UPDATED GUIDELINES FOR THE REMOVAL OF AQUATIC VEGETATION WITHIN SPOTTED GAR CRITICAL HABITAT

Context

The removal of aquatic vegetation via chemical or mechanical means may be pursued for socioeconomic reasons, such as to create swimming areas, improve boat access, or facilitate the retrieval of commercial fishing gear. Vegetation removal, both large and small scale, has occurred in Rondeau Bay and Long Point Bay, Lake Erie (Ontario), including areas inhabited by Spotted Gar (*Lepisosteus oculatus*), a species listed as Endangered under Canada's *Species at Risk Act*. Because vegetation removal has the potential to impact Spotted Gar and its habitat, the 2012 Recovery Strategy for Spotted Gar (Staton et al. 2012) outlined interim guidelines for the removal of aquatic vegetation in Spotted Gar habitat (Appendix), which were created to minimize harm to the species when small-scale vegetation removals take place. Although the interim guidelines have been in place since 2012, considerable research on Spotted Gar and its habitat in Canada has occurred since the guidelines were published, particularly in Rondeau Bay. Critical Habitat Order(s) have also been established within areas where vegetation removal has occurred in the past, raising questions about the consequence of this activity to Spotted Gar. Fisheries and Oceans Canada's (DFO) Species at Risk Program has requested that DFO Science review the 2012 interim guidelines to ensure that best management practices are scientifically defensible in light of recent research on Spotted Gar and its habitat.

This Science Response Report results from the Science Response Process "Updated Guidelines for the Removal of Aquatic Vegetation within Spotted Gar *(Lepisosteus oculatus)* Critical Habitat", July 16, 2019, held in Burlington, Ontario.

Analysis and Response

Relationship between Spotted Gar and Aquatic Vegetation

Spotted Gar prefers shallow, clear, well-vegetated waters. The life cycle of the species has been described for Canadian populations by Scott and Crossman (1998), Holm et al. (2009), Bouvier and Mandrak (2010), and COSEWIC (2015). In brief, adults make spawning migrations in the spring period (May to June) to shallow, nearshore, and (or) flooded vegetated areas; females deposit adhesive eggs onto the stems and leaves of submerged and (or) emergent vegetation; eggs are fertilized by males immediately before or following adhesion; and, eggs develop while attached to stems or leaves. Hatching occurs approximately one week after fertilization, but young of year (YOY) may remain fixed to aquatic vegetation or hang motionless in the surface film owing to specialized, disc-shaped jaws (Cudmore-Vokey and Minns 2002), until free swimming begins shortly thereafter. Growth of juveniles is rapid due to the switch from invertebrate to fish-based forage early in development. Adults rely almost exclusively on fishes for forage and consume species that are commonly found with aquatic vegetation (e.g., Yellow Perch [*Perca flavescens*], Central Mudminnow [*Umbra limi*], Fathead Minnow [*Pimephales promelas*], *Centrarchidae* spp.; Ostrand et al. 2004, COSEWIC 2015). Opportunistic feeding on large aquatic invertebrates may also occur.

Spotted Gar has one of the strongest relationships of any freshwater fish species with aquatic vegetation, with all life stages relying on emergent and (or) submerged plants. Numerous authors have described the importance of aquatic vegetation for the species (Carlander 1969, Lee et al. 1990, Lane et al. 1996a,b,c, Scott and Crossman 1998, Snedden et al. 1999, Page and Burr 2011, Cudmore-Vokey and Minns 2002), noting its role in reproduction (Redmond 1964, Parker and McKee 1984, Snedden et al. 1999), nursery habitat (Simon and Wallus 1989), food supply and foraging (Ostrand et al. 2004), and cover (Glass et al. 2012). Of the few empirical studies that have quantified habitat use of Spotted Gar, Snedden et al. (1999) conducted radiotelemetry and determined that Spotted Gar in a Louisiana floodplain used large areas of inundated aquatic habitat, which was hypothesized to be for spawning and nursery purposes. Tyler and Granger (1984) described the capture of 172 adult Spotted Gar in a lake in southwestern Oklahoma that was composed of dense beds of submerged and emergent vegetation (*Polygonum*, *Potamogeton*, *Myriophyllum*, and *Justicia* spp.). Simon and Wallus (1989) indicated that areas of dense aquatic vegetation are preferred nursery habitat; however, studies on YOY and juvenile habitat associations are generally lacking (but see Glass and Mandrak 2014, DFO unpublished data 2017, 2018; summarized below). Ostrand et al. (2004) indicated that foraging success of Spotted Gar decreased with increasing stem density for certain prey (Bluegill [*Lepomis macrochirus*]); however, this pattern was not observed for other prey species. Almost all published work indicates a positive association between the occurrence, abundance, and (or) density of aquatic vegetation and the productivity of Spotted Gar habitat.

Recovery Potential Modelling of Spotted Gar in Canada

As part of the listing process for Spotted Gar under the *Species at Risk Act*, DFO conducted a Recovery Potential Assessment (RPA) of Spotted Gar in Canada (DFO 2010, Bouvier and Mandrak 2010, Young and Koops 2010). Based on indices of population trajectory and relative abundance, status of the Long Point Bay, Point Pelee, and Rondeau Bay populations were considered ‘poor’, ‘fair’, and ‘good’, respectively. Recovery potential modelling indicated that Spotted Gar populations in Canada are most sensitive to harm (i.e., mortality) to YOY, followed by juveniles, then adults (Young and Koops 2010). If a Spotted Gar population is growing with a population growth rate of $\lambda = 1.078$ (mean rate based on assumed decline associated with COSEWIC’s criterion B and the maximum possible growth rate of the species), modelling indicates that (i) annual survival rate cannot be reduced by more than 19% for YOY, 15% for juveniles, or 14% for adults; and, (ii) fertility cannot be reduced by more than 21% for young adults; otherwise, the population trajectory would decline below $\lambda = 1.0$ (Young and Koops 2010). Population decline ($\lambda < 1.0$) is also likely if harm reduces the survival of all ages by more than 5%, survival of immature individuals by more than 8%, or the fertility of all adults by more than 15%. If the realized population growth rate is lower than $\lambda = 1.078$, smaller declines in survival or fertility would lead to a greater chance of population decline below 1.0. Previous interpretation by DFO Science is that harm which leads to $\lambda < 1.0$ would jeopardize the survival and recovery of a SARA-listed species; therefore, populations in decline (i.e., baseline $\lambda < 1.0$) cannot experience any human-induced harm without jeopardizing their survival or recovery (Vélez-Espino and Koops 2007, 2009). Standardized monitoring programs do not exist for Spotted Gar populations in Canada, so the trajectory of the species in areas subject to proposed vegetation removal is unknown.

Recovery potential modelling of Spotted Gar in Canada indicated that the minimum viable population (MVP) is 1,424 adults, assuming a 0.15 probability of catastrophic decline per generation (~ 5 years; i.e., an one-year 50% population decline every 33.3 years) and a quasi extinction threshold of two adults. However, if a larger extinction threshold is assumed (e.g., 20 adults, to account for the compounding effects of inbreeding depression, demographic stochasticity and Allee effects), MVP rises to 13,840 adults. Based on the allometric relationship between body size and habitat 'area per individual' required (Minns 1995, Randall et al. 1995, Minns 2003), a MVP of 1,424 adults would require 360.8 ha of habitat, while a MVP of 13,840 adults would require ~ 3,500 ha. These projections assume separate habitat for each life stage, including spawning habitat, and that all habitat is of optimal quality. For an MVP of 13,840 adults requiring ~ 3,500 ha of total habitat area, ~ 1,400 ha would be required as YOY habitat, ~ 1,400 ha would be required as juvenile habitat, ~ 650 ha would be required as adult habitat, and ~ 0.05 ha would be required as spawning habitat. If juvenile and adult Spotted Gar share habitat but do not directly compete for space, the minimum area for population viability (MAPV) could be much lower. Young and Koops (2010) and Staton et al. (2012) determined that the minimum habitat area for population viability of Spotted Gar was available in Rondeau Bay, but not in Long Point Bay or Point Pelee, based on the MVP of 13,840 adults (Table 1); for the MVP of 1,424, minimum habitat area for population viability is present at Long Point Bay and Rondeau Bay, but not Point Pelee. Results from Young and Koops (2010) indicate that early life-stage habitat may be limiting, given the sensitivity of population growth rate to YOY and juvenile perturbations, the loss of YOY or juvenile habitat is of greatest concern to the viability of Spotted Gar in Canada.

The population size of Spotted Gar in Canada is known for only a subset of locations. Glass et al. (2012) estimated the population size of Spotted Gar in Point Pelee National Park to be 483 mature adults (95%, CI 433–519); an extrapolation of this population density (2.2 fish/ha) to Rondeau Bay indicated that the Rondeau Bay population could be as large as 8,124 adults (95%, CI 7,281–8,278). Therefore, based on the MVP of 1,424 adults, the Rondeau Bay population is above MVP, while Point Pelee is below MVP. No Canadian population appears to be above MVP based on the target of 13,840 adults (Table 1).

Table 1. Comparison of population size, minimum viable population size (MVP), and minimum area for population viability (MAPV) for Long Point Bay, Point Pelee, and Rondeau Bay populations. Population estimates are from Glass et al. (2012); MVP and MAPV are from Young and Koops (2010). MVP¹ represents Pr catastrophe = 0.15 and a quasi-extinction threshold of 2 adults; MVP² represents Pr catastrophe = 0.15 and a quasi-extinction threshold of 20 adults. Modified from Staton et al. (2012).

Population and Identified Critical Habitat Area	Estimated Population Size	MVP¹	MVP¹ achieved?	MAPV¹	MAPV¹ achieved?	MVP²	MVP² achieved?	MAPV²	MAP² achieved
Long Point Bay/Big Creek NWA (7.7 km²)	Unknown	1,424 adults	Unknown	3.6 km²	Yes	13,840 adults	Unknown	35 km²	No
Point Pelee (2.2 km²)	483 adults	1,424 adults	No	3.6 km²	No	13,840 adults	No	35 km²	No
Rondeau Bay (37 km²)	8,124 adults	1,424 adults	Yes	3.6 km²	Yes	13,840 adults	No	35 km²	Yes

Estimates of MAPV in Young and Koops (2010) indicate the habitat area needed to support minimum viable population sizes. However, the approach for estimating MAPV assumes that the entirety of the measured habitat area is functioning as Spotted Gar habitat and does not account for how habitat quality may vary across the area. Changes in the condition or quality of habitat area may lead to changes in population status. If certain habitat areas are avoided by Spotted Gar, the estimate of MAPV would need to be revisited. As with many species at risk in Canada, a detailed understanding of the relationship between the occurrence of habitat features and the productivity of Spotted Gar does not exist. Therefore, there is currently no population model available to estimate the change in population productivity associated with changes in aquatic vegetation for Canadian populations.

Research on Spotted Gar in Canada Following the 2012 Interim Guidelines

Following the publication of the Recovery Strategy for the Spotted Gar (*Lepisosteus oculatus*) (Staton et al. 2012), several targeted field studies were performed to better understand the population ecology and habitat use of Spotted Gar in Canada. The bulk of this research was conducted in Rondeau Bay (Glass et al. 2012, Glass et al. 2015, DFO unpublished data) because the population is large enough for repeated captures for research purposes, whereas populations in Long Point Bay and Point Pelee generally produce less frequent captures (Glass et al. 2012, COSEWIC 2015). Research conducted since the 2012 interim guidelines includes:

1. radiotelemetry of adult Spotted Gar in Rondeau Bay to evaluate spring and summer habitat use (Glass et al. 2012);
2. field collections of juveniles in Rondeau Bay to identify habitat associations (Glass and Mandrak 2014);
3. genetic analysis of Spotted Gar in Point Pelee, Rondeau Bay, and Long Point Bay (Glass et al. 2015); and,
4. two field studies undertaken by DFO-Great Lakes Laboratory for Fisheries and Aquatic Sciences (DFO-GLLFAS) to better understand the spawning ecology and early life history of Spotted Gar in Canada (DFO unpublished data 2017, 2018).

Each study has led to new insights about the role of aquatic vegetation for Spotted Gar in Rondeau Bay, summarized below.

Glass et al. (2012) used radiotelemetry to better understand the spring and summer distribution and habitat use of adult Spotted Gar in Rondeau Bay. A total of 37 adult Spotted Gar (515–745 mm TL; 0.53 to 1.94 kg) were tagged with radio tags and tracked to 224 discrete locations throughout spring and summer 2007. Habitat measures at discrete locations consisted of water depth (m), surface temperature (°C), pH, and conductivity (µS/cm). When present, aquatic macrophytes were identified to genus. Tracking periods were divided into spring (May–June; assumed to encompass spawning period) and summer (July–September). Habitat associations were evaluated seasonally based on electivity indices, which determined preference and avoidance of habitat features. During the spring period, Spotted Gar exhibited preference for: 1) the shallowest (< 0.5 m) and deepest (> 2.5 m) waters; 2) areas with no macrophyte growth; 3) water with high conductivity and pH > 9.5; whereas, 4) moderate depths (1.0–1.99 m) were strongly avoided. In summer, Spotted Gar exhibited preference for: 1) deepest depths (> 2.5 m) and shallowest depths (< 0.5 m); 2) areas with two or greater macrophyte genera; and, 3) pH between 8.09 and 8.49. Overall, 90% of the locations where Spotted Gar was detected had aquatic vegetation (3.1% of sites consisted of emergent only, 4% of sites consisted of emergent and submerged; and, 82% of sites were submerged only). Glass et al. (2012) reported that when aquatic vegetation was present with Spotted Gar, complex and highly branched species were common (*Chara*, *Potamogeton*, *Myriophyllum*, *Ceratophyllum*, *Elodea* spp.), but *Valisneria* and *Lemna* spp. also occurred. In decreasing order of prevalence, *Potamogeton, Chara, Myriophyllum, Valisneria, Ceratophyllum, Elodea*, and *Lemna* spp. were associated with Spotted Gar detections and often occurred in mixed beds. Based on interpolation, the authors estimated that approximately 1,543 ha (1.5 km^2) of Rondeau Bay was occupied by two or more macrophyte genera. Similar to Ostrand et al. (2004), Glass et al. (2012) hypothesized that mixed aquatic macrophyte beds provide three-dimensional habitat structure that may aid prey capture. The avoidance of aquatic vegetation during the spring period differed from *a priori* expectations and was assumed to be related to feeding on seasonal migrations of small-bodied fishes that rely on sandy substrates (e.g., Spottail Shiner [*Notropis hudsonius*]).

Glass and Mandrak (2014) conducted field studies to evaluate the use of tributaries in Rondeau Bay for spawning and to assess juvenile habitat. The tributary study involved fine-mesh fyke nets set during late May 2013 in seven tributaries (i.e., agricultural drains) that flow into the western shore of Rondeau Bay. Nets were set upstream and downstream of the first upstream road crossing as well as the mouth of each tributary. A standard coarse-level habitat assessment was conducted (water temperature, conductivity, dissolved oxygen, secchi depth, pH, and dominant vegetation). A total of 45 adult Spotted Gar were captured at seven locations; 37 were captured below the first major road crossing; eight were captured upstream of the first major road crossing.

The juvenile habitat assessment involved quatrefoil light traps, mamou trawling, and bag seining in nearshore areas at 36 sites throughout Rondeau Bay and its tributaries from late July to early August 2013 (Glass and Mandrak 2014). Following the approach of Glass et al. (2012), electivity of juvenile Spotted Gar in Rondeau Bay was calculated. Spotted Gar was not captured in quatrefoil traps or the mamou trawl. However, seining captured eight juvenile Spotted Gar at six different locations, as well as one adult. Juveniles were captured in nearshore areas of Rondeau Bay and Mill Creek. Attributes of these sites were mean depth of 0.64, mean water temperature of 22.4 °C, and mean secchi depth of 0.15 m. Capture sites had mean coverage of 30% emergent, 9% floating, and 32% submerged vegetation, respectively. Electivity indicated strong avoidance of: 1) the deepest locations; 2) highest turbidity; 3) highest conductivity; and, 4) extreme dissolved oxygen concentrations (low and high values), while strong selection existed for habitats with moderate turbidity (50–149 NTU). Moderate preference existed for the shallowest depths (< 0.5 m) and temperatures greater than 23.5 °C. Electivity for moderate turbidity was assumed to reflect the dominant conditions of nearshore and tributary sites, rather than optimal conditions for juveniles. Sampling was also conducted at Long Point Bay, but did not detect juvenile Spotted Gar.

Glass et al. (2015) conducted genetic analysis of Spotted Gar from Point Pelee, Rondeau Bay, and Long Point Bay, as well as populations from the southern range in the United States. Multilocus microsatellite data were used to determine genetic structure within and among populations. Primary findings indicated that gene flow among populations and subpopulations is very low, suggesting a high degree of geographic and reproductive separation among Canadian populations. Analysis revealed that the physical isolation of Point Pelee has likely resulted in distinct genetic differentiation, but such differentiation also provides a source of genetic variation for Lake Erie when breaches to the barrier beach occur. The analysis also indicated that multiple distinct populations of Spotted Gar exist in Rondeau Bay. These findings indicate that the effective number of breeders in each sub-population is smaller than the current population estimate of 8,124 adults, implying that one or more of the subpopulations within Rondeau Bay is below MVP.

DFO-GLLFAS undertook two studies in 2017 and 2018 to better understand the spawning ecology and early life history of Spotted Gar. In the first study, DFO unpublished data (2017) used radiotelemetry to investigate spawning site selection in relation to environmental factors. Because Glass et al. (2012) and Glass and Mandrak (2014) identified the western shoreline of Rondeau Bay as supporting the bulk of spawning activity, tracking focused on the entire western shoreline. Tracking occurred between late April and mid June, 3-4 days per week, with tagged fish previously collected in this area. When a tagged Spotted Gar was detected, its location was recorded along with observations of spawning activity (spawning observed/not observed). Sites where spawning was detected were subsequently visited for detailed habitat measures at the centroid of the spawning site. Habitat variables included site depth, substrate composition, water temperature, turbidity, dissolved oxygen, and the relative displacement volume of aquatic plants, identified to genus. Background habitat measures were conducted at randomly selected sites between 0 and 100 m from the shoreline (including tributaries to the first upstream impassable barrier), which were presumed to represent ‘null’ spawning locations. A total of 13 spawning pairs were detected, with spawning noted as early as May 23 (mean water temperature 16.6 °C) and as late as June 14 (25.6 °C). Spawning pairs were detected within tributaries as well as shoreline areas. Statistical analysis of the factors associated with spawning locations indicated a negative association with distance from shore (i.e., probability of locating and utilizing a spawning site decreases with increasing distance), a positive association with the displacement volume of *Potamogeton* sp. and substrates that support aquatic macrophytes (e.g., detritus, silt), a positive association with depth and conductivity, a negative association with dissolved oxygen, a positive association with the genus *Lemna*, and a negative association with *Ceratophylum*. During the laboratory processing of aquatic macrophyte samples, eggs were detected and removed from stems and leaves of numerous genera of macrophytes, including: (Emergent): *Phalaris arundinacea, Poaceae* sp., *Carex* sp., *Sparganium eurycarpum*, other unidentified stems, (floating) *Hydrocharis morsus-ranae; Lemna minor*, *Spirodela polyrhiza*; (submerged) *Ceratophyllum demersum*; algae sp.; *Potamogeton zosteriformis*; *Potamogeton richardsonii*; *Myriophyllum sibiricum*; *M. spicatum*; *Vallisneria americana*; *Elodea canadensis*; *Potamogeton crispus*; *Stuckenia pectinatus*; *Chara* sp; and, unknown submerged spp. Genetic analyses of these samples to confirm fish species identity is underway.

In the second study (DFO unpublished data 2018), the habitat associations of larval Spotted Gar were investigated in Rondeau Bay. Based on the results of the previous study (DFO unpublished data 2017), the 2018 study focused on sampling larval Spotted Gar in known spawning locations using visual dip netting and quatrefoil light traps. Areas near Flat Creek (midpoint of western shoreline of Rondeau Bay) and Drain 1 (northern tip of western shoreline) were targeted, focusing on the following strata: 1) habitat areas < 1m from shore within tributaries (“tributary onshore”); 2) areas > 1 m from shore within tributaries (“tributary offshore”); 3) areas < 1 m from shore along the lakefront (“lakefront onshore”); and, 4) areas > 1 m from shore along the lakefront (“lakefront offshore”). Quatrefoil light traps failed to detect larval *Lepisosteus* sp.; however, dip netting detected 57 larval *Lepisosteus* sp. in Drain 1, Flat Creek, and the associated lakefront areas. The bulk of larval *Lepisosteus* were sampled in the tributary onshore strata; secondarily in the lakefront onshore strata, followed by tributary offshore, and lakefront offshore. Areas where larval *Lepisosteus* sp. were collected exhibited variation in the relative abundance of submerged aquatic macrophytes, which ranged from 0 (no submerged macrophytes detected during rake survey) to three (no tines visible on rake due to abundant vegetation). Dominant vegetation in the vicinity of larval *Lepisosteus* sp. collection sites included "Milfoil", *Valisneria* sp., Cattail, Sago pondweed, Water Celery, and Pondweed. Milfoil was the dominant vegetation in 60% of larval *Lepisosteus* sp. capture locations. However, due to the difficulty of positively identifying *Myriophylum spicatum* relative to *Ceratophylum* sp., it is unknown if each record of "Milfoil" represents a definitive record of the invasive macrophyte *Myriophylum spicatum*.

Collectively, insights from recent research following the interim guidelines indicates the following:

Adult Spotted Gar prefer diverse patches of aquatic macrophytes, which may include invasive species (e.g., *M. spicatum*); adults show seasonal preferences for shallow (< 0.5 m) and deep (> 2.5 m) areas of available habitat; spawning occurs predominantly < 30 m from shore, but is associated with greater water depth; and, plants of the genus *Potamogeton* are associated with spawning activity, though other species may also support egg development. Larval Spotted Gar are found primarily in the shoreline margins of tributaries (including agricultural drains) and lakefront areas, but secondarily may be found offshore of these areas; larvae associate with sparse through heavy aquatic vegetation, and are commonly found in areas that include *Myriophylum* (or) *Ceratophylum* sp. Juvenile Spotted Gar were associated with the shallowest depths available and moderate turbidity levels.

Existing Research about the Harm of Vegetation Removal

Several authors have identified the removal of native aquatic vegetation as a threat to the survival or recovery of Spotted Gar. Bouvier and Mandrak (2010) indicated that both mechanical and chemical removal would have a high impact on the species in Rondeau Bay (threat impacts were considered 'low' in Point Pelee and Long Point Bay due to the reduced frequency and extent of vegetation removal in those areas). These findings were reiterated by COSEWIC (2015). Bouvier and Mandrak (2010) and COSEWIC (2015) emphasized that the mechanical removal of aquatic vegetation from areas occupied by Spotted Gar could harm the species by disturbing sediments and creating turbid conditions, as well as by removing or harming individuals physically attached to aquatic vegetation or those found among the vegetation; whereas, chemical vegetation removal via herbicides can introduce chemicals into occupied habitats, reduce dissolved oxygen, and reduce overall habitat availability and function. Numerous written works exist on the overall impact of the removal of aquatic vegetation in aquatic ecosystems, and relevant issues are summarized in Gilbert et al. (2007). An exhaustive review of the approaches for vegetation removal and their impact is outside the scope of this Science Response.

Interpretation and Evaluation of the 2012 Interim Guidelines

The interim guidelines (Staton et al. 2012) state:

"Nutrient loading leading to excessive overgrowth of aquatic vegetation can reduce the quality of Spotted Gar habitat. In these situations, it is possible that limited vegetation removal could benefit the long term survival and recovery of Spotted Gar. Subject to site-specific reviews, small-scale vegetation removal projects using approved means may be allowed. Site-specific reviews may be required for proposed vegetation removal projects in Spotted Gar habitat. To minimize the potential impacts, the Rondeau Bay Aquatic Vegetation Issues Working Group in

consultation with the Spotted Gar Recovery Team has recommended the following interim guidelines (2010) for limited vegetation removals:

- removals within the nearshore zone (up to 1 m in water depth) will be restricted to a perpendicular channel not more than 1 m in width (to minimize potential harm to spawning and nursery habitat);
- private swimming areas will be limited to a maximum area of 6 m x 10 m, in water depths greater than 1 m; and
- private boating channels will not exceed 4 m in width in water depths greater than 1 m; and
- 'main' or 'collector' boating channels will not exceed 6 m in width."

Interpretation and evaluation of the interim guidelines is as follows:

The possibility exists that excessive overgrowth of aquatic vegetation can reduce the quality of Spotted Gar habitat through several mechanisms such as reduced prey availability and (or) reductions in foraging area owing to water quality declines, loss of wetted area, or reduced swimming performance of the species. Reductions in the productive value of Spotted Gar habitat may be associated with monocultures of aquatic vegetation (COSEWIC 2015), particularly invasive plant species (e.g., *Phragmites australis*, *M. spicatum*). However, the ecological impact of invasive monocultures, including the response of Spotted Gar to control activities, is poorly understood and complicated by the collection of larvae in areas dominated by *M. spicatum*. Relationships with *P. australis* have not been identified. Moreover, although Glass et al. (2012) demonstrated the avoidance of aquatic vegetation by adults during parts of the spring period, most field studies conducted following Staton et al. (2012) have demonstrated positive associations with the highest observed densities of submerged aquatic vegetation during spawning, especially *Potamogeton* sp., or generally with cover provided by submerged and emergent species, including invasive *M. spicatum* and possibly *Ceratophylum* sp. Adults display a positive association with mixed stands of branched, submerged macrophytes, which may include *M. spicatum*. One study has indicated a reduction in Spotted Gar foraging on a single prey species as a function of increased density of aquatic vegetation (Ostrand et al. (2004); however, it is unclear whether these results are directly comparable to Canadian populations or how foraging reductions may be mediated by increases in egg or larval survival owing to high-density patches.

Therefore, based on available evidence, it is unlikely that limited vegetation removal would benefit the long-term survival and recovery of Spotted Gar in Canada, especially if the spatial configuration of removal is dictated by areas with greatest socioeconomic demand, rather than habitat patches hypothesized to reduce Spotted Gar viability (e.g., species monocultures; see COSEWIC 2015). Moreover, given that population sizes of Spotted Gar in Point Pelee, Long Point Bay, and Rondeau Bay are below MVP, the small critical habitat area of these areas, the sensitivity of Spotted Gar to changes in YOY survival, and the important role of aquatic vegetation in the development of YOY, it is likely that small-scale vegetation removals would jeopardize the survival and recovery of Spotted Gar, particularly if vegetation is removed within tributaries and shoreline areas or includes mixed stands of submerged aquatic macrophytes.

If vegetation removals are pursued for socioeconomic reasons, the following best practices would reduce harm to Spotted Gar in Canada:

- <u>Minimize removal area</u>, given the importance of submerged vegetation extent, density, and richness to all life stages (Glass et al. 2012, Glass and Mandrak 2014, DFO unpublished data 2017, 2018). Minimizing removal area is also supported given that MAPV has not been met for the majority of Canadian populations. If habitat is reduced below MAPV, particularly for juveniles, the probability of extirpation climbs rapidly (Young and Koops 2010). Specific, area-based removal targets (e.g., X m^2) are a risk tolerance decision.

- Avoid the removal of vegetation within tributaries and shoreline areas, including the wetted area between the land-water interface and that which extends to 30 m from the shoreline, given preference for spawning in these areas. In addition, vegetation removal should be avoided in areas < 0.5 m depth that are beyond the 30 m distance from shore. To minimize harm to adult foraging habitat or home ranges, vegetation removal should also be avoided in areas > 2.5 m in depth.
- Avoid the removal of mixed stands of submerged aquatic macrophytes, given the preference of adults for these features. The avoidance of mixed stands is also justified given the relatively low availability of these features, particularly in Rondeau Bay (Glass et al. 2012).

Conclusions

Significant insights have been gained about the movement, reproductive ecology, and habitat associations of Spotted Gar following the publication of Staton et al. (2012). Research on adult, spawning, larval, and juvenile habitat of Spotted Gar indicates strong associations with high densities of submerged aquatic vegetation, particularly mixed stands and *Potamogeton* sp. in nearshore areas and tributaries. In some cases, early life stages have been associated with the presence of invasive, submerged macrophyte species. The relationship between Spotted Gar and monocultures of emergent and submerged plant species remains poorly understood as does the response of Spotted Gar to chemical or mechanical control of these species (Bouvier and Mandrak 2010, COSEWIC 2015). Best management practices presented above are based on best available science following Staton et al. (2012). However, based on available evidence, it is unlikely that limited vegetation removal would benefit the long-term survival and recovery of Spotted Gar in Canada. Moreover, it is likely that small-scale vegetation removals would jeopardize the survival and recovery of Spotted Gar, particularly if vegetation is removed within tributaries and shoreline areas or includes mixed stands of submerged aquatic macrophytes.

New research findings may warrant re-visiting the advice contained within this Science Response, particularly given: 1) the potential for newly identified associations of life stages with submerged and emergent species following genetic analysis of collected eggs; and, 2) the lack of a detailed understanding of how aquatic vegetation influences the productivity of Spotted Gar populations.

If aquatic vegetation removals are pursued, it is strongly recommended that the response of affected habitat patches (e.g., re-colonization by native or invasive plant species) and Spotted Gar populations be evaluated, including the cumulative effect of multiple removals for a given population.

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Appendix: Aquatic Vegetation Removal – Guidelines, from Staton et al. (2012)

“Nutrient loading leading to excessive overgrowth of aquatic vegetation can reduce the quality of Spotted Gar habitat. In these situations, it is possible that limited vegetation removal could benefit the long term survival and recovery of Spotted Gar. Subject to site-specific reviews, small-scale vegetation removal projects using approved means may be allowed. Site-specific reviews may be required for proposed vegetation removal projects in Spotted Gar habitat. To minimize the potential impacts, the Rondeau Bay Aquatic Vegetation Issues Working Group in consultation with the Spotted Gar Recovery Team has recommended the following interim guidelines (2010) for limited vegetation removals. Note that future research may inform changes to these interim guidelines:

- removals within the nearshore zone (up to 1 m in water depth) will be restricted to a perpendicular channel not more than 1 m in width (to minimize potential harm to spawning and nursery habitat);
- private swimming areas will be limited to a maximum area of 6 m x 10 m, in water depths greater than 1 m;
- private boating channels will not exceed 4 m in width in water depths greater than 1 m; and
- ‘main’ or ‘collector’ boating channels will not exceed 6 m in width.”

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