

Determining habitat suitability for the Rocky Mountain ridged mussel (*Gonidea angulata*, Lea 1838), in Okanagan Lake, BC, Canada

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The Rocky Mountain ridged mussel (RMRM; *Gonidea angulata*, family Unionidae) is a freshwater mussel, native to the Pacific Northwest. It's most northern distribution is located in Okanagan Lake in the Okanagan Valley, BC, Canada. RMRM is a species of special concern (Species at Risk Act, 2015), declining in numbers throughout most of its range (Davis et al. 2013), and has been recommended for endangered status (COSEWIC 2010). One main objective of this study was to develop a habitat suitability model to determine important habitat variables within Okanagan Lake for RMRM.

RMRM is easily distinguished from other Unionoidea in British Columbia. It has a unique and distinct ridge along its posterior margin, hence the name, Rocky Mountain ridged mussel (Figure 1). RMRM also have a thick, heavy shell ($\leq 5\text{mm}$) in comparison to other native freshwater mussels (Clarke 1981, Fisheries and Oceans Canada 2010). The shell shape is ovate to trapezoidal (" $\leq 125\text{mm}$ long; $\leq 65\text{ mm}$ high; $\leq 45\text{ mm}$ wide"; Clarke 1981 as cited in Stanton et al. 2012, Fisheries and Oceans Canada 2010). The periostracum (outer shell layer) is yellowish-brown to brown to blackish-brown in colour (Fisheries and Oceans Canada 2010, Jepsen et al. 2010, Stanton et al. 2012). RMRM have no lateral teeth (Jepsen et al. 2010). RMRM have small pseudocardinal teeth on the right valve, while the left valve may have one poorly developed tooth or none at all (Nedeau et al. 2009). These differences are distinctive compared to other freshwater mussels with overlapping distributions in the Pacific Northwest (COSEWIC 2010).

Like all members of Unionidae, RMRM are temporarily parasitic on the gills of host fish (while some other species may be parasitic on amphibians). On suitable fish hosts organogenesis (i.e., development of organs) occurs and the larvae metamorphose into juvenile mussels, which drop off the fish. Encystment on the host fish must be successful in order to complete reproduction (O'Brien et al. 2013). RMRM have been found to metamorphose into juvenile mussels on different species of fish in different systems. Field data from Okanagan Lake suggest that sculpin (*C. asper* Richardson, 1836 and/or *C. cognatus* Richardson, 1836) are the primary hosts in this system, while longnose dace (*Rhinichthys cataractae* Valenciennes, 1842), leopard dace (*Rhinichthys falcatus* Eigenmann and Eigenmann, 1893), and northern pikeminnow (*Ptychocheilus oregonensis* Richardson, 1836) may also serve as hosts (Stanton et al. 2012, Mageroy 2015). After a short duration (10-11 days) on their host (O'Brien et al. 2013), RMRM 'sluff-off' (excyst) and bury into the substrate as 'juveniles' (sexually immature mussels; Strayer 2008). If the habitat and conditions are suitable, recruitment can be successful at this new location.

There are many threats this mussel faces in Okanagan Lake, including, but not limited to, lakeshore construction, dredging, invasive aquatic macrophytes, and invasive fish. Okanagan Lake is a long and narrow lake of dimensions: 170 km long, 3.5 km wide (on average), and has a shore length of 270km (Stockner and Northcote 1974). The most important variables for RMRM, in my model, include high substrate embeddedness ($>75\%$) as most important (embeddedness defined as the degree to which fine sediments surround substrates), followed by total fetch ($>10 - 16\text{ km}$) (total fetch defined as the distance wind can travel across water without being impeded by land, and summed over many deviation angles), increasing sand ($>20\%$) occurrence, and low or very high boulder occurrence. Embeddedness of substrates, sand and boulder substrate types have been highlighted in earlier studies of RMRM (in the USA) and other unionids (Morales et al. 2006, Cyr 2009, Allen and Vaughn 2009, Bodis et al. 2011, Davis et al. 2013). Site exposure (measured as total fetch) also affected unionid behaviour (Cyr 2009). RMRM are generally found in lotic habitats, where water velocity can easily be measured (e.g., cm/s) and/or categorized directly (e.g., glides, riffles). While embeddedness is often analyzed in unionid studies, it surprised experts that RMRM are better adapted to medium and high embeddedness conditions in Okanagan Lake. However, there are very different hydrodynamic properties for lotic and lentic habitats. In lotic habitats, water movement enables finer sediments and organics to move downstream, delivering a constant source of food to mussels. In lentic habitats, there must be significant wind and wave action to transport and load sites with organics and fine sediments. Higher embeddedness measures observed in lentic habitats supporting RMRM, as observed in Okanagan Lake, can translate to food availability.

Host fish was recommended by experts as a biotic component to include in this model (Steuer et al. 2008, Davis et al. 2013), but was surprisingly ranked as one of the least important variables. However, this is likely because sculpin (*Cottus* sp.) are found at every site, and as such are likely not important in predicting or limiting the distribution of RMRM in Okanagan Lake. Therefore, I would argue host fish is still one of the most important biological components for RMRM survival, but is an independent and saturated variable in this lake system.

The model created from this project identified important habitat variables for RMRM, as well as locations of where these exist within Okanagan Lake. This product will assist the Ministry of Forests, Lands, and Natural Resource Operations and the Ministry of Environment in conservation management for RMRM in Okanagan Lake.



Fig. 1



Fig. 2

Figure 1. Left: a RMRM with a distinct ridge along its outer shell (A), along with concentric growth lines (B) radiating out from the umbo (C; Image Roxanne Snook). Right: the inner mother of pearl nacre, and a hard to distinguish pseudocardinal tooth present on the right valve (Image Steven Brownlee, reproduced with permission).

Figure 2. RMRM feeding in Vaseux Lake, BC, Canada (Image Roxanne Snook).

Figure 3. RMRM wedged between boulders in Okanagan River, BC, Canada (Image Roxanne Snook).

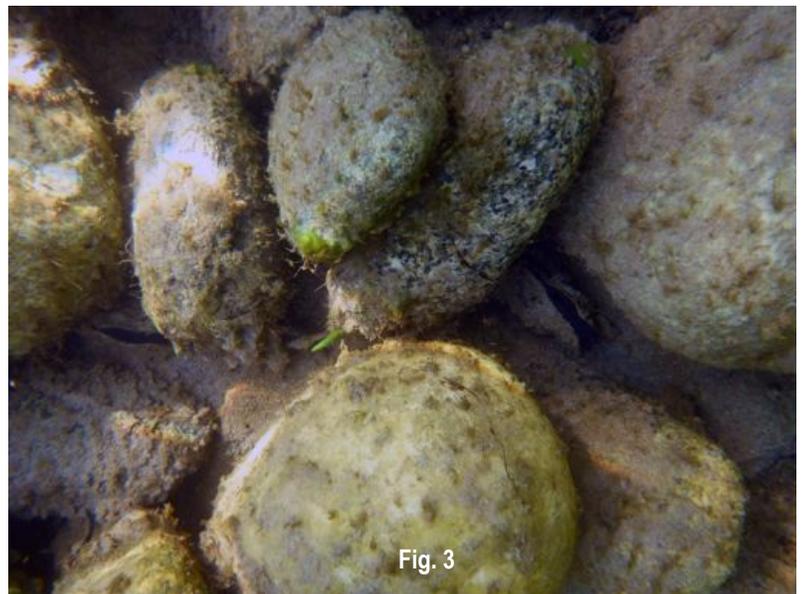


Fig. 3

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