EFFECTS OF WATER FLOW MANAGEMENT REGIMES IN THE TRENT RIVER ON CHANNEL DARTER, *Percina copelandi,* SPAWNING ACTIVITIES

*Channel Darter (*Percina copelandi*)*

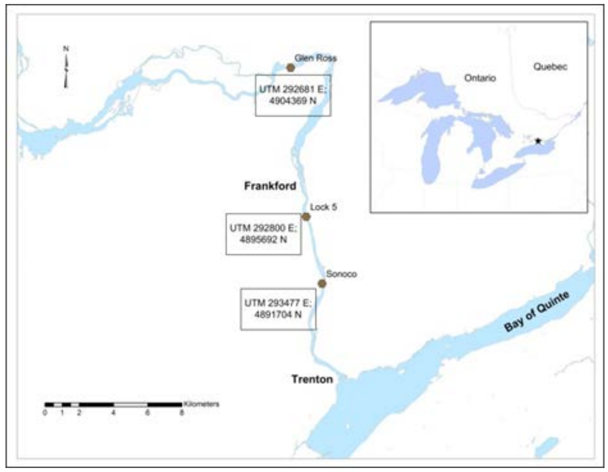

Figure 1. Distribution of Channel Darter study sites along the Trent River.

Context

Water levels in the Trent River, Ontario are managed by the staff of the Trent-Severn Waterway (Parks Canada Agency). There have been observations of dewatering events in areas within the Trent River resulting from current water management practices. Channel Darter is known to inhabit the Trent River and is currently listed as Threatened under Schedule 1 of the Species at Risk Act *(SARA). A recovery strategy for Channel Darter has been published and the area within which Critical Habitat is identified has been delineated from Glen Ross to Trenton, Ontario. Areas delineated as Channel Darter critical habitat have been observed to undergo minor to complete dewatering and there is concern that water flows in this system are not sufficient to support Channel Darter spawning activities.*

Fisheries and Oceans Canada (DFO) Species at Risk Program has requested Science advice on the impacts of dewatering in the Trent River on Channel Darter, minimum flow requirements for spawning, and alternatives and mitigation measures related to flow management to minimize impacts on Channel Darter.

This Science Advisory Report is from the January 15, 2016 regional peer review of the Effects of water flow management regimes in the Trent River on Channel Darter spawning activities. Additional publications from this meeting will be posted on the [DFO Science Advisory Schedule] as they become available.

SUMMARY

- Channel Darter critical habitat has been identified in the Trent River system in Ontario, between Glen Ross and Trenton. To evaluate impacts of river discharge on Channel Darter habitat, a study was undertaken at Glen Ross, Lock 5, and Sonoco sites.
- Channel Darter is generally associated with shallow water depths (0.1 - 0.4 m), water velocities greater than 0.2 m/s, and coarse river bed material (gravel, cobble, boulder). Spawning sites were identified at each site. Spawning and egg incubation generally occurs between May and mid-July in the Trent River.
- A single Trent River flow recommendation cannot be made as areas of Channel Darter habitat along the Trent River respond differently to changes in river discharge. Therefore, an adaptive management approach is recommended.
- An adaptive management plan should be developed using the recommended targets. Monitoring should be undertaken, impacts assessed, and targets reassessed to protect Channel Darter spawning.
- At Glen Ross, river discharge should not go below 30 m^3/s during the spawning period.
- At Lock 5, the greatest improvements in habitat suitability occurs at spill discharges between 5 and 7.5 m^3/s, therefore, these daily discharges should be maintained from the eastern dam gate during the spawning period.
- Under low flow conditions, flow should be directed over Channel Darter spawning habitat during the spawning period to mitigate impacts.
- Sources of uncertainty include habitat preference inferred from adult Channel Darter, population status, transferability of habitat suitability curves between sites, accuracy of river discharge estimates, amount of dam leakage, and impacts other than flow on Channel Darter populations and spawning activities.
- Mitigation measures to reduce impacts on Channel Darter spawning, other than minimum flows, should include directing flows over Channel Darter habitat during low-flow years, limiting maintenance to times that do not coincide with Channel Darter spawning or egg incubation, avoiding large flow reductions during the spawning period, backing up water to maintain elevations where possible, and investigating the potential to recycle water to increase or maintain flow.
- Research and monitoring should include Channel Darter population monitoring, Lock 5 bed topography, habitat selection studies, evaluation and adjustments to the River2D model, and evaluating the relationship between Channel Darter populations and Composite Suitability Index (CSI).

BACKGROUND

The Channel Darter, *Percina copelandi*, is a small benthic fish, listed as Threatened under Federal *Species at Risk Act* (SARA) and under the Ontario *Endangered Species Act* (ESA). Channel Darter is known to use shallow habitats with moderate current along river edges, riffles or at shoals. These habitats are strongly affected by changes in river discharge. Degradation or loss of preferred habitat is considered a threat to this species (COSEWIC 2002, DFO 2010).

Channel Darter in the Trent River in Ontario is found downstream of dams used to manage flow for navigation, flood control, and hydropower generation. Shoals used by Channel Darter have been observed to be temporarily de-watered during the spawning period (DFO 2013). The 22 km stretch of the Trent River from Glen Ross to Trenton, Ontario (Figure 1) has been identified as an area containing critical habitat for Channel Darter (DFO 2013).

An instream flow needs assessment was planned jointly by Parks Canada Agency (PCA), Fisheries and Oceans Canada (DFO), and Ontario Ministry of Natural Resources and Forestry (OMNRF) for this portion of the Trent-Severn Waterway (TSW) to recommend minimum flow levels during the Channel Darter spawning period.

The objectives of this Science Peer Review were to provide advice on flow management regimes, in the Trent River system, to ensure that flows are sufficient for Channel Darter spawning and specifically, to:

1) determine the minimum flow required to ensure that Channel Darter successfully spawn in the Trent River;
2) provide alternatives to the current flow management regime that would minimize the impacts to Channel Darter in the Trent River; and,
3) provide additional mitigation measures that could be implemented to minimize the effects of the current flow management regimes in areas known to be occupied by Channel Darter.

This Science Advisory Report summarizes the conclusions and advice from the peer-review meeting, held in Burlington, Ontario on January 15, 2016. The research document (Reid et al. 2016), combining field data collection and habitat modelling, provides the technical details and full list of references to support the advice. The meeting discussions will be documented in the Proceedings (DFO 2016).

Trent-Severn Waterway Flow Regulation

The Trent-Severn Waterway (TSW) is a 386 km series of lakes, river channels and artificial canal cuts from Port Severn on Georgian Bay to Trenton on the Bay of Quinte, Lake Ontario. Water levels and flows in this system are managed by Parks Canada Agency. The TSW was built between 1879 and 1920. The TSW works co-operatively with the OMNRF and DFO to protect fish spawning areas and other wildlife habitat, and with Conservation Authorities to reduce flooding. Several Conservation Authorities operate dams within this system. The Waterway also keeps in daily contact with Ontario Power Generation Inc. and other public utilities and private interests that operate and maintain generating stations within the waterway.

This waterway is made up of the Trent and Severn river watersheds and includes approximately 160 dams and 26 hydroelectric power stations. The Severn River watershed drains into Georgian Bay. The Trent River watershed flowing into Lake Ontario includes 218 lakes in the Haliburton Highlands region of which 37 are controlled by Waterway dams. The basin drains more than 12,000 km^2 of central Ontario, making it the largest river in southern Ontario.

Generally, the reservoir lakes in the Haliburton Highlands are lowered during the fall and winter seasons by increasing their outflows to prepare for the spring snowmelt and reduce the threat of high water and ice damage. During the spring (March, April, May), flow management focuses on flood mitigation while storing water for the summer. During the summer, the main focus is to preserve water levels and flows for summer navigation. Water from the reservoir lakes is gradually released during the summer. Minimum flows are maintained to sustain water quality.

The dams maintained by TSW include dams that are opened and closed mechanically with either vertical or radial gates, dams that are adjusted by adding or removing stoplogs, smaller structures that cannot be adjusted, and kilometres of constructed canals. All of the dams work together as a system and the lower portion of the river is the combined product of all of these operations. There are five dams in the section of the river from Glen Ross to Sonoco. There is limited capacity to store water in the system to mitigate impacts on very low flow years.

ASSESSMENT

A study was undertaken to inform setting minimum flow levels for the Trent River during the Channel Darter spawning period. Glen Ross, Lock 5, and Sonoco were the three sites chosen for the study. The Glen Ross site (Figure 2) includes a dam but does not include a hydro-electric facility, whereas, the sites located downstream of Lock 5 (Figure 3) and Sonoco (Figure 4) are both subject to water diversion from hydropower generating station spillways in addition to dams. To describe the relationship between river discharge and Channel Darter habitat conditions, monitoring stations were established at these three sites. Channel Darter spawning occurs at all three sites.

From May to October, Channel Darter are found in the shallow habitats along the Trent River. When temperatures drop in the fall, they move into deeper waters. The habitats studied were known areas where good numbers of Channel Darter could be expected to be found and, therefore, studied. At all sites, the areas studied were a sample of all the habitats available to Channel Darter. At the Lock 5 site, there was a limited amount of additional suitable habitat outside of where sampling occurred, while at Glen Ross there was much more. Coker and Portt (2012) identified Channel Darter spawning habitat in each of the river runs.

Spawning activity is triggered by the warming of water temperatures that occur in mid-May. However, the occurrence of high-flow events (e.g., floods after a big storm) can disrupt and delay the timing of spawning of riverine fishes in general.

Field sampling was completed at the three sites to determine the relationship between river discharge and Channel Darter habitat conditions in terms of suitability, availability, and/or quality. Systematic transect sampling was completed at each site to describe habitat availability and included physical habitat data [water depth (m), mid-water column water velocity (m/s), and bed material composition (%)].

Channel Darter were collected at Glen Ross and below the Lock 5 dam using a backpack-electrofisher between May 31 and June 29, 2012. This corresponds to observations of spawning readiness from previous studies. At each site, Channel Darter collection points were marked and physical habitat characteristics were measured. Total length, identification of sex, and spawning readiness (based on differences in colouration and the release of eggs or milt excluded under slight pressure) were recorded for each Channel Darter collected.

Figure 2. Aerial photo of the Glen Ross study reach with the dam and Channel Darter habitat study area indicated.

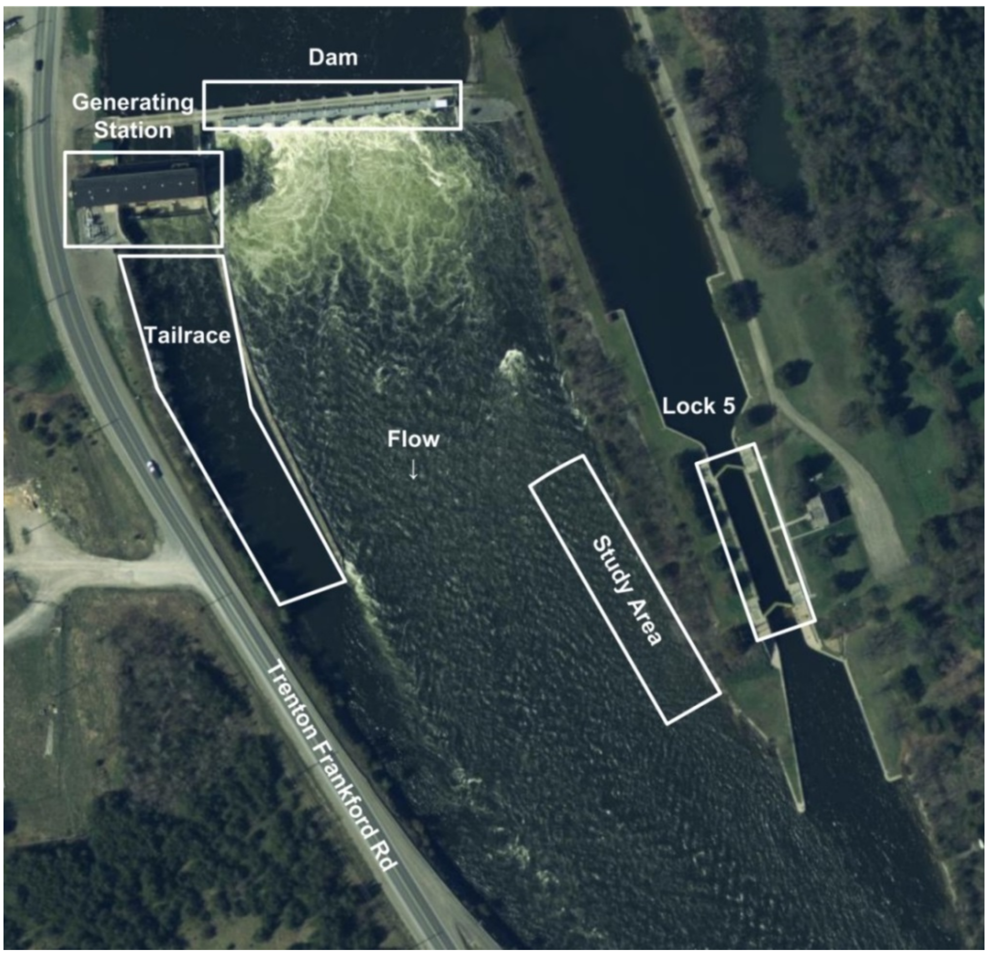

Figure 3. Aerial photo of the Lock 5 study reach with the lock, dam, Ontario Power Generation Station, and Channel Darter habitat study area indicated. Lock 4 is located approximately 2.5 km downstream.

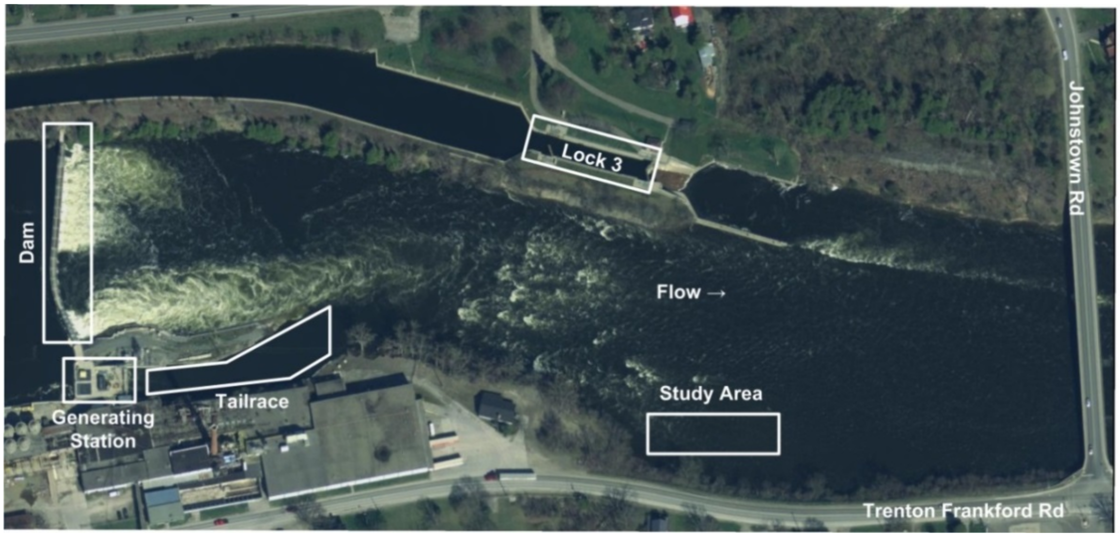

Figure 4. Aerial photo of the Sonoco study reach with the lock, dam, Sonoco Generating Station, and Channel Darter habitat study area indicated.

Habitat Suitability Modelling

Using the data collected during the field studies at Glen Ross and Lock 5, habitat suitability curves, which translate hydraulic and structural elements of rivers into indices of habitat quality, were developed for water depth and water velocity. Habitat preferences for different bed material (i.e., substrate) compositions have been reported for Channel Darter and other darter species. However, substrate suitability curves were not constructed as there were large differences in bed material between the Glen Ross and Lock 5 sites, and the potential transferability of curves was considered poor.

Modeling was conducted using a Bayesian approach to determine resource use in proportion to availability at site. These analyses were conducted in OpenBugs (version 3.2.3) using Markov chain Monte Carlo algorithms (two chains, 100,000 iterations with a 10,000 iteration burn-in period). For detailed methodology see Reid et al. (2016).

Glen Ross

From May 31 to June 26, 2012, 121 Channel Darter were collected below the dam at Glen Ross. Channel Darter spawning habitat at Glen Ross is located downstream of the dam on the southern bank of the river (Figure 2). Over the sampling period, 19 spawning-ready individuals (7♀ and 12♂) were collected. Channel Darter captures were generally associated with shallow water depths (0.1 - 0.3 m), water velocities greater than 0.2 m/s, and gravel and cobble substrates.

Habitat suitability at Glen Ross was predicted to improve rapidly as water velocities increased from zero, and to be greatest at water depths between 0.1 and 0.4 m.

Lock 5

From June 4 to June 25, 2012, 127 Channel Darter were collected below the Lock 5 dam. The Channel Darter spawning habitat is located downstream of the dam on the shoal along the eastern bank, opposite the generating station tailrace (Figure 3). Seven spawning-ready individuals (1 ♀ and 6 ♂) were collected during sampling. Channel Darter captures were generally associated with shallow to moderate water depths (0.1 - 0.4 m), low water velocities (<0.1 m/s), and cobble and boulder substrates.

Channel Darter habitat suitability at Lock 5 was predicted to improve as water velocities increase from zero, and to be greatest at water depths between 0.3 and 0.6 m.

Sonoco

Sampling for Channel Darter did not occur at Sonoco, therefore, summary information on numbers and location of fish collected are not available for this site. Sampling at this site was completed to inform the discharge habitat modelling.

Channel Darter spawning habitat at the Sonoco site is located downstream of the dam on the western bank of the river, below the generating station tailrace (Figure 4).

Discharge-Habitat Models

Regression relationships were developed to relate daily river discharge to mean water depth, mean water velocity, and a composite habitat suitability index (CSI) score for the three sites. Relationships differed among the three sites (Figure 5).

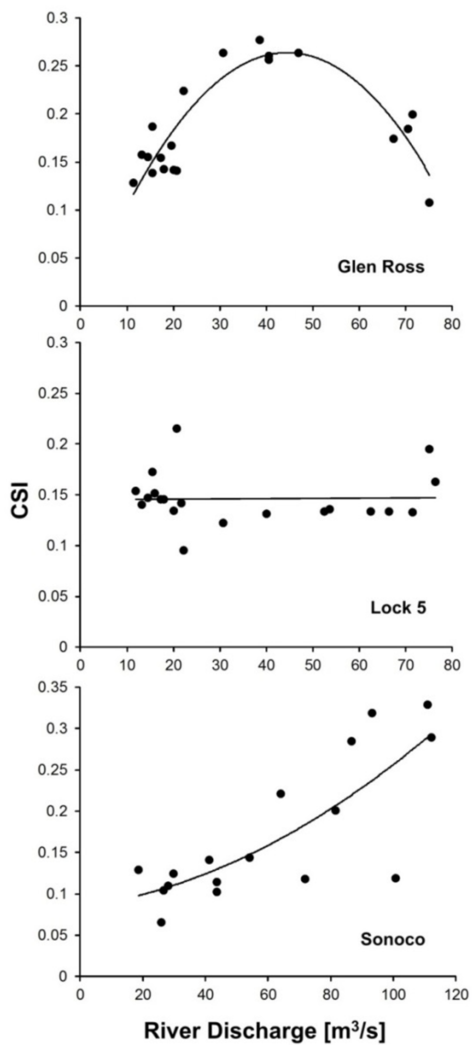

Figure 5. Relationships between Trent River discharge and Channel Darter habitat suitability (based on a composite suitability index, CSI) at three monitoring sites. Trend lines are provided to aid interpretation.

At Glen Ross, water depth and velocity were significantly and positively correlated to discharge. At Lock 5, discharge was not a significant predictor of water depth or water velocity. At Sonoco, there was a significant positive relationship between discharge and water velocity, but not between discharge and water depth (for detailed information see Reid et al. (2016)).

At Glen Ross, habitat suitability improved as discharge increased from 10 to 40 m^3/s, but declined above 50 m^3/s. Glen Ross and Lock 5 CSI scores were similar when discharge was ≤ 20 m^3/s. At Lock 5, there was no change in suitable habitat as discharge increased. At Sonoco, habitat suitability generally improved in a linear fashion as discharge increased above 20 m^3/s. The highest Sonoco CSI scores were associated with river discharges (>80 m^3/s), higher than present when Glen Ross and Lock 5 were sampled in 2012.

River2d Modelling

A two-dimensional hydrodynamic model, River2D, was used to predict water depths and velocities at a Channel Darter shoal along the east bank downstream of the Lock 5 dam. Field surveys were completed to collect the data necessary for input into River2D and included bathymetric and topographic surveys, collection of low altitude drone aerial imagery, discharge measurements, water depth and velocity measurements. The model was calibrated and validated by matching modelled water depths and velocities to field-measured water depths and velocities. Model simulations examined the effects of increasing the amount of water released from the eastern-most dam spill gate and different downstream water surface elevations. For detailed methodology see Reid et al. (2016).

Water depth, water velocity, and habitat suitability downstream of the Lock 5 dam at the Channel Darter habitat were predicted to be strongly influenced by river discharge, the amount of water released through the eastern-most gate (spill discharge) and downstream water elevation. River2D model output predicted that most improvements in habitat suitability would occur with spill discharges between 5 and 7.5 m^3/s (Figures 6 and 7). There is additional gain in habitat suitability above these flows, but it is incremental.

Sources of Uncertainty

A key assumption of the study was that the habitat preferences inferred from adult Channel Darter are representative of conditions required for successful spawning and egg incubation. This needs to be confirmed.

The relationship between population size and habitat suitability of Channel Darter in the Trent River is unknown.

Spawning triggers in Channel Darter can be interrupted or delayed by stochastic events so the spawning period is based on approximate dates.

Channel Darter populations and habitat are not limited to the three sites studied in the stretch of river between Glen Ross and Trenton. How recommendations will impact these other sites is unknown.

The interpretation of River2D water depth and velocity predictions was based on habitat suitability curves developed from a single site (Glen Ross) and field season (2012). The transferability of suitability curves to other Trent River sites is unknown.

River discharge estimates were back-calculations from energy production rather than being measured directly. The accuracy of the estimates was unknown and may be poor given the age of the Lock 5 facility, which was constructed in 1913.

The amount of leakage at each of the locations is unknown so advice is based on total flow.

The habitat suitability index does not consider aspects other than habitat that may influence the population and spawning success (e.g., non-indigenous species).

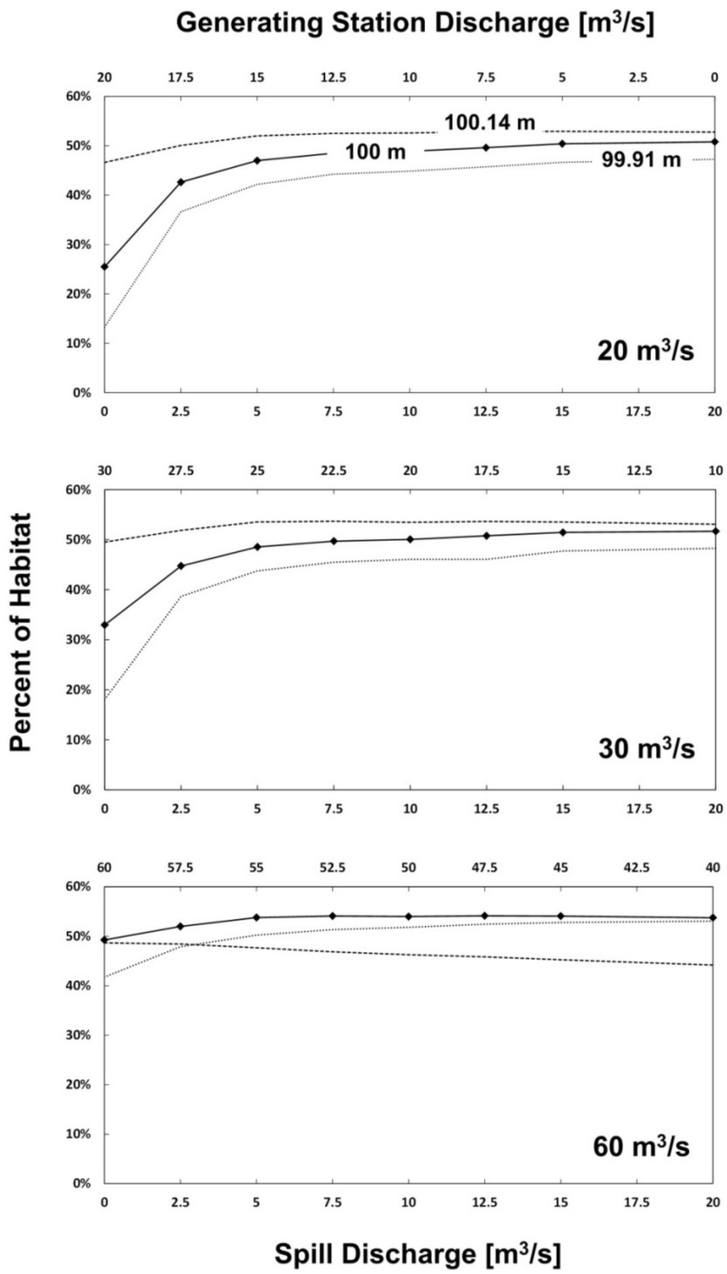

Figure 6. Availability of suitable water depths (0.1 to 0.3 m) at the Lock 5 Channel Darter shoal at different river discharges, gate spill discharges, and downstream water elevations (grey lines 99.91 m, black lines 100 m, dotted lines 100.14 m). Water depths were predicted using the River2D model.

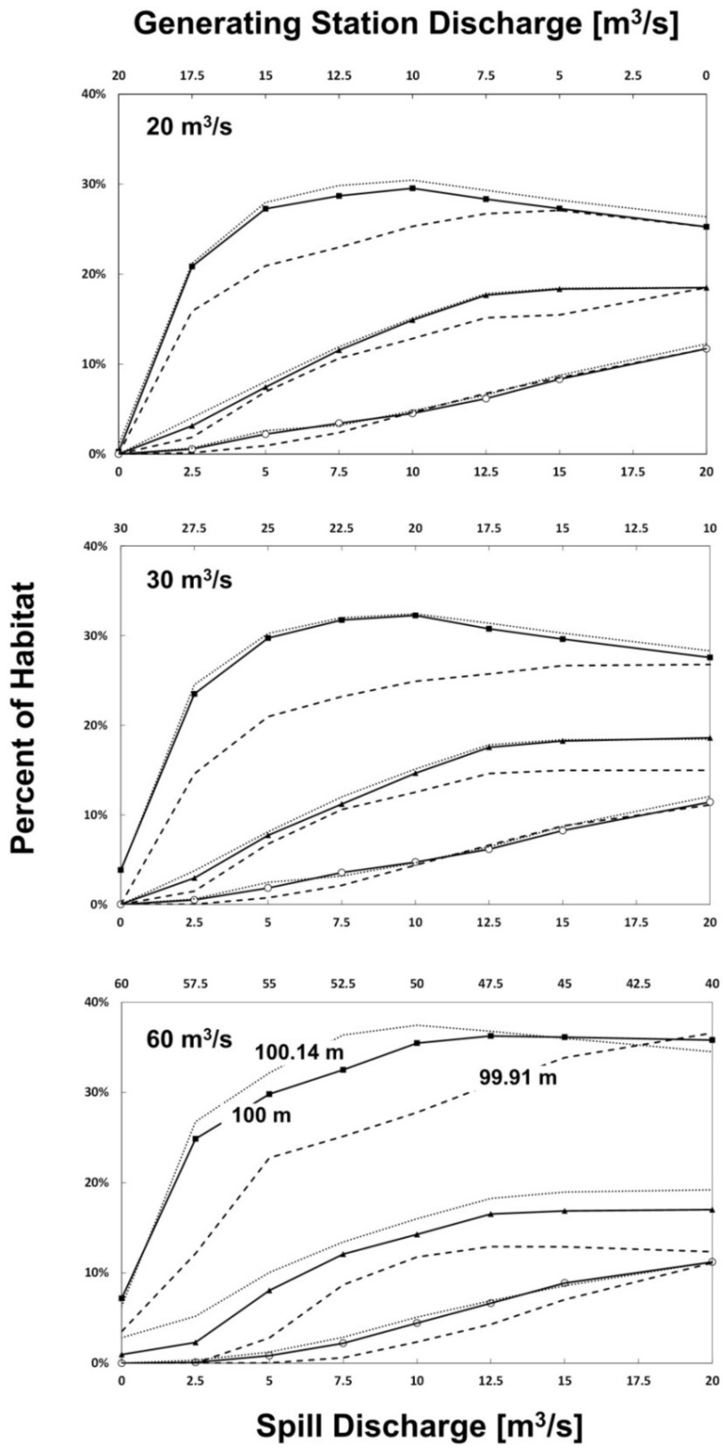

Figure 7. Water velocities (■ = 0.21–0.4 m/s; ▲= 0.41-0.6 m/s; ○ = 0.61-0.8 m/s) at the Lock 5 Channel Darter shoal at different river discharges, gate spill discharges, and downstream water elevations (dotted lines 99.91 m, black lines 100 m, grey lines 100.14 m). Water velocities were predicted using the River2D model.

CONCLUSIONS AND ADVICE

The TSW is a complex system of lakes, rivers, locks, dams, and hydro-electric generating stations. The lower portion of the Trent River is the combined product of flow management throughout the system. Areas containing Channel Darter critical habitat in the Trent River system have been observed to undergo partial or complete dewatering, which may not be sufficient to support Channel Darter spawning activities.

The narrow range in Channel Darter habitat characteristics in the Trent River result in Channel Darter restricted to shallow sections of riffles, which exist almost exclusively in bypass channels downstream of dams, making these habitats vulnerable to impacts caused by dam operations, including habitat dewatering (Coker and Portt 2011).

Spawning locations were identified at each of the three study sites. Spawning-ready Channel Darter have been collected from late-May to early-July (Reid 2004 and, this study) in the Trent River. Based on a number of studies (see Reid et al. 2016 for details), egg incubation can be expected to extend into the second week of July in the Trent River. The minimum water temperature expected for Channel Darter spawning is 14°C. Importantly, these dates can vary depending on weather and stochastic events.

Minimum Flow Requirements for Channel Darter Spawning

Channel Darter habitat at the three study sites (Glen Ross, Lock 5, Sonoco) along the Trent River respond differently to increases in river discharge. Setting a single target flow would impact each site differently so an adaptive management approach is recommended. Adaptive management uses the best available information to set flow recommendations, monitoring is undertaken and, if needed, flow management may be adjusted. One of the first steps would be to verify that predicted flow and/or habitat changes at different spill discharges are realized. Population-level monitoring would also be needed to detect demographic changes that might be linked to spawning and recruitment success.

Of the three sites, Glen Ross and Sonoco have the highest likelihood of encountering Channel Darter. At Glen Ross, relatively low flows are sufficient for Channel Darter, although this is the location where a dewatering event occurred during dam maintenance. Since this dewatering event, a training and awareness plan was implemented to educate the operators to help prevent similar incidents in the future. Minimum flows should not go below 30 m^3/s at Glen Ross. Historical frequency distribution curves for the Trent River using discharge data from 1961 to 2003 (Figure 8) indicate that minimum flows of 30 m^3/s were maintained over 80% of the time. Situations will occur where these minimum flows will not be realized due to the challenges associated with implementing a low-flows strategy during stochastic drought events.

At Glen Ross and Sonoco, habitat suitability increased with discharge although, Glen Ross appeared to be more sensitive to water flow changes than Sonoco. Predicted improvements to habitat suitability at Sonoco continue to occur at discharges > 80 m^3/s. Minimum flow at Sonoco will depend on the flow set at Glen Ross.

To improve habitat suitability at Lock 5, daily spill discharges from the eastern dam gate should be between 5 and 7.5 m^3/s during the spawning period.

When there is insufficient flow in the system to meet recommended levels, flow should be directed over Channel Darter spawning habitat during the spawning period.

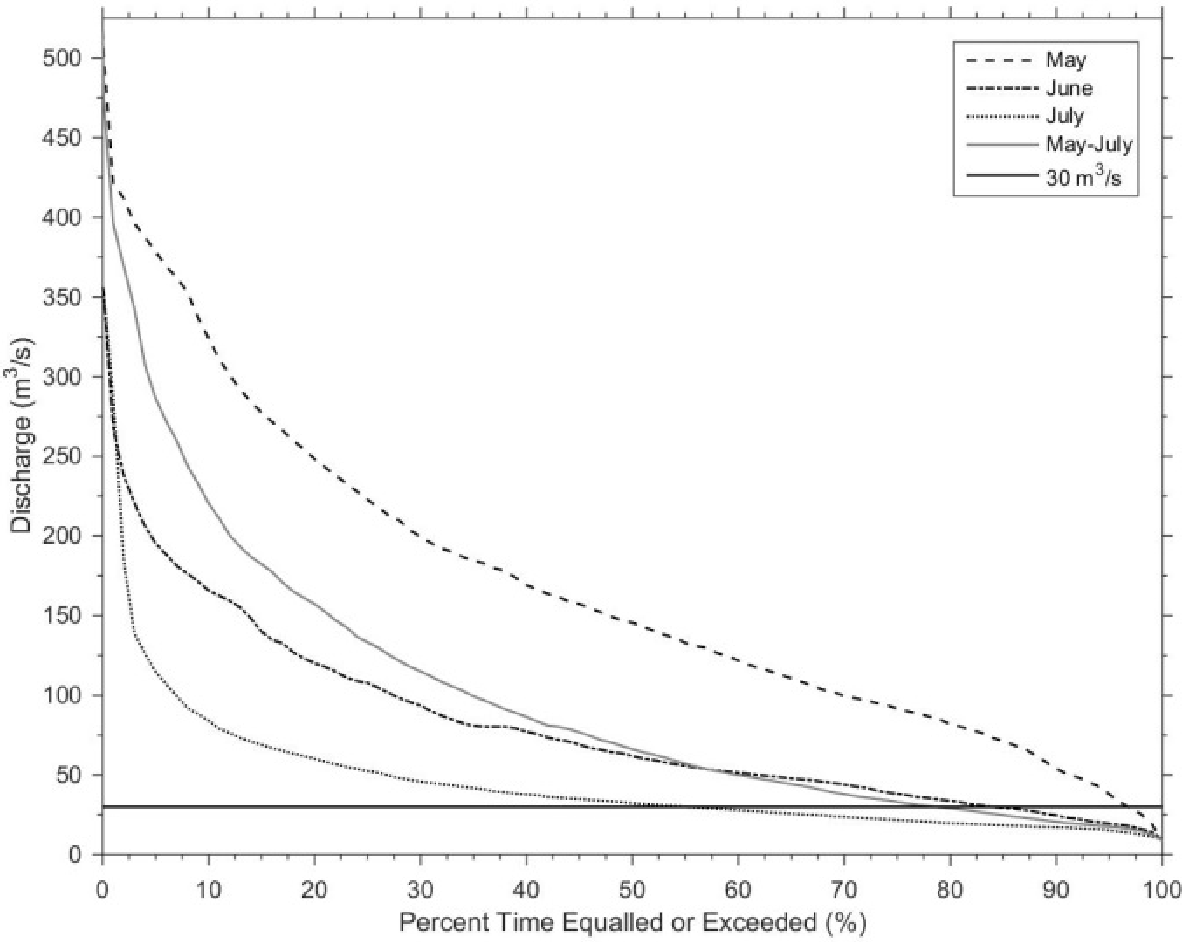

Figure 8. Frequency-distribution curves for historical Trent River discharge measurements from 1961 to 2003.

Alternatives to Current Flow Management

Alternatives to activities that may cause a negative effect on Species at Risk involve using different approaches to achieving an objective that reduces the impact of the activity on these species. Alternatives, such as redesigning the project or selecting an alternate site (Coker et al. 2010), are not feasible here. Such alternatives are appropriate when a new project or activity begins. An alternative to the current flow-management regime would be to manage flow for Channel Darter as opposed to managing flow for navigation, flood control, and power generation. There are no other realistic alternatives.

Additional Mitigation Measures

Under SARA, in any area where an activity is proposed that impact species at risk, alternatives must be considered, all feasible mitigation measures must be taken to minimize the impact of the activity on the species or its critical habitat, and the activity must not jeopardize the survival and recovery of a species. Mitigation measures are conditions or options that can be incorporated into a project or activity to avoid or minimize negative impacts. Some activities that harm a species listed as Threatened or Endangered may be allowed if all feasible mitigation measures are implemented. The first mitigation measure is minimum flows.

Coker et al. (2010) provides additional mitigation measures for flow management to protect fish and fish habitat (e.g., seasonal timing windows, dam design or operation to allow for fish passage and reducing changes to downstream water chemistry).

Under spring drought conditions, there may not be sufficient flow for Channel Darter habitats. Under such conditions, impacts to Channel Darter may be mitigated by directing what flow is available over Channel Darter spawning habitat (Figures 2, 3, and 4). For example, Channel Darter habitat can be improved downstream of Lock 5 by releasing water through the eastern-most gate.

It may be possible to back up water in flat reaches of the river to maintain water elevations upstream. For example, it may be possible to back up water at Lock 4 to maintain water depth below the Lock 5 dam.

Coker and Portt (2011) suggested incremental flow reductions to allow fish to move from shallow water habitats and to avoid significant flow reductions during Channel Darter spawning periods as spawning is known to be interrupted by flow reductions and nests with eggs can become exposed.

Timing of maintenance for control structures should not coincide with Channel Darter spawning or egg incubation (late May to mid-July).

There may be the potential to use waste water to increase flow (e.g., remove water from the tail race and pump it back up to the pool).

Offsetting

Offsetting is required if there are population or habitat losses. Examples of offsetting could include population augmentation (e.g., stocking) to offset population losses, and habitat augmentation or creation to offset destruction of habitat. In addition, Loughlin and Clarke (2014) reviewed a number of methods used to offset impacts of projects on fisheries productivity. Offsetting options were not evaluated for feasibility, habitat function, constraints, or risks as part of this review.

DFO (2010) identified that Channel Darter vital rates early in life were more important to population growth rate than vital rates later in life. Venturelli et al. (2010) recommended recovery actions that will increase the annual survival rate of Channel Darter in their first three years of life by 10% as this will decrease recovery times. This information is relevant to both mitigation measures and offsetting for population or habitat losses.

Adaptive Management, Research, and Monitoring

An Adaptive Management Plan (scope, monitoring design) should be developed, which will allow monitoring, assessment, and then reassessment of current guidance. The plan should include monitoring to determine how the remaining portions of this system react when river discharge at Glen Ross is 30 m^3/s. Based on the results of the monitoring, strategies may be adjusted.

Lock 5 should be continuously monitored to ensure that flow recommendations are still valid. The bed topography at the Lock 5 site is very complex and, therefore, has a large influence on local flow patterns and characteristics. Extreme flow events are expected to redistribute coarse bed material, and change the relationship between spill discharge and local water depth and velocity conditions. If the bed topography changes, River2D model predictions would need to be revised using updated bed topography information.

The plan should include monitoring of additional Channel Darter populations in this stretch of the Trent River.

Future field surveys, including bed material compositions or substrate, should be undertaken to evaluate and adjust the River2D model and associated flow recommendations and should include controlled releases from the eastern-most Lock 5 dam gate (to further validate River2D model and assess the response of Channel Darter).

Habitat-selection studies at Glen Ross and other river sites (where water is not diverted through hydro-electric stations) should be conducted to assess how habitat variation across sites and among years affects flow recommendations. Visual-based studies should be completed to ensure that the habitat preferences used in the model (presence of adult Channel Darter) are representative of conditions required for successful spawning.

Studies are needed to determine the relationship between Channel Darter populations and CSI for this species.

SOURCES OF INFORMATION

This Science Advisory Report is from the January 15, 2016 regional peer review of the Effects of water flow management regimes in the Trent River on Channel Darter spawning activities. Additional publications from this meeting will be posted on the DFO Science Advisory Schedule as they become available.

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