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Recovery Potential Assessment for Rocky Mountain ridged mussel (*Gonidea angulata*)

Évaluation du potentiel de rétablissement de la gonidée des Rocheuses (*Gonidea angulata*)

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ABSTRACT

The Rocky Mountain ridged mussel *(Gonidea angulata)* is a freshwater bivalve mollusc that reaches the northern extent of its global distribution in southern British Columbia. *Gonidea angulata* is restricted to the Okanagan Basin with small aggregations present in the northeast and southwest areas of Okanagan Lake in addition to a few individuals encountered in Vaseaux Lake and the Okanagan River. Recent broad-brush surveys indicate that their range and distribution is decreasing and their numbers are in decline. The preponderance of large adult mussels and the apparent absence of small and/or young juveniles could indicate a relict or ageing population with limited reproductive potential. Potential or known threats and their impacts to habitat such as channelization of the Okanagan River, dams and weirs, development of shoreline and littoral zones, pollutants, introduced species such as Eurasian watermilfoil and dreissenid mussels, are evaluated and mitigation measures are discussed. Recommendations for future research are provided in an attempt fill knowledge gaps and to meet recovery objectives to sustain viable populations and prevent the extirpation of the Rocky Mountain ridged mussel in Canada.

RÉSUMÉ

La gonidée des Rocheuses *(Gonidea angulata)* est un mollusque bivalve d'eau douce. Le sud de la Colombie-Britannique correspond à la limite septentrionale de sa répartition mondiale. L'aire de répartition de la *Gonidea angulata* se limite au bassin de l’Okanagan; de petites concentrations sont présentes dans les zones nord-est et sud-ouest du lac Okanagan. En outre, on en retrouve quelques spécimens dans le lac Vaseux et la rivière Okanagan. De récentes études globales indiquent que leur aire de répartition et leur distribution connaissent un rétrécissement et que leur nombre est en déclin. La prépondérance des gonidées adultes de grande taille et l'absence apparente de petits et de jeunes gonidées pourraient être le signe d'une population relique ou vieillissante dont le potentiel reproductif est limité. Les menaces potentielles ou connues pour l'habitat de cette espèce, à savoir la canalisation de la rivière Okanagan, la construction de barrages et de déversoirs, l’aménagement des rives et des zones littorales, la présence de polluants et l’introduction d’espèces comme le myriophylle en épi et les moules de la famille des dreissénidés ainsi que des mesures d’atténuations sont à l'étude. On fournit des recommandations quant aux recherches à effectuer dans le but de combler les lacunes en matière de connaissances et d'atteindre les objectifs de rétablissement, c’est-à-dire le maintien des populations viables et la prévention de la disparition de la gonidée des Rocheuses au Canada.

1 INTRODUCTION

In 2003, the Rocky Mountain ridged mussel was designated as a species of special concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and under the Canadian Species at Risk Act (*SARA*). The status of the population was re-examined in November 2010, based on an updated COSEWIC status report, recent evidence of reduced abundance and distribution, and a risk assessment of dreissenid mussel infestation with expected potentially devastating impacts on native mussels in the Okanagan Basin as its most serious threat, it was designated Endangered.

The objective of this working paper is the compilation of background information to complete a Recovery Potential Assessment (RPA) for the Rocky Mountain ridged mussel. The completion of an RPA is a procedural requirement in the listing decision process for species at risk. The RPA provides the scientific background, identification of threats and probability of recovery of a species, or population that is deemed at risk. A detailed compilation of information, including details of recent surveys and assessments will be provided and published in an upcoming DFO manuscript report. The Request for Science Information and/or Advice provides detail on why this scientific information is needed and how it will be used, is provided in Appendix 1.

2 SPECIES BIOLOGY

The Rocky Mountain Ridged Mussel, *Gonidea angulata* (I. Lea, 1838), is a freshwater bivalve mollusc in the family Unionidae and is thought to be most closely related to the North American Subfamily Ambleminae (Heard and Guckert 1971; Davis and Fuller 1981; Graf 2002). Taxonomically and morphologically unique, *Gonidea angulata* is the only extant species in this genus and is consequently difficult to classify among the Unionidae (Graf 2002). Asian taxonomic affinities have been suggested based on a number similar anatomical characteristics (Heard 1974; Watters 2001), but no taxonomic and/or molecular studies have been conducted to confirm this relationship.

Clearly distinct from other freshwater mussels found in north western North America, *G. angulata* is a large, thick shelled (5mm) trapezoidal shaped mussel (≤ 125mm long, ≤ 65mm high and ≤ 45mm wide) with a sharp and prominent posterior ridge, hence the common name Rocky Mountain ridged mussel (Clarke 1981) (Figure 1). The periostracum, or outer shell, is commonly yellowish brown to blackish brown with obvious concentric growth lines or growth rests and the nacre, or inner shell, is centrally white or salmon coloured but pale blue along the outer posterior margin (Clarke 1981). Another distinguishing feature is the irregular and poorly developed hinge teeth; *Anodonta* species lack hinge teeth altogether while *Margaritifera falcata* teeth are more prominent in comparison to *G. angulata.*

All freshwater mussels of the order Unionoida possess a unique life history trait; an obligate parasitic larval stage (glochidia) during which they depend upon the availability of a fish host to complete their reproductive cycle (Neves et al. 1985). Female unionids brood glochidia in a modified portion of their gills, called marsupium and will expel glochidia using a wide range of species dependant mechanisms to find, attract and attach to a suitable fish host (Kat 1984; Neves and Widlak 1988; Haag et al. 1995). Some species will produce packages of glochidia surrounded by mucous called conglutinates (Kat 1983) while other species modify their entire gill to produce superglutinates that mimic fish prey or small fish to lure hosts (Haag et al. 1995). Once a suitable host is found, the larvae will attach to the gills, fins or scales of the fish (encystment) develop into juvenile mussels after a short period of time, ranging from a few days to months, and will then release themselves (excystment) to begin a free-living benthic lifestyle (Strayer 2008). Mussels are considered to be either host generalists- parasitizing a wide variety of fish (Trdan and Hoeh 1982), or host specific- parasitizing one to a few closely related species (Zale and Neves 1982; Yeager and Saylor 1995). The loss, decline or displacement of natural fish populations may therefore, adversely affect freshwater mussel populations by limiting their dispersal, chances of recruitment, reproductive success and overall fecundity.

G. angulata is considered to be a short term brooder (tachytictic) where spawning begins in spring, when water temperatures exceed 10-12°C, and hookless glochidia are released during the same season (Spring Rivers 2007). The exact mechanisms by which *G. angulata* expel glochidia and attract host fish are unknown. Although *G. angulata* are thought to release free glochidia, conglutinates have been observed in Okanagan Lake (Lee pers. comm. 2008; Heron pers. comm.). Puerile conglutinates, or immature eggs released prematurely due to stress, may explain what was seen in Okanagan Lake as they are described as white, leaf-like and are joined together in small groups (Barnhart et al. 2008). A recent study in California conducted by Spring Rivers (2007) documented the occurrence of spawning, glochidial release and periods of encystment and excystment for *G. angulata*. Gravid females were observed in California from early April to mid-July and glochidia were found on host fish from late March to late July/ early August, however seasonal timing of reproduction may vary regionally and locally (Spring Rivers 2007). Similar studies focussing on the reproductive timing of *G. angulata* populations have not been conducted within their Canadian range.

G. angulata appears to be a host generalist, parasitizing a wide variety of fish. Confirmed fish hosts for *G. angulata* in northeastern California include the Pit sculpin (*Cottus pitensis*), Tule perch (*Hysterocarpus traski*) and hardhead (*Mylopharodon conocephalus*) (Spring Rivers 2007), but all three of these species are absent for the Okanagan Drainage Basin. Unconfirmed fish species include the torrent sculpin in Oregon and the Sacramento pikeminnow, Pit roach, rainbow trout, green sunfish, black crappie and mosquito fish in California. Of these species, only the black crappie (*Pomoxis nigromaculatus*), rainbow trout (*Oncorhynchus mykiss*) and torrent sculpin (*Cottus rhotheus*) occur in the Okanagan Basin and could serve as potential fish hosts in southern British Columbia.

3 ECOSYSTEM ROLE

During the broad brush surveys conducted for *G. angulata*, a number of other freshwater mussels species (anodontids and margaritiferids) were encountered either in isolation from *G. angulata*, in close proximity to, or coexisting with *G. angulata* (L. Stanton pers.obs.). The previous mussel community structure that existed before developmental pressures is unknown. The survival of a predominance of *G. angulata* in close proximity to development activities as seen by the aggregations near Summerland and Vernon, may be due to its tolerance of increased siltation over other mussel species.

Healthy mussel communities occur as multispecies assemblages in which positive species interactions are likely very important, such as enhanced resource acquisition, resource quality, habitat stability, juvenile survival and glochidia fish host attraction. There are two under-lying processes in multi-species mussel communities: competition and facilitation, and the net effect may change over different scales (Vaughn et al. 2008). Rare mussels have been shown to benefit from being a component of multi-species assemblages by having higher body condition and lower mass-specific metabolic rates than those occurring in species-poor assemblages (Spooner 2007 as cited in Vaughn et al. 2008). Bivalves affect the nutrient dynamics of freshwater systems by filtering algae, bacteria and particulate organic matter from the water column where it is incorporated in the growth of the burrowing animals or cycled into the sediments as faeces or pseudofaeces. In addition, bioturbation of sediments by mussel burrowing increases sediment water and oxygen content and releases nutrients form the sediments to the water column (Vaughn and Hakenkamp 2001). Molluscs have been described as ecosystem engineers, with their shells providing substrates for attachment of various epibionts and refugia from predation and stress. They control the transport of solutes and particles in the benthic environment. Changes in the availability of the resources resulting from shell production have important consequences for other animals (Guitérrez et al. 2003). Across North America, Unionidae are declining at alarming rates. The significant loss of benthic biomass and the stability and diversity it provided is lost, and the invasion of exotic species may result in large alterations to ecosystem processes (Vaughn and Hakenkamp 2001). While restoration and recovery of single imperilled species is to be commended, it may not be very effective at maintaining community and ecosystem function. Restoration and recovery efforts should focus on the restoration and recovery of whole communities, rather than individual species, in order to restore ecosystem function (Vaughn et al. 2008).

The mandated focus of this RPA is for single species recovery, that of *G. angulata*. However, there are ecosystem components that need to be addressed in the single-species recovery efforts, but a larger issue is the recovery of a component of overall ecosystem function. Habitat partitioning and succession has been seen between *G. angulata* and *Margaritifera falcata* in aggrading river habitats due to effects of logging and mining (Vannote and Minshall 1982). There is evidence in the scientific literature that *G. angulata* is more tolerant than other freshwater mussel species of developmental pressures resulting in increased nutrients, contaminants and siltation. What may be seen in the Okanagan Basin are not only relict populations of a relatively rare mussel, but the last remnants of once-healthy diverse mussel communities that served important ecosystem functions.

4 ASSESSMENT

4.1 PHASE I: ASSESS CURRENT/RECENT SPECIES STATUS

4.1.1 Range, number of populations and abundance

Gonidea angulata is restricted to the Pacific drainages of western North America (Graf 2002). Historically, its range extended from southern British Columbia to southern California and eastward to Idaho and Nevada (Figure 2). Once common throughout California, it is now considered extirpated from the Central Valley and southern portions of the state (Taylor 1981). Abundant populations occur in the large tributaries of the Snake and Columbia River in Washington, Idaho and Oregon, however a reduction in its original range has also occurred in the Snake River (Frest and Johannes 1995). Currently, extant populations are found in southern British Columbia, Washington, Oregon, southern Idaho, northern Nevada and California (COSEWIC 2003).

Within Canada, *G. angulata* reaches the northern limit of its global range with populations in the Okanagan basin in southern British Columbia accounting for approximately 5% of its global distribution (COSEWIC 2010). According to Clarke (1981), *G. angulata* is thought to occur in the Columbia River system which includes the Okanagan and Kootenay Rivers, however despite a considerable amount of search effort no specimens have been observed in the Kootenay region (Table 1 and Figure 3). (COSEWIC 2010). Recent surveys conducted from 2005-2008 by the British Columbia Ministry of Environment (MoE) staff focussed its search effort in five specific areas including: Vancouver Island, the Similkameen Basin, Okanagan Basin, the Kootenay Boundary (Kettle River east to Christina lake and the central and east Kootenays. Live specimens have only been observed within the Okanagan Basin and relatively large aggregations as well as sporadic numbers of individuals (live and/or dead shell) have been documented from Okanagan Lake, Okanagan River, Skaha Lake, Vaseaux Lake, Osoyoos Lake and Park Rill Creek (COSEWIC 2010).

The current observed range of *G. angulata* in southern British Columbia is exclusively within the Okanagan River watershed with live specimens observed from north Okanagan Lake in Vernon south to Okanagan River (Figure 4)(Fisheries and Oceans Canada 2010). The highest concentration of *G. angulata* specimens are found in Okanagan Lake from Crescent Beach to just south of Kinsmen beach in Summerland, BC consisting of four separate aggregations (Crescent beach, north of Summerland Boat launch, Dog Beach and Kinsmen Beach) (L. Stanton pers. comm.). Occupying an estimated area of approximately 95m^2 over several hundred meters of the littoral zone, these aggregations, given their close proximity, are likely part of a single continuous but sporadic population (R. Lauzier pers.obs.). Few mussels have been observed outside this described area, most notably small aggregations were discovered on Okanagan Lake near Vernon, Okanagan River and Vaseaux Lake based on the most recent surveys conducted by DFO in 2008 and 2009 (Figure 4). From these recent surveys evidence indicates that their range may have decreased from previous years. For example, some known sites where empty shells were once found in both Osoyoos (1990) and Skaha Lake (from 1991-2006) were not observed in 2009 (L. Stanton pers. obs.).

Quantitative surveys conducted in collaboration with Fisheries and Oceans Canda (DFO) and the Ministry of Environment (MoE) in 2009 provide the first available information and preliminary estimates for population abundance and density of *G. angulata* in Okanagan Lake (L. Stanton pers.comm.). The total estimated population at Dog Beach in Summerland, BC is 1,130 individuals with maximal densities of 8 mussels/m^2 and a average density of 0.49 mussels /m^2 over a 2,313 m^2 survey area (Table 2) (L. Stanton pers. comm.). Similar quantitative studies conducted in Washington State revealed populations with densities as high as 16 mussels /m^2 in the Okanogan River and densities as low as 0.04 mussels/m^2 in the lower Granite Reservoir (T.J. Frest, unpublished data, as cited within COSEWIC 2010). Densities in the Salmon River Canyon, Idaho ranged from 5.5 to 183 mussels /m^2 depending upon substrate composition (Vannote and Minshall 1982) and densities as high as 575 mussels/m^2 where observed in the Middle Fork John Day River in eastern Oregon (Brim Box et al. 2006).

Although quantitative surveys were not conducted in other areas of suspected or known *G. angulata* aggregations, exploratory surveys utilizing a timed search method counted the number of live specimens while snorkelling in Okanagan Lake (Beachcomber Beach in Vernon and Crescent Beach, north of Summerland Boat Ramp, Dog Beach and Kinsmen Beach in Summerland) Okanagan River and Vaseaux Lake (L. Stanton pers. comm.). The largest number of live *G. angulata* specimens were found in the Summerland area accounting for more than 88% of all individuals observed (Table 1).

4.1.2 Recent species trajectory

Specific information on the biology, ecology, abundance and distribution of *G. angulata* is limited and until recently, little work has been done to determine their exact range and abundance in southern British Columbia. Therefore, due to this lack of data it is difficult to establish and evaluate current population trends or recent species trajectories for abundance, range and number of populations. As described above recent surveys indicate that their range may have decreased from previous years. Further surveys should concentrate on areas such as Skaha and Osoyoos Lake to confirm if *G. angulata* is present or if it has become locally extirpated.

From recent surveys, *G. angulata* appears to be sporadically distributed and limited to the Okanagan Basin. What was particularly striking to surveyors was the amount of dead and old shell seen during broad brush surveys. Dead shell was found in 14.5% of all sites searched within the Okanagan Basin in 2009, but most sites with live *G. angulata* specimens had a large proportion of dead shell compared to live shell. There is a paucity of live specimens in Skaha Lake, Vaseaux Lake, Osoyoos Lake and the Okanagan River south of Vaseaux Lake (L. Stanton pers. comm.), and the numbers seem to be dwindling from previous surveys (COSEWIC 2003; Fisheries and Oceans Canada; COSEWIC 2010). There were very few (7) small and medium sized mussels detected at the most populous sites in the Summerland area, but considerable accumulations of large adult dead shells, indicating these may be relict aggregations of previous population(s).

It is not known if there is undetected reserve aggregations at depth, as all of the surveys were limited to depths reached by snorkeling. There were indications from snorkel divers (S. Pollard pers. comm. D. Biffard pers. comm.) that the mussel beds in the Summerland area and Vaseaux Lake extend beyond snorkeling depths.

4.1.3 Life history parameters

Limited information is available on specific life history parameters such as mortality, fecundity, age at maturity, longevity and recruitment for *G. angulata* and for many freshwater mussels in general. The majority of freshwater mussels are extremely long-lived with many species reaching a maximum age of over 50-100 years (Strayer el al. 2004). Based on growth ring counts, *G. angulata* is thought to reach a lifespan of 20-30 years (COSEWIC 2003) however, recent evidence suggests that age estimates calculated using growth rings may greatly underestimate longevity (Anthony et al. 2001). While the exact lifespan of *G. angulata* remains unknown, studies conducted by Vannote and Minshall (1982) and Frest and Johannes (2006) have reported maximum ages of 24 and 60 years old, respectively. Although total and natural mortality have not been studied for this particular species, unionids exhibit extremely low juvenile survivorship and high adult survivorship. Glochidia that survive to the 1-2 year stage is estimated to range from 10 to 18,000 individuals in some species (Jansen et al. 2001), whereas mortality rates among adults is thought to range between 5-19% and is thought to decline drastically after mussels reach sexual maturity (Negus 1966; Zale 1980 as cited in Neves and Widlak 1987). The age of maturity for most freshwater mussels is thought to occur between 6-12 years of age and average fecundity (young/average adult/breeding season) reportedly ranges from 200,000-17,000,000 (Paterson 1985; Young and Williams 1984 as cited in Thorp and Covich 1991). High glochidial mortality results in extremely low fecundity and greatly reduces chances for successful recruitment in unionid populations. In some freshwater mussel populations successful recruitment occurs once every 5-10 years, while other populations recruitment may occur every year (Payne and Miller 2000; Strayer et al. 2004).

4.1.4 Habitat requirements and habitat use patterns

Strayer (2008) proposes the following functional characteristics of suitable mussel habitat:

1. Flows allow juveniles to settle and instream shears are not excessive during juvenile attachments;
2. Bottom substrate suitable penetrability and support, i.e. soft enough for burrowing, yet firm enough for support;
3. Substrate stability to ensure no movement during floods and no sudden scour or fill;
4. Provides adequate and suitable food, such as sediment organic matter for juveniles and overlying current provides suspended matter for adults;
5. Provides essential materials for metabolism and growth, such as oxygen and calcium;
6. Provides favourable temperature for growth and reproduction;
7. Provides protection from predators such as interstitial spaces for juveniles;
8. Contains no toxic materials

Species-specific information for *G. angulata* shows they are found in shallow waters (typically <3m), and in a variety of substrate types and water velocities (Clarke 1981; COSEWIC 2003; Spring Rivers 2007). In the United States they primarily occur in rivers, creeks, and streams of various sizes, but are rarely found in lakes or reservoirs unless with substantial flow (Frest and Johannes 1995). Conversely, in Canada, *G. angulata* are more commonly found in lakes, such as Okanagan and Vaseaux Lakes, and only a few specimens have been observed in Okanagan

River and Park Rill Creek (COSEWIC, 2010). It is thought that *G. angulata* prefer areas that exhibit stable habitat conditions avoiding areas with shifting substrates, extreme water or oxygen fluctuations, high turbidity, or seasonal hypoxia or anoxia (COSEWIC 2003). According to the 2003 COSEWIC report, *G. angulata* requires cold, clear, oligotrophic waters with constant flow and well-oxygenated substrates. In addition, the COSEWIC 2003 report states that this species has a reduced tolerance to nutrient loading, siltation and low flow yet other studies indicate that *G. angulata* may be more pollution tolerant than other species (Frest and Johannes 1995), and is also thought to be better adapted to aggrading rivers, where an increase in land elevation occurs due to sedimentation (Vannote and Minshall1982).

Similar to studies conducted in California, *G. angulata* in southern British Columbia is often found in a variety of substrates ranging from sand and silt where specimens are deeply borrowed into the substrate with only their siphons exposed or wedged between cobbles and boulders (Spring Rivers 2007; L. Stanton pers. obs.). Within the Okanagan Basin live *G. angulata* were most abundant in cobble, sand and silt along the littoral zone of Okanagan Lake in the Summerland area (L. Stanton, pers. obs.). Okanagan Lake is a large oligotrophic lake considered to have significant wave and seiche action along exposed shorelines to create substantial flow regimes similar to riverine habitats where *G. angulata* commonly occur in the United States (S. Pollard pers. obs., as cited in COSEWIC 2010). In contrast, specimens in Vaseaux Lake and North Okanagan Lake near Vernon were found in muddy sand substrates at depths greater than 7.5 meters (S. Pollard pers. comm.). While *G. angulata* are typically found in shallow waters, live specimens have been encountered at depths between 10-20 meters in the Lower Granite Reservoirs in Washington and the Lower Columbia River in Washington and Oregon (COESWIC 2003). Attempts to venture into deeper depths in Okanagan Lake with a submersible video camera in 2008 and snorkelling surveys in 2009 proved to be ineffective for conclusively detecting live mussels, nevertheless future surveys should incorporate SCUBA diving to uncover potential populations at greater depths within Lakes in the Okanagan Basin (R. Lauzier pers. comm.).

No information regarding juvenile habitat requirements or habitat use patterns have been documented for this species. Juvenile freshwater mussels are small (<1 mm long), transparent and not calcareous (soft) making them extremely difficult to detect and therefore, few studies have described their habitat, behaviour or ecology (Neves and Widlak 1987). Juvenile mussels in lakes are primarily found in sandy substrates (Coker et al.1921; James 1985) whereas juveniles in rivers are found in coarse gravel and boulder with swift water currents (Coker et al. 1921; Neves and Widlak 1987). A few juvenile mussels were buried under approximately 5cm of sand at Dog Beach in Okanagan Lake (L. Stanton pers. obs.).

It is difficult to make comparisons between *G. angulata* habitat use in the Okanagan Basin and habitat use in the U.S. as the largest mussel aggregations in B.C. are in lacustrine habitats, yet the occurrence of *G. angulata* in the U.S. is mainly from riverine habitats, with the exception of Clear Lake in California (Taylor 1981, Cordeiro 2007).

Another challenge is the apparent wide diversity of habitats in which *G. angulata* are found in the Okanagan Basin, from the shallow (1-3 m) gravel/cobble bars with overlying silt and deeper (2.5-4 m.) mud/sand/cobble with rooted macrophytes in Okanagan Lake and Vaseaux Lake. Single individuals were also found in depositional areas behind boulders in the Okanagan River (S. Pollard pers. comm.)

When encountered during 2008-2009 surveys, *G. angulata* were commonly observed in cobble, sand, silt substrate, often wedged between cobbles or buried completely within the sand in Okanagan Lake near Summerland (L. Stanton pers. obs.). Most mussels were found within 30m from shore and in shallow water with depths ranging from 0.25-1.5m. (L. Stanton pers.

comm.). In Vaseaux Lake and Okanagan Lake near Vernon *G. angulata* were found in muddy, silty substrates at depths greater than 7.5 meters (S. Pollard pers. comm.).

In riverine habitats (Salmon River canyon), *G. angulata* shared various habitat types with Western pearl shell mussel (*Margaritifera falcata*) ranging from boulder-controlled reaches (least preferred) to cobble/boulder shielded runs and sand and gravel bars (most preferred) (Vannote and Minshall 1982).

Although the host fish for the glochidia stage is unknown, it obviously plays an important role for successful recruitment and sustainable population levels. As a result the host fish may be considered a feature of critical habitat if *G. angulata* were to be listed under SARA.

4.1.5 Population and distribution targets

Setting population and distribution targets depend on the expected outcomes. Given the apparent trends of declining freshwater mussel populations throughout North America, extirpations of *G. angulata* in the middle of its range in the U.S. and how little is known on *G. angulata* biological parameters, it is unrealistic to expect full recovery to a status of not at risk. Due to the poissbile status of *G. angulata* as relict population(s) at the northern edge of its range in British Columbia, as a minimum, the prevention of *G. angulata* extirpation from the Okanagan Basin is the primary goal followed by a significant reduction in the risk of extirpation from the Okanagan Basin. This would be a 3-step process:

1. conserve the structure and abundance of the identified Summerland and Vernon Rocky Mountain ridged mussel aggregations and enhanced protection of the delineated habitat of the existing population(s);
2. ensure the continued sustainability of the identified Summerland and Vernon *G. angulata* aggregations by protecting/enhancing the ability of successful larval settlement and recruitment to the reproductive adult stage
3. re-establishment of self-sustaining *G. angulata* sub-populations/aggregations where only dead shell has been seen, in order to provide some stability to reducing the risk of extirpation.

Monitoring progress will require:

- annual quantitative relative abundance estimates at Summerland and Vernon to monitor abundance trends with a degree of certainty and assess the impact of protective measures;
- periodic estimate of recruitment to the Summerland and Vernon populations to assess the viability of several age classes promoting sustainability of the populations and reducing the risk of extirpation;
- periodic broad-brush presence/absence surveys at previously observed/historic sites.

The ultimate goal in recovery processes is moving towards a status classification of lesser risk. This will be particularly challenging with *G. angulata*, considering the past historical damage to habitat, developmental pressures, potential threats from invasive species, and the lack of sufficient biological information to design a biological program to increase productivity and expand the distribution.

4.1.6 Expected population trajectories and time to recovery

The following biological information is needed for a biological management plan in support of preventing extirpation and reducing the risk of extirpation:

1. Evaluation of glochidia dispersal by host fish, as the fish host is unknown in the Okanagan Basin. Evidence of conglutinate production seen at the Summerland site, but no effort has been made at other sites.
2. Minimum viable population size
3. Assessment of predator pressure and assessment of sources of mortality
4. Assessment of microhabitat features that support *G. angulata.*

Assuming three generations required for stability and/or recovery, with estimated generation time of 15 years and reported maximum age of 22-24 years from U.S. studies, evidence of stable naturally reproducing populations or recovery to previously existing self-sustaining populations in the Okanagan Basin is expected to take 50-70 years.

The only available information on *G. angulata* naturally increasing in abundance is in a river impacted by sedimentation as a result of mining and forestry activities is over a 60 year period (Vannote and Minshall 1982). In this case *G. angulata* replaced *Margaritifera falcata* as the dominant species due to increased stream siltation.

4.1.7 Residence requirements

SARA defines "residence" as a dwelling-place, such as a den, nest or other similar area or place, that is occupied or habitually occupied by one or more individuals during all or part of their life cycles, including breeding, rearing staging, wintering, feeding or hibernating. (SARA 2003).

DFO (2010) provides further guidance on defining "residence" as " Individuals (not a population) should make an investment (e.g., energy, time, defense) in the residence and/or invest in the protection of the place and structures that are the residence (and not just protecting the individual, its mate and/or its young)." There is no indication that *G.angulata* meets these criteria and as a result the issue of residence does not apply.

4.2 PHASE II: SCOPE FOR MANAGEMENT TO FACILITATE RECOVERY

4.2.1 Probability that the recovery targets can be achieved

Knowing the fish host(s) of *G. angulata* glochidia would greatly enhance recovery planning and conservation programs for this species as well as providing important information on the abundance and distribution of these mussels within the Okanagan Basin. As stated previously, freshwater mussels depend upon the availability of a suitable fish host to complete their reproductive cycle. This is their only form of dispersal, therefore, a loss or decline in natural fish populations may reduce their chances of successful recruitment, decrease their reproductive success and overall fecundity. Other life history parameters for this species are largely unknown. Consequently, without adequate information it would be extremely difficult to ascertain which parameters would influence the likelihood and time for recovery for this species. Freshwater mussels in general are long-lived and slow-growing making them particularly sensitive and slow to recover from chronic stressors such as pollution (Strayer et al. 2004). Successful recruitment maybe the limiting factor inhibiting their recovery as many unionid populations are known to persist for long periods of time with negative population growth (Strayer et al. 2004).

Virtually all *G. angulata* specimens encountered during quantitative surveys conducted at Dog Beach, Summerland were >70mm long, with only seven juveniles observed (L. Stanton pers. comm.). The absence of juveniles could indicate a relict or aging population that could be considered functionally extinct or may represent an "extinction debt" (Tilman et al. 1994), where populations have ceased reproducing (Bogan 1993; Cosgrove et al. 2000). Based on the very limited biological information available for this species, research indicates that mortality rates for adults are considered extremely low and the intrinsic rate of increase is also likely very low, therefore the potential for recovery with increased productivity are achievable only over a long time period (~50-70 years)

Strayer (2008) outlines challenges in the ability to predict distribution and abundance of unionoid mussels in stream reaches, both from the perspective of suitable models and from the extensive information requirements for the models. In the case of *G. angulata* in the Okanagan Basin, there is the further complication and challenge of assessing the probability of success in a lacustrine ecosystem where the majority of *G. angulata* are found. While the principles or prediction may be similar between riverine and lacustrine ecosystems, the mechanism of mussel-fish host interactions is likely very different.

In the absence of biological productivity information to inform a management plan, and lack of suitable models with the information required to predict abundance and distribution of *G. angulata*, determining the probability of success is dependent on the elimination or mitigation of limiting factors and threats.

4.2.2 Magnitude of each major potential source of mortality

Channelization of the Okanagan River

There have been solitary *G. angulata* found in the remaining natural section of the Okanagan River, indicating their established presence and habitat suitability of what little habitat remains. What is not known is the distribution and abundance of *G. angulata* before channelization and dredging. Assuming *G. angulata* was in the natural sections, the activities of channelizing and dredging had severe detrimental impacts on Strayer's (2008) first three functional characteristics of suitable mussel habitat, namely: suitable flows allow juveniles to settle and instream shears are not excessive during juvenile attachments; bottom substrates suitable for penetrability and support; and substrate stability to ensure no movement during floods and no sudden scour or fill. Broad brush surveys for *G. angulata* indicate a degree of depositional material is required for the species, yet the purpose of channelizing and dredging is to change river hydrology to minimize depositional processes.

Channelizing the Okanagan River reduced the total length by one third, which resulted in a steeper channel (Rae 2005). Common unmodified river features such as riffles, pools, cutbanks, islands, side channels, eddies and woody debris have largely disappeared from most of the Okanagan River. Only 4 kilometers of the original 61 kilometers remains in a natural or semi-natural state, resulting in the removal of 93% of natural river habitat (Rae 2005). Channelizing the river not only severely impacted mussel habitat as outlined above, but also detrimentally impacted potential glochidia fish host habitat by reducing instream habitat complexity and changing river hydraulic characteristics. Building dykes resulted in the removal of an estimated 85% removal of riparian vegetation (Rae 2005). As a result, elevated water temperatures may be beyond the maximum tolerance for native fish and may have lethal effects on mussels or sublethal effects by reducing reproductive success and growth (Strayer 2008)

Dams and Weirs

There are three dams on the Canadian portion of the Okanagan River: Penticton Dam at the outlet of Okanagan Lake; the Skaha Dam at the outlet of Skaha Lake at Okanagan Falls; and the McIntyre Dam, approximately 2 kilometres downstream of Vaseaux Lake. All dams were built with fish ladders, but they are not in use because of historical concerns about introduced species (Rae 2005). In addition, there is the Zosel Dam at the outlet of Osoyoos Lake in Oroville, Washington, which was upgraded in 2006 with state-of-the–art fish passage facilities (Osoyoos Lake Water Quality Society 2011). There are also nine large dams on the Columbia River downstream of the Okanogan River confluence which blocked the migration of some anadromous fish species that had been present according to Traditional Ecological Knowledge. While these fish species may or may not have been glochidia fish hosts, their contribution to in-stream organic nutrient input from spawned out carcasses may have been an important factor affecting mussel growth and reproductive success.

In addition to the three major dams, seventeen vertical drop structures or weirs were installed to reduce water velocities in the steeper modified river channel. Recently (2007), at least 100 live mussels of various sizes and with unusually heavily worn periostracum, were found between two weirs, indicating individuals were likely tumbled through dams and/or weirs and/or from sediment abrasion (Ramsay pers. obs. cited in COEWIC 2010).

Flow regulation by dams and weirs can be advantageous and/or disadvantageous to mussels. *G. angulata* populations in the U.S. are most often found in natural rivers headed by lakes, which have moderated flow regimes in comparison to stream-headed rivers. Depending on the purpose of the flow regulation as well as structure and magnitude of the regulated hydrograph, there could be an improved stability and moderated peak flows that would enhance and protect riverine mussel habitat. The effective use of fish passage structures could benefit glochidia dispersal, but this would require careful planning and operation to ensure the natural glochidia host fish are not out competed by potential invasive species. Because most of the *G. angulata* occur in lacustrine habitats in the Okanagan Basin, controlling the level of Okanagan Lake to protect the remaining populations of *G. angulata* is the most obvious advantage of flow control. Dams on many of the inlet streams of Okanagan Lake may be acting as nitrogen traps, as Okanagan Lake may be deficient in nitrogen (Rae 2005). This could be considered mitigative in conserving the oligotrophic characteristics (required by *G. angulata*) of Okanagan Lake, considering the amount of and type of development surrounding Okanagan Lake.

The disadvantages often seen as a result of flow control and flow control structures on mussel habitat include: fractionating riverine habitats; detrimental impacts on depositional processes; and detrimental changes to hydrograph. Depending on the structure and operations of the flow control structure, removing the ability of potential host fish to bypass barriers may result in too little habitat to support viable glochidia host fish populations and severely restrict the dispersal of glochidia past the barriers. Instream depositional processes may be impacted increasing beyond tolerable levels upstream of the dam and decreasing them to the point of scouring downstream of the dam, potentially leaving too small an area of suitable deposition to support *G. angulata*.

Development of Shoreline and Littoral Zones

Due to rapid growth in the Okanagan Basin over the past 70 years, there has been considerable alteration and loss of natural shoreline features and the littoral zone which likely impacted a portion of *G. angulata* lacustrine habitat. Whether this was the majority of *G. angulata* habitat is unknown, as the extent of habitat beyond lake littoral zones is unknown. Alteration of river shoreline and littoral zone was substantial, with 93% removal of the natural river habitat and reduction of total river length by one third (Rae 2005) (see **Channelization of the Okanagan River**).

Shoreline development and alteration of the littoral zone around the lakes for residential, commercial, industrial and recreational purposes may have resulted in a number of detrimental impacts on mussel habitat. As outlined in the channelization of the Okanagan River, removal of riparian vegetation often results in elevated water temperatures which could impact mussels as well as potential glochidia host fish. This may be exacerbated in the shallow areas of the lake littoral zone that doesn’t have the flow characteristics of moderately sloped river channels, possibly resulting in even higher temperatures than those seen in the rivers devoid of riparian vegetation. Fish commonly avoid areas of unsuitable temperature which could result in lessening the chance or opportunity of glochidia encystment by host fish. Local changes to light and temperature regime may also impact phytoplankton and aquatic vegetation growth (Strayer 2008). Dock construction and installation, dredging the littoral zone to establish access, and navigable channel maintenance all have potential detrimental lethal and sublethal effects by either direct contact and disturbance or by producing increased suspended materials beyond the tolerable range. Prop washing to reduce sediment accumulation in navigable channels may physically displace juvenile and adult mussels, as well as reduce organic matter to below the required levels for mussel sustenance. In total, 1,220 docks have been built on Okanagan Lake, which is 65% of all docks in B.C. (Rae 2005).

Agriculture developments including orchards, vineyards, food crops and livestock farms may contribute runoff and/or groundwater effluent containing fertilizers, herbicides and pesticides to the littoral zone, depending on the slope of the land, geological properties and proximity to the lake. Nutrient input from septic fields originating from shoreline residential development and campgrounds may contribute to localized littoral zone enrichment beyond the tolerable range of mussels. Altering the shoreline by bank armouring with retaining walls may change the energy dissipation characteristics of breaking waves to the detriment of mussel habitat by potentially de-stabilizing the organic flocculent layer overlying the gravel and cobble, as well as displacing any juveniles in sand or silt. Replacement of natural riparian vegetation with lawns and sand may increase littoral zone temperatures as well as increased ammonia and nitrogen loading as reported by Morris and Corkum (1996). Ammonia is particularly toxic to mussels (Strayer 2008), especially at the glochidia stage. Adding sand to the shoreline may result in washouts altering mussel habitats by infilling interstitial spaces or smothering resident mussels.

One of the largest aggregations of *G. angulata* is in the littoral zone off Dog Beach and adjacent Summerland Beach, where sand has been dumped and spread. It is not known if this has decreased the abundance and distribution of mussels from historic levels. As outlined in COSEWIC 2010, in the Okanagan Region, a number of activities potentially detrimental to mussel habitat, such as the creation of beaches, dumping of sand and removal of littoral vegetation are considered illegal and almost all require permitting under the *B.C. Water Act*. However, a recent compliance study of developed sites on Okanagan Lake and Skaha Lake showed non-compliance was almost 100% (Robbins pers. comm. as cited in COSEWIC 2010). In addition, an estimate of Okanagan Lake shoreline alterations in the mid-1990s showed that 80% of the southwestern and northern shores had been altered, mainly by house, road and dock construction (Rae 2005), which is in the area of greatest concentration where *G. angulata* have been found in surveys.

Pollutants

Developmental pressures in the Okanagan Basin may also have contributed to mussel habitat degradation by chemical pathways as well as by physical means outlined above. There are three mechanisms by which pollutants may impact mussels: ammonia; nutrient enrichment; and compounds with a high affinity to for suspended particles or sediments; and endocrine disruptors (Strayer 2008). High nitrogen levels coupled with the morphology and elevated temperature profile of Osoyoos Lake has led to very extensive algal growth on the bottom substrate in the summer as well as oxygen depletion as the organic matter decomposes (Rae 2005). Ammonia is also produced from the decomposition of organic matter (Strayer 2008) and usually the predominant of inorganic nitrogen in low-oxygen or anoxic environments (Wetzel 2001 cited in Strayer 2008). Before extensive development around Osoyoos Lake, mussels (unknown species) were commonly seen in several areas along the littoral zone (B. Shepherd pers. comm.). In the north basin of Osoyoos Lake, there is a temperature-oxygen squeeze that occurs in the summer, restricting fish to the middle of the water column (16-18 m) (Rae 2005), which may restrict potential glochidia dispersal and survival. It is not known if the bottom oxygen depleted waters impact *G. angulata* habitat, as their distribution at depth is unknown.

The use of pesticides (current and past) in agricultural practices may have introduced contaminants that are toxic to mussels. Acute toxicity testing of two current use herbicides (atrazine and pendimethalin), two insecticides (fipronil and permetherin) and three fungicides (chlorothalonil, propiconazole, and pyraclostrabin) on the glochidia of five mussel species and juveniles of two mussel species from the southern U.S. showed particular species sensitivity to two of three fungicides tested (Bringolf et al. 2007). There was the identified need to pursue chronic exposure tests on survival and growth of juvenile mussels. Two common pesticides formerly used in agricultural application, aldicarb, a carbamate pesticide and acephate (Orthene), an organophosphate pesticide have been shown to have low-level sublethal effects on cholinesterase activity on the adductor muscle of freshwater mussels, thereby reducing their shell closure responsiveness. Other endocrine disruptors include human and agricultural pharmaceutical products, tributyl tin anti-fouling paints and residuals from detergents (Strayer 2008). These contaminants may not only impact mussel reproduction (Blaise et al. 2003 cited in Strayer 2008; Gagné et al. 2004 cited in Strayer 2008), but also potential fish host reproduction (Kidd et al. 2007).

Copper sulfate was a commonly used herbicide in swimming pools and beaches for the control of aquatic invasive plants and algae in many areas of North America, but its past use in the Okanagan Basin is unknown. Juvenile freshwater mussels from the southern U.S. were chronically sensitive to copper from copper sulfate and ammonia at lower levels than the1996 U.S. EPA hardness-dependent water quality criterion for copper and the 1999 pH and temperature-dependent water quality criterion for ammonia (Wang et al. 2007). Glochidia larvae of freshwater mussels in southern Ontario are extremely sensitive to copper, depending on the dissolved organic carbon and hardness (Gillis et al. 2008).

Many contaminants (metals, organochlorines, polychlorinated biphenyls and polyaromatic hydrocarbons) that are not soluble in water have a high affinity to binding to suspended material and sediments. Concentrations of these contaminants may be orders of magnitude greater in the sediments than in overlying water. Juvenile mussels living in the sediments and deposit feeding are exposed to much higher levels of these contaminants than adult mussels (Strayer 2008), and because of their small size, their body burden is that much higher. These types of compounds are not readily released from the sediments and there persistence and continued impacts could affect the recovery of mussels for an extended period of time.

Other Introduced Species

Fourteen introduced fish species live in Okanagan Basin Lakes but not all species live in all lakes (Rae 2005). Okanagan Lake has 21 fish species, 5 of which are not native. Skaha Lake has 19 fish species, 6 of which are not native and Osoyoos Lake has 27 species of fish with 10 confirmed non-native species and the possibility of another 3 reported but unconfirmed introduced fish species (Rae 2005). Within the Okanagan River, there are 15 native fish species and 7 introduced species. There are Traditional Ecological Knowledge reports on an extensive distribution of sockeye and Chinook salmon compared to the present day and the historical presence of steelhead trout. There are also unconfirmed reports on the presence of chum, pink and coho salmon that were blocked from migration by the Rock Island Dam on the Columbia River from 1939-1943 (Rae 2005). The potential competitive pressure of introduced fish species on native glochidia host fish is unknown. The selectivity of glochidia to fish hosts is unknown, although from the reported number in the literature, they are suspected to be generalists. However, a change of glochidia fish hosts may affect the success of glochidia attachment and metamorphosis to juvenile mussel stage (McNichols et al. 2011).

First introduced to Okanagan Lake as a food source for Kokanee salmon, *Mysis relicta*, a small freshwater shrimp was found to compete with fish for food. They have been directly linked to the decline of Kokanee salmon, and have since been found in varying numbers throughout the

Okanagan Basin (Rae 2005). The impact of food chain alteration resulting in the decline of fish and change in nutrient levels is unknown on *G. angulata*.

Likely the best known and most highly visible introduced species, Eurasian watermilfoil *Myriophyllum spicatum*, is an aquatic plant that grows quickly and spreads throughout the shallow littoral zone. It was first seen in Okanagan Lake in 1970, and has since spread to Skaha Lake, Vaseux Lake and Osoyoos Lake, as well as the Okanagan River (Rae 2005). Some potential impacts of milfoil proliferation on *G. angulata* include: increased siltation by entrapment and reduced capacity for silt clearance by wave action and currents; changes in fish distribution and reduced capacity for glochidia dispersal; changes to light regime and plankton productivity; and accumulation of large amounts of decaying organic matter on the bottom with seasonal vegetation die-backs. Eradication and control of milfoil uses two methods in the Okanagan Basin. The least obtrusive method is harvesting by mowing with underwater cutter blades about 2 m below the surface during the summer close to peak seasonal biomass. The second method is rototilling with specially designed equipment which operates at water depths up to 4.5 m to penetrate and work into the top 10-20 cm of the bottom substrate displacing the roots (Okanagan Basin Water Board 2011). This usually carried out from November to April to take advantage reduced survival of dislodged and remaining root survival in cold water (Okanagan Basin Water Board 2011). However, this type of activity occurs at or near *G. angulata* habitat (Dunbar 2009; B.C. Conservation Data Centre 2008 cited in COSEWIC 2010). This also occurs during a time when freshwater mussels are least likely able to cope with habitat changes, dislodgement or relocation due to reduced metabolism at lower temperatures (Mackie et al. 2008). Since the inception of the milfoil program the emphasis has changed from cut harvesting to rototilling, as the latter is considered most effective (Okanagan Basin Water Board 2011). While there has not been a targeted study on the impacts of rototilling on mussels, field observations showed no mussels were present in an area that had been rototilled, yet there was an abundance of mussels in a nearby area that had not been rototilled (COSEWIC 2010).

Dreissenid mussels

While zebra mussels (*Dreissena polymorpha*) and quagga mussels (*Dreissena rostriformis)* have not yet been detected in the Okanagan Basin, they are likely the greatest potential threat to resident *G. angulata*. Both species of dreissenid mussels became established in Eastern North America in the 1980s and zebra mussels in particular has become one of the most widespread and abundant freshwater animals (Strayer 2009). The overall impact of dreissenid mussels on resident unionids is well documented (Schloesser et al*.* 1996; Ricciardi et al. 1998).

The most recent USGS distributional information (Figure 5) shows live zebra mussels have proliferated from the Great Lakes to an extensive distribution throughout the northeastern U.S., the Mississippi basin and have been seen in Utah, Colorado and central California. Quagga mussels have become established in the Lake Mead National Recreational Area in Nevada (Hickey 2010), and have been seen in southern California, Utah, New Mexico and Colorado (USGS 2011). As can be seen in Figure 5, reports of mussels on boats or trailers have occurred much closer to the Okanagan Basin. In the past 10 years, there have been at least twelve documented reports of boats being trailered from known dreissenid mussel infested in the western U.S. (COSEWIC 2010). Since 2007, there have been at least three reported incidents of mussel-infested boats travelling into B.C. (Herborg, pers. comm. cited in COSEWIC 2010). A susceptibility analysis of Okanagan Lake to zebra/quagga mussel infestation was conducted based on nine water quality parameters for the COSEWIC Mollusc Species Subcommittee. The risk potential was ranked high in seven of nine water quality parameters with an overall result of a high risk of dreissenid mussels not only surviving in some parts of Okanagan Lake, but also with a high potential for massive infestations (Mackie 2010).

Okanagan Lake has one of the highest and most widespread uses of recreational boating in B.C., based on the number of docks and marinas. (see **Development of Shoreline and Littoral Zones**). The Okanagan region has also evolved into an important tourism and recreation destination, increasing the likelihood of dreissenid mussel introduction to the Okanagan Basin through recreational boating; the major vector to their spread throughout the U.S. Attempts to curtail quagga mussel proliferation in the Lake Mead National Recreational Area failed despite an early-detection program, a clear operational mandate, sufficient funding and access to the best available science (Hickey 2010). Given the high risk potential derived from water quality parameters, the high profile of recreational boating and tourism access, as well as the failure to prevent dreissenid mussel proliferation in the U.S. despite a dedicated program, the risk of future dreissenid mussel establishment and proliferation in the Okanagan Basin is high. Extensive monitoring programs both for prevention and for early detection is a necessity. In addition, coordinated contingency and operational plans need to be formulated to prevent a potentially catastrophic ecological shift in the Okanagan Basin lakes and rivers.

4.2.3 Likelihood that the current quantity and quality of habitat is sufficient

The likelihood that the current quantity and quality of habitat is sufficient to allow recruitment and stability at present levels is difficult to evaluate as basic biological requirements, micro-habitat preferences, and quantifiable tolerances of *G. angulata* are unknown. Evidence from the recent past of declining abundance or absence from previously reported areas, indicates the species is in decline with reduced survival. Also, there is very little evidence of recruitment indicating either the existing pressures are too great and/or the present habitat supporting the existing population(s) is not of sufficient quantity or quality to support the sustainability and continued survival of *G. angulata*.

4.2.4 Magnitude by which current threats to habitat have reduced habitat quantity and quality

Channelizing and dredging the Okanagan River has devastated river habitat for *G. angulata* with a 93% loss of natural river channel. Not only has this reduced the physical habitat of *G. angulata*, but it has no doubt altered the habitat of glochidia host fish species, likely resulting in their displacement by the major changes in riverine habitat characteristics.

In Okanagan Lake, alteration of an estimated 80% of shoreline and littoral zone where mussels presently occur, likely has had a major impact, but not to the same degree as the riverine habitat losses. The only remaining extensive *G. angulata* aggregations are in two areas of Okanagan Lake. Most of the Skaha Lake shoreline has been altered by road, railway or residential development. During the field searches of 2008 and 2009, only old dead shell was found in Skaha Lake. Osoyoos Lake has higher nutrient levels that either Okanagan Lake or Skaha Lake, resulting in a very productive (mesotrophic) lake with extensive algal growth (Rae 2005). Despite the mesotrophic characteristics of Osoyoos Lake, a single live specimen of *G. angulata* was found in the littoral zone of the north basin in fall 2010 (L. Nield pers. comm.).

For future potential habitat losses, a risk analysis for dreissenid mussel infestation indicates the risk is high (Mackie 2010, see **Dreissenid mussels**), and could have catastrophic impacts as seen in other areas (Strayer 2009, Hickey 2010).

4.3 PHASE III: SCENARIOS FOR MITIGATION AND ALTERNATIVE TO ACTIVITIES

4.3.1 Inventory of mitigation measures

Improvement of water quality has resulted from the operation of sewage treatment plants to remove most of the phosphorous from effluents (Rae 2005). This assists in conserving the oligotrophic characteristics of Okanagan Lake in spite of developmental pressures surrounding

Okanagan Lake. The B.C. Ministry of Environment monitors nutrient levels in all Okanagan Basin lakes in spring, summer and fall.

There is real potential for management of Okanagan Lake levels to protect existing *G. angulata* populations with Fish Water Management Tool (FWMT) (Kim Hyatt pers. comm.); a computer model that incorporates all the available information on impacts from dam operation on specific aquatic biota (currently sockeye and kokanee salmon). It is used to assist water managers in managing flow releases through the Penticton Dam at the outlet of Okanagan Lake. The depth of the shallowest mussels in Lake Okanagan or Okanagan River segments could be converted to stage height, and the potential for protection of the existing mussel beds could be flagged within FWMT by a minimum stage height risk of loss threshold indicator for the most vulnerable colonies of mussels (i.e., in Okanagan, Skaha or Osoyoos Lakes and various stretches of the Okanagan River between these lakes).

The Okanagan River Restoration Initiative (ORRI) has a phased approach to restoring natural river habitat conditions by providing access to the old river channel from a channelized portion of the of the lower river in the vicinity of the town of Oliver. The first phase is a demonstration project and the second phase will open up a greater portion of the former natural portion of the river. The benefits of the ORRI are reduction of flood stage and instream flow velocities, fine sediment deposition on the floodplains, increased stability and quality of spawning gravel, improved water quality, improved aquatic habitat for salmonids and whitefish, and improved riparian habitat. While the focus of ORRI is to improve instream habitat for finfish, there are potential benefits to some of the functional habitat characteristics outlined by Strayer (2008), namely: flows that allow juveniles to settle and instream sheers that are not excessive during juvenile attachments and substrate stability to reduce the risk of movement during flows and sudden scour or in-fill. The improvement in riparian habitat would also result in a temperature regime in the littoral zone more favourable to mussels.

4.3.2 <u>Alternatives to human activities and threats to habitat</u>

The compliance rate of some activities such as the creation of beaches, dumping of sand and removal of littoral vegetation that require permitting under the *BC Water Act* is very low (COSEWIC 2010). With growing developmental pressures, active enforcement of existing legislation on habitat protection measures is a start in mitigating and/or alleviating the threats to habitat. When considering activities and threats to habitat within permitting processes, often the focus is on the limiting factors of rare or at-risk species. However, there is the issue of cumulative effects of past activities (legal or illegal) that need to be considered, as well as the potential impacts on the overall littoral zone ecology. The distribution of freshwater mussels is highly dependent on the presence of suitable fish hosts (Watters 1992), and the recruitment success is highly dependent on fish hosts that provide the highest glochidia to juvenile survival (McNichols et al. 2011). Within permitting processes, any detection, salvage or relocation activity with mussels should follow the guidelines of Mackie et al. 2008 and only occur at temperatures where they are active and re-burrow in suitable substrate. While these guidelines were developed for Ontario, they can be applied in B.C. until specific or revised guidelines are developed and available for B.C. species.

The DFO Protocol for the Detection and Relocation of Freshwater Mussel Species at Risk utilizes a detection protocol developed by Pacific Region in 2006 specifically for Rocky Mountain ridged mussels in the Okanagan. The relocation aspect of the protocol is based on Mackie et al. (2008). It is uncertain if the relocation protocol is effective for the Okanagan situation as: a) although there have been 3 relocations following this protocol to-date (2 for Rocky Mountain ridged mussel), a review of the monitoring results to assess survival has not yet been undertaken; and b) there are currently no provisions to limit the number of times the mussels are relocated. Relocations have been to adjacent areas 2 or 3 properties away. The Province will be reviewing the management of Rocky Mountain ridged mussels in the Okanagan in 2011-2012 to determine if there is sufficient protection (L. Nield, pers. comm.).

The control and harvest of Eurasian watermilfoil is likely one of the most extensive on-going in-water activities in the Okanagan Basin. Specific guidelines based on the best available scientific information (as it develops) for protection of mussel habitat are recommended to avoid potential inconsistencies of one-of referrals to different permitting staff and habitat managers. As a start, milfoil harvesting by conventional methods of cutting and rototilling should not occur with a specified (yet to be determined) distance of mussel occurrence. Should milfoil harvesting be required in close proximity to mussel beds, pre and post surveys should be conducted, and alternatives developed (i.e. hand harvesting or other method) to reduce the risk of harm to mussels. The use of a heavy geotextile fabric as a weed barrier is used by homeowners to control weeds around docks and shallow swimming areas (OBWB 2011). This should require permitting to ensure it only be used in habitats not suitable for mussel settlement.

Prop washing within lake littoral zones is often used by residents to maintain sufficient clearance for access to their private docks. This may have localized effects such as dislodging mussels from their substrate, far-field impacts by smothering mussels with dispersed material, and it may have detrimental impacts on potential glochidia host fish by reducing their cover, reducing their food source, and therefore reduce the attraction of potential fish host to mussel habitat. Procedures and guidelines for boat channel maintenance to docks need to be reviewed for near-field and far-field potential impacts on mussels and potential glochidia fish hosts and their respective habitats.

Installation of geothermal heating pipes in the littoral zone may have detrimental impacts on benthic community habitat and the presence of potential glochidia host fish species, depending on the method of installation, changes on localized temperature shifts and changes in near-bottom hydraulics. This method of heating and cooling has become increasingly popular as it is thought of as a “Green” energy source. However, due to its more recent use, no best management practices have been created. Relying on individual approvals may result in inconsistencies with impact assessments and may not adequately consider cumulative impacts of other installations or other developmental pressures. Best management practices need to be developed with careful consideration of ecological impacts on littoral zone species and habitats.

4.3.3 Reasonable and feasible activities that could increase the productivity or survivorship parameters

In the absence of detailed biological information on *G. angulata* to assist in developing action plans to increase productivity and reduce mortality, the alternative approach is to rely on a generalized risk management framework for habitat management (DFO 2006), habitat management guidelines for *SARA* listed species (DFO 2007), as well as derived pathways of effects models that result from the identified pressures and threats to habitats similar to that of Coker et al. 2010 to conserve and enhance Strayer’s 2008 functional characteristics of suitable mussel habitat. For example, with the removal of aquatic vegetation, design and implement an isolation/containment plan to isolate temporary in-water work zones to maintain clean flow around the work zone at all times (Link 15-3 in Coker et al. 2010) or in-water silt curtains to contain suspended sediments (Link 15-4 in Coker et al. 2010). Although most mitigative measures identified in Coker et al. (2010) were developed for stream applications, many are applicable to lacustrine habitats. Developing pathways of effects with conceptual models would greatly assist in the development of appropriate mitigation measures to increase productivity and survival.

One of the keys to increasing productivity is to address the limiting factors to recruitment, which are presently unknown. There is an urgent need to determine the limiting factors to recruitment, including determining all the potential glochidia host fish species, determining whether there is differential success of glochidia – juvenile recruitment with host species preferences (as seen in other mussel species), and determining habitat requirements and pressures on glochidia host fish species. Once this information has been developed, there may be opportunities for the enhancement of littoral habitat for preferential glochidia host fish species. The potential impact of habitat pressures and present practices/uses would be clarified if limiting factors were better understood, and mitigation measures could be focused on addressing those limiting factors where possible.

There may be opportunities with river habitat restoration efforts of the ORRI for the reestablishment of riverine *G. angulata* populations. Even though there was no evidence of *G. angulata* in the particular cutoff oxbows, transplanting adult individuals from the Summerland populations could be considered as a means of seeding the newly restored habitat. Minimum viable population size is unknown and this could be an opportunity to consider controlled experiments.

The refinement of sampling protocols, implementation of a monitoring program and any proposed restoration/recovery activities should be done in consultation the Guidelines and Techniques Committee of the Freshwater Mollusk Conservation Society, to ensure the risk of harming mussels is minimized, and what harm is unavoidable is kept to an absolute minimum. For example, in terms of monitoring, there are non-lethal ways to assess the physiological health of unionid mussels by measuring glycogen reserves in the foot. Glycogen concentrations have been successfully used in unionid mussels as indicators of stress following contaminant exposure and infestation by dreissenid mussels. It is useful as a stress indicator long before changes in either growth or survival are evident (Naimo et al. 1998).

Under *SARA*, allowable harm to a species at risk is permitted by Section 73.2 providing:

A. the activity is scientific research relating to the conservation of the species and conducted by qualified persons;
B. the activity benefits the species or is required to enhance it chance of survival in the wild; or
C. affecting the species is incidental to carrying out of the activity

There are preconditions to permitting allowable harm under Section 73.3, namely

A. all reasonable alternatives to the activity that would reduce the impact on the species have been considered and the best solution has been adopted;
B. all feasible measures will be taken to minimize the impact of the activity on the species or its critical habitat or the residences of the individuals;
C. the activity will not jeopardize the survival or recovery of the species.

Due to a lack of basic biological information on *G. angulata* life history parameters, allowable harm will be necessary to develop the information required for a sound plan to reduce the risk of extirpation, and increase productivity and survival. Allowable harm activities should initially be restricted to areas of greatest abundance in Okanagan Lake near Summerland at a level that is comparable to natural mortality. As better more comprehensive information is developed, it could be considered for other areas to facilitate restoration efforts to expand the species distribution.

4.3.4 Expected population trajectories associated with specific scenarios

While specific information on productivity parameters for *G. angulata* to assist in predicting population trajectories is missing, using existing information on extirpation from areas within its range in the U.S., recent declines in abundance and distribution in B.C., and the potential risks of dreissenid mussels with their documented impacts in the U.S., under different scenarios, the following population trajectories can be expected in B.C.:

1. Without a comprehensive action plan to address and manage the dreissenid mussel threat and the means to successfully implement it, the extirpation of *G. angulata* is likely within 3-5 years after the introduction of dreissenid mussels to the Okanagan Basin
2. Continuation of the status quo with low compliance of existing protection measures and no efforts to determine and address the limiting factors of recruitment of existing populations at Summerland and Vernon, the extirpation of *G. angulata* from the Okanagan Basin is likely within 10 years.
3. Immediate enhanced habitat protection measures at the Summerland and Vernon sites to promote potential recruitment, may provide age classes to replace the dwindling ageing population. Evidence of recruitment success would likely be seen in 5-10 years, and evidence of potentially stable age structures would be seen in 20-30 years. Assuming population sustainability and stability is inferred after three generations, evidence of sustainability of existing populations at Summerland and Vernon would likely be confirmed after 60-70 years. The probability of success is uncertain, as there may be other under-lying factors which are presently unknown. However, the probability of success would increase if the limiting factors to recruitment were known, and measures were undertaken to alleviate or mitigate those limiting factors. This is Step 1 of reducing the risk of extirpation outlined in **Population and distribution targets.**
4. Enhanced habitat protection measures at designated mussel-sensitive (where they have been previously seen live or where there is dead shell) and at sites where a few sporadically distributed live mussels were seen (such as 3-mile beach at Naramata) may provide age classes to replace the dwindling ageing population. Evidence of success would be in the same time frame as outlined above in (3). This is Step 2 of reducing the risk of extirpation outlined in **Population and distribution targets.**
5. Efforts to restore key selected and previously degraded lacustrine and riverine habitats to the functional characteristics of suitable mussel habitat (in stages, first following Strayer's 2008 guidelines, then refinement as more information is developed) would establish populations in several areas, providing more overall stability to Okanagan Basin populations. Determining and maintaining minimal viable population size is a key requirement to re-establishing populations where they previously occurred. Evidence of success would be in the same time frame as outlined above in (3). This is Step 3 of reducing the risk of extirpation outlined in **Population and distribution targets.**

4.3.5 Parameter values for population productivity and starting mortality rates

Due to a paucity of biological information for *G. angulata*, the basic parameter values of recruitment, reproductive age, fecundity, mortality, growth and minimum viable population size are unknown, and the maximum age is unconfirmed. Under the circumstances it is not possible to estimate or predict parameter values for population productivity. However, it is possible to predict population sustainability by size structure (assuming it reflects the age structure). The present size distribution of *G. angulata* is a narrow range of large individuals, indicating ageing populations with very little evidence of replacement by younger mussels. There could be several reasons for the lack of evidence of young age classes: the growth of *G. angulata* may be asymptotic, with a relatively narrow size distribution representing several age classes; the mortality rate of young individuals may be differentially high as compared to larger adults; detectability of juveniles and small adults may be difficult; and sampling techniques of interstitial and fine silt habitats may need to be developed and refined. Nevertheless, there is very little evidence of younger smaller individuals, despite limited sampling efforts at Dog Beach in 2009.

Only 7 small individuals have been seen in a soft silty area off Summerland Beach during snorkel surveys, where there is an abundance of large adults in close proximity. Evidence of a broad range of size and age classes is needed to have some confidence in the sustainability of the present populations. Another indicator of population productivity is the production of conglutinates. While this is one of the initial steps in the reproductive and recruitment process and does not predict survival and recruitment to reproductive age, it is an indicator of productive potential.

4.3.6 Suggested research activities

1. Glochidia host fish determination – According to Strayer 2008, what is known with a high degree of certainty on glochidia distribution is that the number of glochidia on fish hosts is a Poisson distribution. However, detailed knowledge of fish hosts is key to a number of issues: determining limiting factors to recruitment and productivity; habitat protection, enhancement and restoration; predicting recovery trajectories; and determining feasibility of establishing populations in previously degraded areas. Consequently, in the absence of this information, measures developed for the adequate conservation and protection of the remaining *G. angulata* populations have a high degree of uncertainty. Future research should concentrate efforts on determining potential fish hosts during known periods of glochidial encystment (Spring Rivers 2007) and accurately identify glochidia either by morphological characteristics or genetically.
2. Adult and juvenile micro-habitat preferences - Specific habitat preferences of both adult and juvenile *G. angulata* populations need to be determined in order to successfully restore and protect this species in southern British Columbia. This basic knowledge is necessary before the translocation of mussels is considered.
3. Determination of at-depth distribution - Virtually all broad brush surveys conducted to date have focused on shallow waters where *G. angulata* are typically thought to occur. Preliminary evidence suggests potential populations/aggregations may exist at greater depths within Okanagan Lake and Vaseaux Lake. Future surveys should incorporate SCUBA diving performing exploratory broad brush surveys to determine the exact distribution of *G. angulata* within the lakes of the Okanagan Basin.
4. Genetic analysis - Given the apparent differences in habitat preferences between *G. angulata* populations in Canada and the United States (i.e. lacustrine versus riverine habitats), it is plausible that the southern British Columbia populations are genetically distinct. *G. angulata* populations in southern British Columbia are small, at the northern extent of their range and are potentially isolated from U.S populations due to barriers such as large dams, etc. which would restrict fish host movement and gene flow among populations. In addition, genetic analyses are a necessary and important prerequisite to translocating individuals thereby increasing success in the re-established habitat and preserving genetic diversity.
5. Re-establishment in restored river habitat - Once glochidia fish hosts and habitat preferences are determined translocating small aggregations of either host fish infected with glochidia or mussels to restored areas of the Okanagan River needs to be considered.

5 CONCLUSIONS AND RECOMMENDATIONS

Evidence from existing aggregations (or populations) at Summerland and Vernon, with their narrow size distribution and very little evidence of recruitment, the sporadic distribution of very few individuals in other areas of the Okanagan Basin, as well as dead shell seen in several more areas, indicates this is likely a relict population or metapopulation of a species at the edge of its range, which is in decline and at risk of extirpation in the Okanagan Basin.

While RPAs usually focus on single-species recovery, a more comprehensive recovery process is needed to address the issues of extensive habitat degradation, recovery/enhancement of glochidia host fish abundance, distribution and habitat, threats from invasive and exotic species, and ecosystem services to the benthic community and *G. angulata* in particular.

There is very little known of *G. angulata* life history parameters to assist in developing and implementing measures to reverse the decline and ensure the persistence of stable self-sustaining populations. In the absence of such species-specific information, there are still opportunities to develop mitigative and remedial measures to promote recruitment by using general guidelines of habitat management and habitat restoration to achieve and maintain the functional characteristics of suitable mussel habitat.

Reducing the risk of species extirpation and increasing the likelihood of restoring ecosystem function depends on the commitment to take appropriate actions identified in this RPA.

Based on the high risk of dreissenid mussel infestation identified by the risk assessment undertaken by a well-known and well-respected authority on freshwater mussels, as well as impacts seen throughout North America, there is the urgent need for the development of a dreissenid mussel action plan to avoid the potential catastrophic impacts on the remaining freshwater mussel community in the Okanagan Basin.

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Table 1. Summary of all sites surveyed in 2008-2009 including approximate distance of shoreline searched, effort expended, the number of sites surveyed, and the number of live Gonidea angulata *as well as other mussels found in each drainage/river basin or waterbody.*

Drainage/River Basin	Waterbody		Shoreline (linear) distance (km)	Search effort (person-hours)	# of sites surveyed	# of sites with *G. angulata*	# of live *G. angulata*
Okanagan			27.26	54.06	69	12	>565
	Okanagan Lake		19.8	29.44	50	8	>550
		Northeast	2..5	3.13	10	1	50
		Northwest	0.9	5.35	2	0	—
		Central	1.0	0.91	4	0	—
		Southeast	4.9	5.44	14	1	—
		Southwest	10.5	14.61	20	5	>500
	Skaha Lake		3.6	2.86	9	0	—
	Osoyoos Lake		0.52	0.53	5	0	—
	Vaseaux Lake		0.05	1.23	1	1	3
	Okanagan River		3.29	20.0	4	3	12
Similkameen	Similkameen River		1.48	9.85	3	0	—
Columbia-Kootenay			2.55	23.76	22	0	—
	Little Bull Creek		0.15	0.67	1	0	—
	Peckhams Lake		n/a	0.33	1	0	—
	Little Sand Creek		0.15	3.33	2	0	—
	Sand Creek		0.25	2.83	2	0	—
	Wasa Lake		n/a	1.67	1	0	—
	Cherry Creek		0.2	2.0	1	0	—
	St. Mary's Lake		0.75	1.25	2	0	—

Table 1. Continued.

Drainage/river basin	Waterbody	Shoreline (linear) distance (km)	Search effort (person-hours)	# of sites surveyed	# of sites with *G. angulata*	# of live *G. angulata*
	Skookumchuck	0.05	1.5	1	0	—
	Columbia River	0.4	2.5	2	0	—
	Columbia Lake	0.15	2.0	1	0	—
	Windermere Lake	0.1	1.5	1	0	—
	Whiteswan Lake	0.2	2.0	1	0	—
	Koocanusa Creek	n/a	0.17	1	0	—
	Kikomun Creek	0.03	0.67	1	0	—
	Caithness Lake	0.025	0.17	1	0	—
	Tie Lake	0.1	0.17	1	0	—
	Kootenay Lake	n/a	1.0	2	0	—
Total		31.29	87.67	94	12	

Table 2. Results of the quantitative survey conducted at Dog Beach, Okanagan Lake in Summerland.

Location	Total Area Surveyed (m^2)	Quadrat Mean ($\#/m^2$)	Quadrat Variance	Upper 95% Confidence Interval	Lower 95% Confidence Interval	Population Total	Population Variance	Upper 95% Confidence Interval	Lower 95% Confidence Interval	Survey Precision
Summerland; Dog Beach	2,313	0.49	0.0145	0.73	0.25	1,130	77, 314	1,675	585	48.2%

Table 3. Physical characteristics of sites surveyed in 2009 with live Gonidea angulata in the Okanagan Basin.

Site	Site Length(m)	Mean Depth Searched (m)	# live *G. angulata*	Substrate	Aquatic Vegetation
Okanagan Lake; Vernon	330	3.25	50	Mud, sand, cobble, boulder	Rooted macrophytes
Okanagan Lake; Narramata	50	1.0	1	Sand, gravel, cobble	None
Okanagan Lake; Summerland; Crescent Beach	40	1.5	8	Sand, silt cobble	None
Okanagan Lake; Summerland; North of Boat Ramp	170	1.0	38	Sand, cobble	Submergent
Okanagan Lake; Summerland; Dog Beach	330	1.25	150	Sand, cobble, silt	None
Okanagan Lake; Summerland; Kinsmen Beach	30	1.5	123	Sand, silt, cobble, boulder	Submergent, algal mats
Okanagan River; South of Vaseux Lake	65	1.25	2	Large cobble, gravel, sand	Emergent, algae, low periphyton cover
Okanagan River: Old Rail Crossing	610	0.75	4	Cobble, boulder	None
Okanagan River; Inventory Site	213	0.75	6	Cobble, boulder	None
Vaseaux Lake	50	4	3	Mud, sand, cobble	Milfoil

Figure 1. Rocky Mountain ridged mussel, Gonidea angulata at Dog Beach, Okanagan Lake in Summerland, July 2009. Note the prominent posterior ridge. (Photo by L. Stanton)

Figure 2. Historic range of Gonidea angulata in British Columbia and the western United States (COSEWIC 2003).

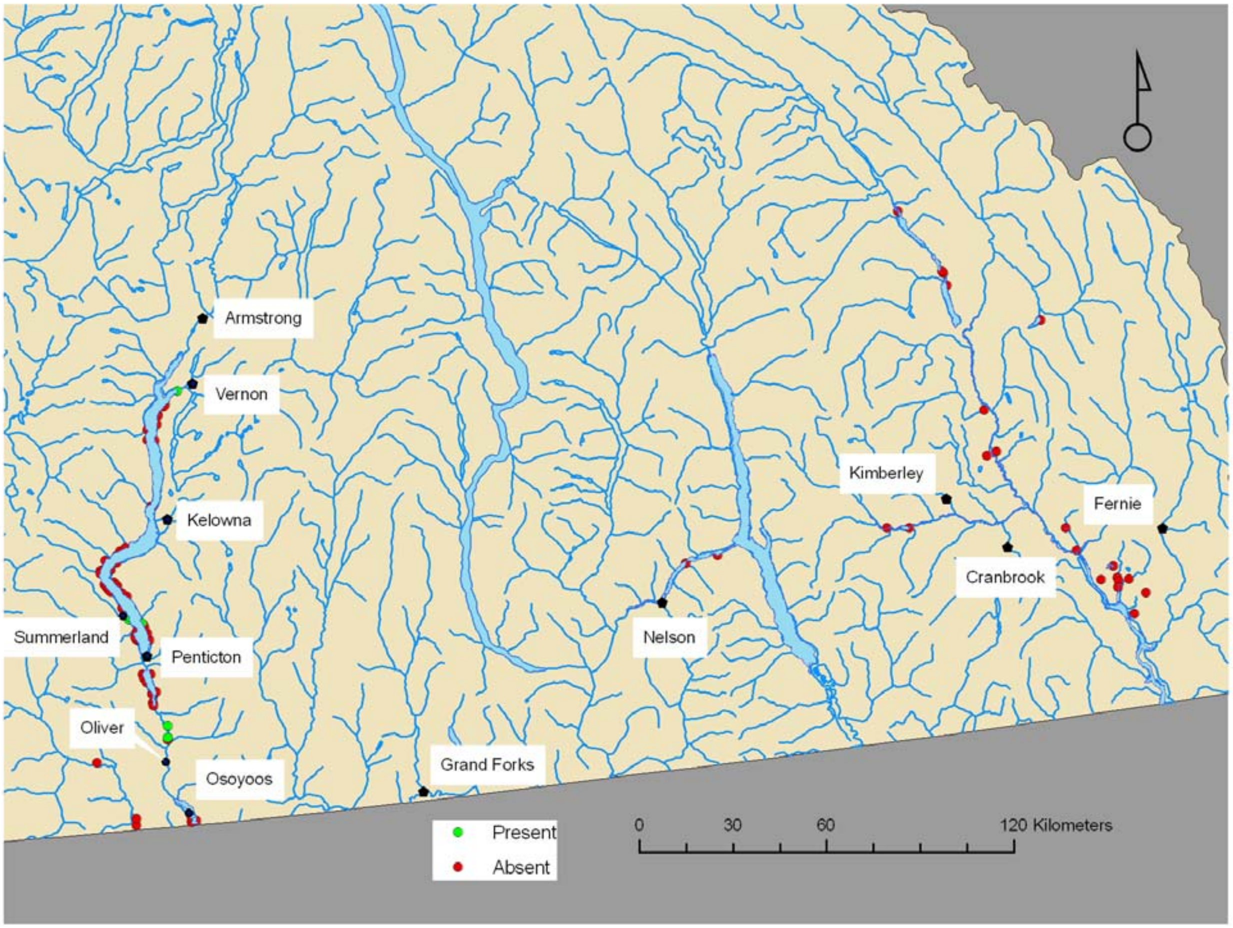

Figure 3. All Gonidea angulata survey locations conducted from 2008-2009 in southern British Columbia including the Columbia, Kootenay, Similkameen and Okanagan River Basins.

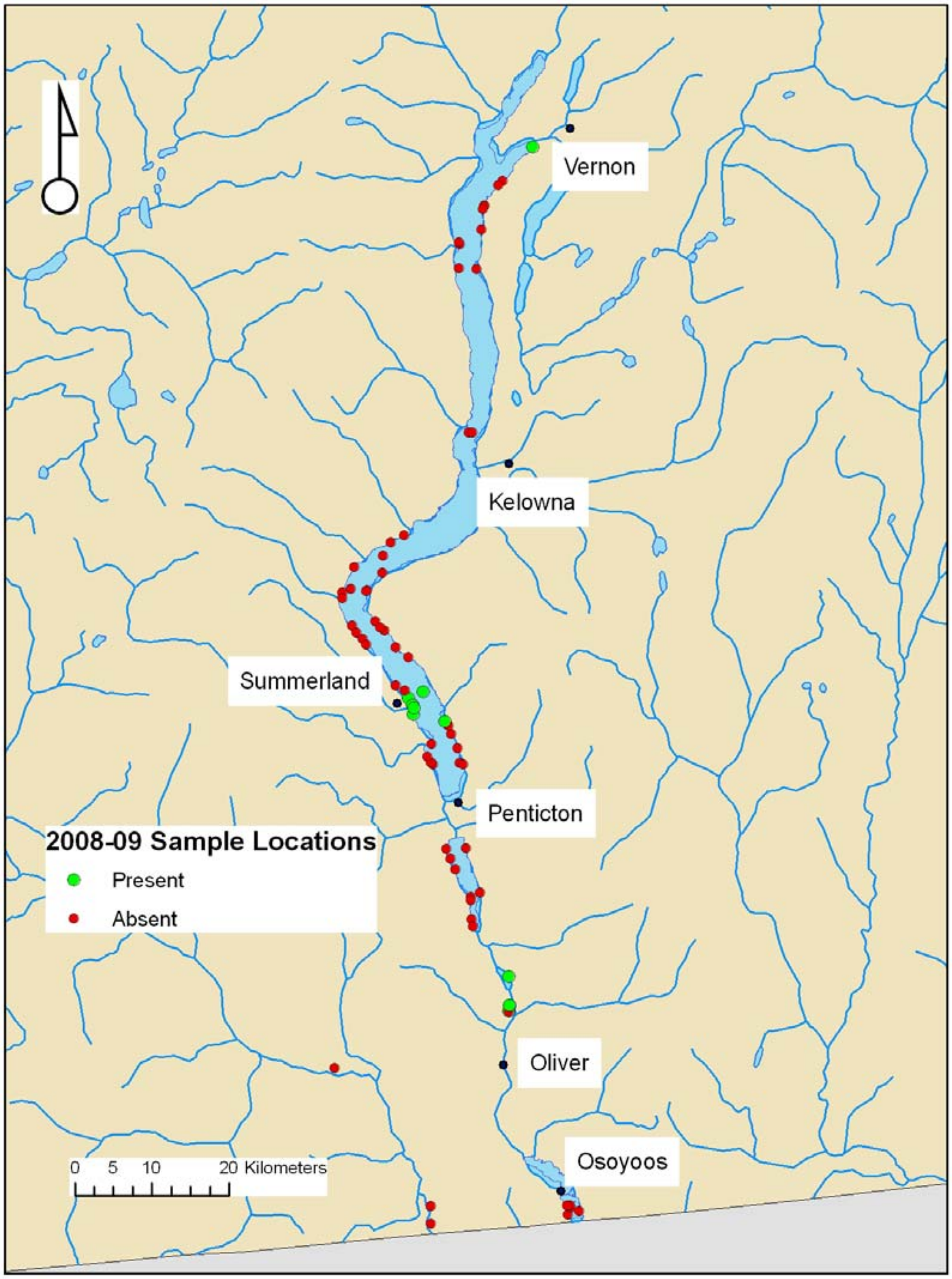

Figure 4. Gonidea angulata survey locations conducted from 2008-2009 within the Okanagan Basin.

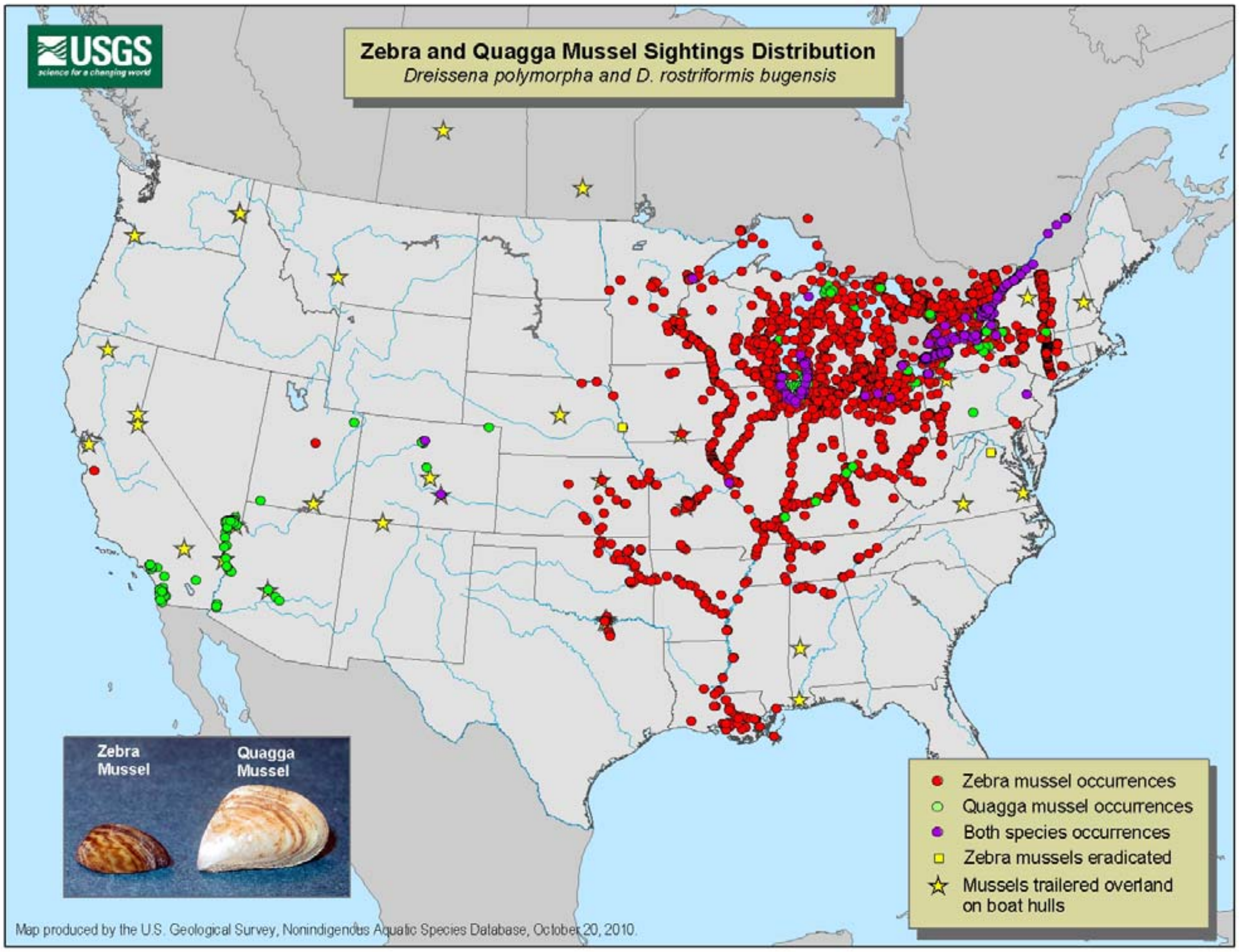

Figure 5. Zebra and Quagga mussels sightings and distribution. Map from United States Geological Survey website

APPENDIX 1

REQUEST FOR SCIENCE INFORMATION AND/OR ADVICE

PART 1: <u>DESCRIPTION OF THE REQUEST – TO BE FILLED BY THE CLIENT REQUESTING THE INFORMATION/ADVICE</u>

Date *(when initial client's submission is sent to Science) (dd/mm/yyyy)***:**

Directorate, Branch or group initiating the request and category of request	
Directorate/Branch/Group ☐ Fisheries and Aquaculture Management ☒ Oceans & Habitat Management and SARA ☐ Policy ☐ Science ☐ Other (please specify):	Category of Request ☐ Stock Assessment ☒ Species at Risk ☐ Human impacts on Fish Habitat/ Ecosystem components ☐ Aquaculture ☐ Ocean issues ☐ Invasive Species ☐ Other (please specify):

Initiating Branch Contact:	
Name: Karen Calla	Telephone Number: 604-666-0395
Email: karen.callla@dfo-mpo.gc.ca	Fax Number: 604-666-0417

Issue Requiring Science Advice (i.e., "the question"): *Issue posed as a question for Science response.*
Compilation of background information to complete a Recovery Potential Assesseement (RPA) for the Rocky Mountain Ridged Mussel.

Rationale for Advice Request: *What is the issue, what will it address, importance, scope and breadth of interest, etc.?*
The completion of a RPA is a mandated requirement in the listing decision process for species at risk. The RPA provides the scientific background, identification of threats and probability of recovery of a species, or population, that is deemed to be at risk. Although Rocky Mountain Ridged Mussel has yet to be designated by COSEWIC as at risk, there is a possibility that it may. This species is scheduled to be assessed in April 2010 and may be desginated as Threatened by COSEWIC. As a result a RPA will need to be produced.

Possibility of integrating this request with other requests in your sector or other sector's needs?

Intended Uses of the Advice, Potential Impacts of Advice within DFO, and on the Public:
Who will be the end user of the advice (e.g. DFO, another government agency or Industry?). What impact could the advice have on other sectors? Who from the Public will be impacted by the advice and to what extent?

The RPA serves as a key piece to inform the Minister in deciding whether or nor to list the species under SARA. The RPA is an important scientific document that other recovery strategies or action plans are to be based.

Date Advice Required:

Latest possible date to receive Science advice (dd/mm/yyyy): 15/12/2010

Rationale justifying this date: After a species has been designated the Minister has 9 months to respond. The completion of a RPA is to be done in this time. Rocky Mountain Ridged Mussel is to be assessed in April of 2010.

Funding:
Specific funds may already have been identified to cover a given issue (e.g. SARCEP, Ocean Action Plan, etc.)

Source of funding: SARCEP

Expected amount: $39.9K

Initiating Branch's Approval:
Approved by Initiating Director: ☐ Date (dd/mm/yyyy):

Name of initiating Director:

Send form via email attachment following instructions below:

Regional request: Depending on the region, the coordinator of the Regional Centre for Science Advice or the Regional Director of Science will be the first contact person. Please contact the coordinator in your region to confirm the approach.

National request: At HQ, the Director of the Canadian Science Advisory Secretariat (Denis.Rivard@dfo-mpo.gc.ca) AND the Director General of the Ecosystem Science Directorate (Sylvain.Paradis@dfo-mpo.gc.ca) will be the first contact persons.

PART 2: **RESPONSE FROM SCIENCE**

In the regions: to be filled by the Regional Centre for Science Advice.
At HQ: to be filled by the Canadian Science Advisory Secretariat in collaboration with the Directors of the Science program(s) of concern.

Criteria characterising the request:	**Constraints regarding the planning of a standard peer review/Workshop:**	**Other criteria that could affect the choice of the process, the timelines, or the scale of the meeting:**

☐ Science advice is requested (rather than just information)
☐ A sound basis of peer-reviewed information and advisory precedent already exists.
☐ Inclusiveness is an issue
☐ Advice on this specific issue has been provided in the past.
☐ Urgent request.
☐ DFO is not the final advisory body.
    ☐ CEAA process
    ☐ COSEWIC process
    ☐ Other:
	☐ External expertise required
	☐ This is a scientifically controversial issue, i.e., consensus does *not* currently exist within DFO science.
	☐ Extensive preparatory work is required.
	☐ Determination of information availability is required (prior to provision of advice).
	☐ Resources supporting this process are not available.
	☐ Expected time needed for the preparatory work:
	☐ Other (please specify):
		☐ The response provided could be considered as a precedent that will affect other regions.
		☐ The response corresponds to a new framework or will affect the framework currently in place.
		☐ Expertise from other DFO regions is necessary.
		☐ Other (please specify):

Recommendation regarding the advisory process and the timelines:		
☐ Science Special Response Process (SSRP)	☐ Workshop	☐ Peer Review Meeting

Rationale justifying the choice of process:

Types of publications expected and if already known, number of report for each series:

☐ Science Advisory Report ( ) ☐ Research Document ( )
☐ Proceeding ( ) ☐ Science Response Report ( )
☐ Other:

Date Advice to be Provided:

☐ Date specified can be met.
☐ Date specified can NOT be met.

Alternate date, as agreed to by client Branch lead and Science lead (dd/mm/yyyy):

OR

☐ No Formal Response to be Provided by Science

Rationale:

- ☐ DFO Science Region does not have the expertise required.
- ☐ DFO Science Region does not have resources available at this time.
- ☐ The deadline can not be met.
- ☐ Not a natural science issue (e.g. socio-economic)
- ☐ Response to a similar question has been provided elsewhere:
  Reference:

Additional explanation:

Science Branch Lead:	
Name:	Telephone Number:
Email:	
* Please contact Science Branch lead for additional details on this request.	

Science Branch Approval:

Approved by Regional Director, Science (or their delegate authority):
☐ Date (dd/mm/yyyy):

Name of the person who approved the request:

Once part 2 completed, the form is sent via email attachment to the initiating Branch contact person.

PART 3: PLANNING OF THE ADVISORY PROCESS

Science Branch Approval:

Coordinator of the event:

Potential chair(s):

Suggested date (dd/mm/yyyy) / period for the meeting:

Need a preparatory meeting:

Leader of the Steering Committee: