	92	78	0	2	0	1	0	0	0	0	0	0	0
12/21/2010	4	4	0	165	98	0	0	0	1	0	0	0	0	0	0	0
12/23/2010	4	2	0	370	172	0	0	0	0	0	0	0	0	0	0	0
1/7/2011	4	0	0	246	42	0	0	0	0	0	0	0	0	0	0	0
1/11/2011	4	6	0	291	42	0	0	0	0	0	0	0	0	0	0	0
1/18/2011	4	0	0	109	8	0	0	0	0	0	0	0	0	0	0	0
1/25/2011	4	0	0	62	16	0	0	0	0	0	0	0	0	0	0	0
2/1/2011	2	0	2	46	0	0	0	0	0	0	0	0	0	0	0	0
2/1/2011	3	0	0	16	4	0	0	0	0	0	0	0	0	0	0	0
2/1/2011	4	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0
2/4/2011	3	0	0	76	0	0	0	0	0	0	0	0	0	0	0	0
2/4/2011	4	0	30	143	0	0	0	0	0	20	0	0	0	0	0	0
2/8/2011	3	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0
2/8/2011	4	0	1	36	0	0	0	0	1	0	0	0	0	0	0	0
2/11/2011	3	0	0	32	0	0	0	0	0	0	0	0	0	0	0	0
2/11/2011	4	1	0	54	0	1	0	0	0	0	0	0	0	0	0	0
2/15/2011	2	0	1	47	0	0	0	0	0	0	1	0	0	0	1	0
2/15/2011	3	0	0	22	0	0	0	0	0	0	1	0	0	0	0	0
2/15/2011	4	4	0	67	0	0	0	0	0	0	0	1	0	0	0	0
2/18/2011	2	0	0	44	0	0	0	0	0	0	1	0	0	0	0	0
2/18/2011	3	0	0	43	0	0	0	0	0	0	0	0	0	0	0	0
2/18/2011	4	1	0	82	0	0	0	0	0	0	0	0	0	0	0	0
2/22/2011	2	0	0	37	0	0	0	0	0	0	0	0	0	0	0	0
2/22/2011	3	0	0	38	0	0	0	0	0	0	0	0	0	0	0	0
2/22/2011	4	0	0	30	0	0	0	0	0	0	0	0	1	0	0	0
2/25/2011	2	0	0	35	0	0	0	0	0	0	0	0	0	0	0	0
2/25/2011	3	0	0	15	0	0	0	0	0	0	0	0	0	1	0	0
2/25/2011	4	0	0	53	1	0	0	0	0	0	0	0	0	0	0	0
3/1/2011	2	0	0	72	0	0	0	0	0	0	0	0	0	0	0	0
3/1/2011	3	0	1	14	0	0	0	0	0	0	0	0	0	0	0	0
3/1/2011	4	0	0	24	0	0	0	0	0	0	0	0	0	0	0	0

Darlington Nuclear Generating Station																
Impingement Counts per 24-hour sampling event																
		Rainbow smelt	Spoonhead sculpin	Round goby	Alewife	White sucker	Pumpkinseed	Smallmouth bass	Emerald shiner	Cottus sp	Slimy sculpin	Threespine stickleback	American eel	Yellow perch	Unid sunfish	Brown bullhead
Date	Unit	RD	RD	Recent dead	RD	RD	RD	RD	RD	RD	RD	RD	RD	RD	RD	RD
3/4/2011	2	0	0	26	0	0	0	0	0	0	0	0	0	0	0	0
3/4/2011	4	0	1	31	0	0	0	0	0	0	0	0	0	0	0	0
3/8/2011	2	0	2	35	0	0	0	0	0	1	0	0	0	0	0	0
3/8/2011	3	1	0	25	0	0	0	0	0	0	0	0	0	0	0	0
3/8/2011	4	0	1	37	0	0	0	0	0	0	0	0	0	0	0	0
3/11/2011	2	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0
3/11/2011	3	1	0	12	0	0	0	0	0	0	0	0	0	0	0	0
3/11/2011	4	1	0	122	4	0	0	0	3	0	1	0	0	0	0	0
3/15/2011	2	0	1	53	0	0	0	0	0	0	1	0	0	0	0	1
3/15/2011	3	0	0	23	0	0	0	0	0	0	1	0	0	0	0	0
3/15/2011	4	0	2	18	0	0	0	0	0	0	2	0	0	0	0	0
3/18/2011	2	0	0	79	0	0	0	0	0	0	0	0	0	0	0	0
3/18/2011	3	0	0	24	0	0	0	0	0	0	0	0	0	0	0	0
3/18/2011	4	0	1	131	0	0	0	0	1	0	1	0	0	0	0	0
3/22/2011	2	0	0	139	0	0	0	0	0	0	1	0	0	0	0	0
3/22/2011	3	0	0	20	0	0	0	0	0	0	1	0	0	0	0	0
3/22/2011	4	1	1	159	0	0	0	0	0	0	0	0	0	0	0	0
3/25/2011	1	0	4	245	0	0	0	0	1	0	2	0	0	0	0	0
3/25/2011	2	0	1	64	0	0	0	0	0	0	0	0	0	0	0	0
3/25/2011	3	0	0	65	0	0	0	0	0	0	0	0	0	0	0	0
3/25/2011	4	2	1	304	0	0	0	0	0	0	3	0	0	0	0	0
3/29/2011	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
3/29/2011	2	0	0	19	0	0	0	0	0	0	0	0	0	0	0	0
3/29/2011	3	0	0	74	0	0	0	0	0	0	0	0	0	0	0	0
3/29/2011	4	0	6	286	0	0	0	0	0	0	2	0	0	0	0	0
4/5/2011	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4/5/2011	2	0	0	96	0	0	0	0	0	0	0	0	0	0	0	0
4/5/2011	3	0	2	150	0	0	0	0	0	0	0	0	0	0	0	0
4/5/2011	4	0	0	260	0	0	0	0	0	0	0	0	0	0	0	0
4/12/2011	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4/12/2011	2	0	1	263	0	0	0	0	0	0	1	0	0	1	0	0
4/12/2011	3	0	0	297	0	0	0	0	0	0	0	0	0	0	0	0
4/12/2011	4	1	3	312	0	0	0	0	0	0	0	0	0	0	0	0
4/19/2011	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4/19/2011	2	0	2	422	0	0	0	0	0	0	2	0	0	0	0	0
4/19/2011	3	0	0	303	2	0	0	0	0	0	0	0	0	0	0	0
4/19/2011	4	1	4	387	0	0	0	0	0	0	2	0	0	0	0	0
4/26/2011	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4/26/2011	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4/26/2011	3	1	1	314	0	0	0	0	0	0	1	0	0	0	0	0
4/26/2011	4	4	0	777	0	0	0	0	0	0	0	0	0	0	0	0