Fisheries and Oceans Canada
Science

Pêches et Océans Canada
Sciences

C S A S

Canadian Science Advisory Secretariat

Research Document 2011/027

Pacific Region

S C C S

Secrétariat canadien de consultation scientifique

Document de recherche 2011/027

Région du Pacifique

Recovery Potential Assessment for Hotwater Physa (*Physella wrighti*)

Évaluation du potentiel de rétablissement de la physe d'eau chaude (*Physella wrighti*)

Raymond Lauzier[1], Sarah C. Davies[1], Jennifer Heron[2]

[1]Fisheries and Oceans Canada, Science Branch, Pacific Biological Station, 3190 Hammond Bay Road, Nanaimo, BC, V9T 6N7

[2]B.C. Ministry of Environment
UBC Fisheries Centre
2202 Main Mall
The University of British Columbia
Vancouver, BC
Canada V6T 1Z4

ISSN 1499-3848 (Printed / Imprimé)
ISSN 1919-5044 (Online / En ligne)

Canada

TABLE OF CONTENTS / TABLE DES MATIÈRES

LIST OF FIGURES

LIST OF TABLES

Correct citation for this publication:
La présente publication doit être citée comme suit :

Lauzier, R., S.C. Davis, J. Heron. 2011. Recovery Potential Assessment for Hotwater Physa (*Physella wrighti*). DFO Can. Sci. Advis. Sec. Res. Doc. 2011/027. vi + 28 p.

ABSTRACT

Hotwater physa (*Physella wrighti*) is a freshwater pulmonate snail endemic to the hot springs complex of the Liard River Hotsprings Provincial Park The snail is present in two hot springs pools, their outlet streams and in a portion of a warm-water swamp. Survey estimates of previous studies are reviewed, and the results of the most recent survey are provided along with a survey protocol designed to minimize harm and habitat disturbance, yet provide consistency for estimates of relative abundance. Relative abundance estimates are likely biased low due to the cryptic nature of the animal and complexity of the habitat it occupies. While specific life history parameters are unknown, the semelparous life history strategy, short generation time and evidence from other related species implies the productivity is high. The occupying habitat characteristics are provided. Potential threats of proposed industrial development to the source water are provided. Potential threats and impacts to the habitat by recreational use of the hot springs complex are provided along with mitigating measures to ensure sustainability of the endemic population at its present relative abundance and distribution. Recommendations are provided for further research required to fill basic information gaps to understand the biological parameters of Hotwater physa in order to better assess the risks and vulnerabilities of the Hotwater physa population exposed to human activities.

RÉSUMÉ

La physe d'eau chaude (*Physella wrighti*) est un gastéropode pulmoné d'eau douce dont la population endémique vit dans le complexe de sources thermales du parc provincial Liard River Hot Springs. Ce gastéropode est présent dans deux bassins de ce complexe, dans la leurs ruisseaux de déversement et dans une portion d'un marécage thermal. On a examiné les estimations dérivées des relevés effectués dans le cadre d'études antérieures, et on a fourni les résultats du plus récent relevé ainsi qu'un protocole de relevé conçu pour minimiser les dommages causés à l'espèce et la perturbation de l'habitat, tout en permettant d'assurer l'uniformité des estimations de l'abondance relative. Les estimations de l'abondance relative sont vraisemblablement biaisées à la baisse en raison de la nature cryptique de ces gastéropodes et de la complexité de l'habitat qu'il choisit. Bien qu'on ignore les paramètres associés au cycle biologique particulier de l'espèce, compte tenu de la nature sémelpare du cycle biologique de la physe d'eau chaude, de son court temps de génération et de données sur d'autres espèces de gastéropodes d'eau douce, on estime que la productivité de l'espèce est élevée. On fournit les caractéristiques de l'habitat de la physe d'eau chaude. On expose les menaces que posent les propositions de développement industriel de la source d'eau. On explique également les menaces et les impacts qui pèsent sur l'habitat provoqués par les activités récréatives dans le complexe de sources thermales. On suggère des mesures d'atténuation visant à assurer la viabilité de la population endémique au taux d'abondance relative actuel et selon la répartition observée. On formule des recommandations incitant à poursuivre la recherche afin de remédier à l'insuffisance d'information générale qui permettrait de mieux comprendre les paramètres biologiques de la physe d'eau chaude dans le but de mieux évaluer les risques et la vulnérabilité de la population exposée aux activités anthropiques.

INTRODUCTION

The recovery potential assessment (RPA) for Hotwater physa (*Physella wrighti*) follows the revised Fisheries and Oceans Canada (DFO) protocol for conducting recovery potential assessments (DFO 2007). Hotwater physa is uniquely endemic to the hot springs pools and outlet stream complex of the Liard River Hot Springs Provincial Park (LRHSPP) in northern British Columbia (Figure 1). It was designated Endangered under the *Species at Risk Act* (SARA) in June 2003. It was reconfirmed as endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in November 2008 (COSEWIC 2008a), with an indication that the species will remain on Schedule 1 as Endangered under SARA. The reason for designation was the species has a small endemic population with narrow ecological requirements occurring in an extremely restricted area subject to potential threats from human use of hot springs pools. When a species is assessed as threatened or endangered by COSEWIC, a RPA is undertaken by DFO to provide science-based advice on current status, the likely impact of human activities on the potential for recovery, and options to mitigate human threats to achieve recovery objectives. While this is not a recovery situation, it is an attempt to collate the best available information to provide science-based advice for the protection and preservation of a unique population within its very narrow natural geographic range and within its current variation of abundance at Liard Hot springs.

BIOLOGY

Hotwater physa are members of the Physidae family, which are commonly referred to as physids. Physids are classified as lower pulmonate gastropods (basommatophora) which have a vascularised pulmonary cavity, formed by the mantle to completely enclose the mantle cavity to extract oxygen from air at the surface (Rupert et al. 2004). This group has evolved a rudimentary gill, which allows for limited gas exchange in water (McMahon 1983).

Physids are oviparous hermaphrodites that lay eggs in the spring. Eggs develop directly into substrate-dependent, crawling juveniles (COSEWIC 2008a), and spawning adults die after eggs are laid. Therefore, each year is a new generation of snails and it is assumed a complete replacement of the population. Temperature has been shown to directly affect life history traits such as growth rate, age of maturity, and fecundity levels in freshwater pulmonates (McMahon 1983). Evidence suggests that the generation time for physids may be accelerated in a warmer environment (McMahon 1983). Physids generally have thin shells and lack an operculum, the plate-like structure that seals and protects the animal when it is contracted within the shell (COSEWIC 2008a), both of which increases their vulnerability to fluctuating environmental conditions and predation (see Threats and Limiting Factors).

Hotwater physa are very small (averaging 5.5mm in length) blackish/grey snails (Figure 2) with narrowly elongate-ovate shell consisting of 3½ - 4 whorls (Te and Clarke 1985). Shells are sinistrally (left-handed) coiled with an ear-shaped aperture, with an outer lip callus along its rim (Lee and Ackerman, 1998). Hotwater physa are habitat specialists, that have adapted to thrive in very warm water (>23˚C) with high concentrations of dissolved minerals (conductivity >1100 $\mu S/cm^2$) (COEWIC 2008). Hotwater physa is taxonomically related to two other species: *Physella gyrina* which is broadly distributed in North America; and the Banff Springs snail (*P. johnsoni)*, which is endemic to only five thermal springs on Sulphur Mountain in Banff National Park (Remigio *et al* 2001).

Hotwater physa and closely related Banff Springs snail (*Physella johnsoni)*, are found on various substrates very close to the water-air interface, which makes them vulnerable to surface disturbance as well as aquatic and terrestrial predation (Lee and Ackerman 1998; Lepitzki 2002). Within the Liard hot springs complex, Hotwater physa have been found in dense aggregations on *Chara* mats (*Chara vulgaris*) as well as other substrates (e.g., edge of water/land, floating wood and refuse such as beer cans) in various densities grazing on algal and microbial growth (COSEWIC 2008a).

Due to a lack of information on species-specific physiological and life history information of Hotwater physa, the general biological characteristics of physids and Banff Springs snails are considered as a surrogate in this assessment.

ASSESSMENT

PHASE I: ASSESS CURRENT/RECENT SPECIES STATUS

Range and number of populations

Hotwater physa is within the hot springs complex of LRHSPP which consist of six separate thermal pools and two warm-water marshes. Of these six pools Hotwater physa have been observed only in both the Alpha and Beta pools, in very limited numbers in the outlet of Beta pool (Beta stream), and the outlet of the Alpha pool (Alpha stream) as it empties into the largest marsh (Figure 3). The largest observed population of snails has been along the margins of outlet of the Alpha stream.

There are two distinct populations found within the LRHSPP complex; those existing in the Alpha pool/stream and those found in the Beta pool (Figure 3). There appears to be no surface water connection between these two pools and it is likely these pools are separate and isolated from each other. It is thought that passive migration by movements of animals, such as attachments to birds and humans takes place between the two pools. Flood events from the Beta pool, located at a higher elevation, may also periodically contribute to migration of Hotwater physa into the Alpha pool.

Hotwater physa was first documented along a 34 metre (m) stretch of the Alpha stream in 1975 during a scientific survey of the area led by Clarke (Figure 3)(Te and Clarke 1985). The snails' natural cycle of expansion and contraction of the area of extent is unknown. Since the initial documentation of the snail in 1975, a number of surveys have been conducted and determined that the snail area of extent is beyond the original observed area of extent, up to 200m along the Alpha Stream into the warm swamp (Figure 3)(COSEWIC 2008, Salter 2001, 2003, 2007). At approximately 150m the Alpha stream splits into two branches, with one branch bearing southwest along the margins of the Alpha marsh towards the camping area and one branch bearing south directly into the Alpha marsh. Salter (2007) observed snails along the southwest branch in the direction of the campground (Figure 3).

Abundance

There have been eight surveys from 1997– 2008 for Hotwater physa within LRHSPP. Results with relative abundance estimates from these previous surveys are shown in Tables 1 and 2. Survey intensity and methodology differs between these previous surveys with most surveys only to re-confirm the snails' presence at particular reference points along the Alpha stream

(Figure 3). Six surveys provided relative abundance estimates using different assessment methods over various distances and at different times of the year. Some surveys also attempted to provide an estimate of habitat availability, and relative population estimates. The length of the stream surveyed varies from 40 – 200m.

Survey methodology has varied partially due to the difficulty with having a consistent stream survey area. The Alpha stream has a hard bottom substrate from the outlet of the Alpha pool to approximately 100 m downstream, with some pockets of soft muddy substrate. Past 100 m, from the start of the Alpha stream, streambed substrate becomes soft mud, which is extremely difficult for surveyors to access and wade through. When disturbed, fine sediment impacts visibility, especially when the stream broadens before it reaches the warm-water marsh.

Not all previous surveys provide an abundance estimate along each metre of the stream. Some surveys enumerate all snails to 100m stream length, and then only enumerate snails at 10m intervals. When comparing the results of the various surveys, the different methods and objectives of the surveys must be recognized in assessing the apparent differences of relative abundance. The Recovery Strategy for the Hotwater Physa in Canada (Heron 2007) recommends a monitoring program with standardized protocols to assess population size as well as habitat suitability and capacity.

Fieldwork and data collection

When planning the 2008 survey that would guide the Hotwater physa RPA, the intention was to refine or modify the methodology used by Lee in 2006 (COSEWIC 2008a). Ultimately, refined methods would allow for estimating habitat availability and providing population estimates in order to meet the objective of standardizing population assessment and habitat assessment protocols.

During the initial field reconnaissance at LRHSPP, dense aggregations of snails were noted within very small areas of habitat, especially on the sediment in the shallow quiet indentations and small edge cuts of the stream bank, on vegetation, and small pieces of woody debris. It quickly became apparent that the use of quadrats was not feasible, primarily due to the inaccuracy this method poses when measuring habitat area and the risk of disturbance that could be detrimental to the Hotwater physa.

To further complicate survey method feasibility, during initial site reconnaissance, it also became apparent that minor disturbance (by surveyors) could impact survey results drastically. For example, the first survey day, a metre tape was laid along the stream bank and individual metres flagged along the bank using long thin pin stakes (irrigation system flags). During the initial flagging of metre marks along the streambank, notable aggregations of snails on the stream sediment or margins were also flagged. When the actual snail count was conducted (less than an hour later), many of the flagged snail aggregations had dispersed, moved, were reduced or absent, and thus it became apparent that snails were extremely susceptible to even minor wave disturbance, and/or were continuously mobile. It was then agreed that a minimum of two direct visual counts on consecutive days were needed. When snails were recounted along the same metre gradient the following day, twice as many were seen and counted (Table 1, Appendix B Figure B-1).

This difference is likely due to human activity and disturbance by surveyors on the first survey day. While precaution was taken to minimize the water disturbance, snails at the water/air interface were particularly susceptible to disturbance and seemingly small wave wake disrupted the streambed and vegetation and caused snails to become dislodged from the fine sediment. During the orientation and site marking the stream was walked up and down several times. When snail counts were completed the following day, Alpha stream was walked once and both banks were counted simultaneously, thus reducing impact by surveyors. In addition, it was also noted snails moved to an apparently more secure and cryptic locations within the surrounding vegetation when they were closely observed or counted.

In order to obtain more accurate abundance estimates, it is recommended that future surveys protocols have flagging the length along the stream the first day and snail counts occur the following day. Effort should be made to reduce the amount of disturbance to the streambed while completing snail counts. Appendix A details the basic protocol used for the 2008 survey, and is recommended for future surveys. The decision to use this comparatively basic protocol gives rise to four questions:

1. Is the protocol outlined in this document appropriate and realistic for future surveys of Hotwater physa in LRHSPP? Is the survey protocol understandable for a non-specialist to complete surveys similar and comparable to a trained specialist?
2. Is there a significant difference between sequential daily snail counts and if so, what factors would contribute to such a difference?
3. Is the maximum snail count taken over two or more consecutive daily snail counts an accurate minimum relative abundance estimate?
4. Can optimal or preferred Hotwater physa habitat be identified and/or delineated through visual snail counts?

Data Analysis

Data was analyzed with Sigma Stat Ver. 11 and initially tested for normality using the *Kolmogorov-Smirnov test* with *Lilliefors' correction*. Since the normality test failed, and there could be no assumptions on the distributional characteristics of the data, non-parametric *Mann-Whitney Rank Sum* and *Wilcoxon Signed Rank* tests were used to test the significant difference between observed counts on the first day of sampling and the second day of sampling (Table 3), and observed counts between the east bank and west bank of the Alpha stream (Table 4) to test for habitat preferences between the apparent predominant streambank structure. For details of statistical tests, see Zar (1999)

There are significant differences at the $p=0.0001$ between the first day counts and the second day counts, and there were significant differences at the $p=0.0001$ between the East Bank and the West Bank counts on both days. The significant differences between the two counts are likely due to the disturbance caused by the stream measurement and orientation activities outlined above. The differences between the east and west bank observed numbers are likely due to predominant bank configurations. The west bank had a higher number of sites with undercut banks, overhanging vegetation and faster water due to the closer proximity of the thalweg for a larger portion of the length of the Alpha stream (Appendix B, Table B-1). The east bank had a higher number of small sheltered indentations with broad submerged light grey silt bars (Appendix B, Table B-1), where not only did snails seem to prefer this type of habitat, but they could be more readily seen and counted. A similar pattern was seen in the 2006 survey (COSEWIC 2008a), and observed by Salter (Salter pers. comm.). Due to the often cryptic nature of the snail in different types of habitat, one should not conclude this is the only preferred habitat.

During the September 2008 survey, snail counts beyond 100 m downstream of the dam in Alpha stream were not possible due to soft substrate, water depth greater than wading depths, slow water velocity limited visibility due to sediment disturbance, were all contributing to difficulty in completing visual snail counts along the stream margins. Access to the stream bank from the bench/viewing area was also attempted along the board walk (Figure 3) but the broad *Chara* mats and soft banks prevented easy access and a greater risk to snails. The access conditions found in September 2008 appeared to be different from those described by Salter in July 2007. In 2007, the access from the observation bench to the Alpha stream consisted of firm dry ground from the bench area to very close proximity of the stream. (Salter, pers. comm. 2008). In addition, there is the increased risk of the public perceiving this as potential access (through the riparian zone to the stream), which would harm the sensitive riparian zone and stream margins.

During the 2006 survey, Lee attempted to measure the available habitat along the first 95 metres of the Alpha stream using 10cm² quadrants (COSEWIC 2008a). The extent of occurrence was estimated at 16,310m² (0.02km²) and area of occupancy 4.6m². Both are likely underestimates, considering the often cryptic nature of the snails and the occurrence of snails beyond 95 m in the Alpha stream reported by Salter (2007).

It is possible *Chara* mats are Hotwater physa preferred habitat within the warm-water habitats. During surveys conducted in 1997 and 1999, in order to estimate snail abundance *Chara* mats were measured and shaken to dislodge (Lee and Ackerman 1999). Further observations of *Chara* mats determined that this method only dislodged approximately 1/3 of the snails (Lee and Ackerman 1999). This information was used to extrapolate a population density for all *Chara* mats found along the stream.

Due to the relatively high risk of snail mortality, 2008 studies did not involve a detailed examination of the *Chara* mats, thus snail numbers within this microhabitat are undocumented. During the September 2008 survey, the water temperature within the broad *Chara* mats at the lower end of the stream was taken along 20 perpendicular lines to the stream flow for a rough estimate of the area on occupancy within the *Chara* mats. At all 20 sampled lines, within 5 cm. of the open water margin, the water temperature dropped to below 18˚C within the *Chara* mats, well below the apparent minimum temperature tolerance of Hotwater physa (23-23.5 ˚C) documented in other studies (Te and Clarke 1985, Lee and Ackerman 1999). While the concentration and numbers of snails within the *Chara* mats is unknown, the area in which they occur is likely somewhat limited to within a few centimetres of the open water margin due to the marked drop in temperature below their tolerance range. However, during the August 2006 survey snails were found unexpectedly in cooler water (temperature undetermined) left from the impressions of footprints during surveys (Barbara Bunting, pers. comm.) It is recognized that snails within the Chara mats contribute to the overall Hotwater physa population, but the extent and magnitude is unknown. Therefore, all visual counts in the Alpha stream can only be considered minimum relative abundance estimates.

Fluctuations in the abundance counts of Hotwater physa may be due to the lack of a standardized survey protocol and/or seasonal or annual fluctuations in abundance or visibility/catchability. Previous surveys had differences in the amount of time, search area and time of year the snails were surveyed. The length of the stream surveyed was not consistent and counts were also not always completed per metre length of the stream. In addition, results from the 2008 survey have suggested that human disturbance can alter snail behaviour and visibility. For these reasons, it is not appropriate to compare abundance numbers. While the numbers may differ between the September 2008 and the last comparable survey (COSEWIC

2008a), there are similar patterns to where the sails were observed. In the 2006 survey by Lee (COSEWIC 2008a), there were noticeable aggregations of snails in the first eleven sections along the west bank, and in the September 2008 survey large aggregations were seen in the first 13 metres of the west bank (Appendix B Table B-1). Due to slight differences in the survey layout, it should be noted that the stream section numbers in the 2006 surveys do not exactly correspond to the metre sections in the 2008 survey. There were noticeably higher numbers of snails along both banks at sections 43-45 in the 2006 survey, and similar numbers along both banks at 40-43m in the September 2008 survey (Appendix B Table B-1). There were slight increases along both banks at sections 28-30 along both banks in the 2006 surveys, with similar increases at 28-31m in the 2008 survey (Appendix B Table B-1). The results of the 2008 survey and previous surveys do suggest that the Hotwater physa population is relatively stable and may have seasonal fluctuations. As encountered in the 2006 survey, surveying beyond 100m can become difficult because the stream bed turns into a soft muddy substrate. Therefore it must be acknowledged that any relative abundance estimate does not reflect the true extent and occurrence of Hotwater physa within the Liard River Hot Springs complex. Surveys of Hotwater physa have taken place at different times of the year with varying conditions and seasonal trends can not be inferred from the current limited data.

Banff Springs snail (*P. johnsoni*) is a closely related physid found only within thermal springs in Banff National Park, Alberta and has similar habitat preferences as Hotwater physa. Population counts Banff Springs snail conducted monthly show snail densities vary seasonally. Lepitzki (2002) documented maximum population numbers in late winter/early spring with declines through May - July. The causes of seasonal population fluctuation are unknown but may be related to abiotic or biotic factors in the thermal springs (Lepitzki 2002). Reproduction is evident year-round. Observations in Banff National Park from 1996 to 2006 have shown that the population typically fluctuate by two orders of magnitude annually with lows occurring during the summer and highs during the winter (COSEWIC 2008b).

There is anecdotal information on the existence of snails with similar size shape and colour in hot springs habitat at Tungsten, Northwest Territories (D. Haggarty, pers. comm. 2008), and other northern thermal springs, including unidentified *Physella* sp. at Deer River (Salter 2003). To date there have been no distributional surveys to confirm the existence of additional Hotwater physa populations at other locations.

Life history parameters

There are no available estimates of growth, age at maturity, longevity or recruitment for Hotwater physa. Life history parameters are likely comparable to other physid species. Daily individual intrinsic growth rates (r_m) for the pond snail (*P. gyrina*) in Michigan, have been estimated to range from 0.0235 to 0.04057 (8.58-14.81 annualized), with generation times ranging from 124 to 246 days and reproductive rate (R_0)ranging from 418 to 492 (DeWitt 1954). Reproductive studies on *P. heterostropha*, a species common throughout North America, show intrinsic rates of increase (r_m) varying between 1.17 – 2.86 per 4 weeks (18.64 – 34.32 annualized) reproductive rates ranging from 286 – 808, depending whether the snails were self-fertilizing, mixed mating or outcrossing (Wethington and Dillon 2006). Maximum longevity for most physids is typically approximately one year (Dewitt and Sloan 1959, Gillespie 1969, Brown 1991 and Dhillon 2000 cited in Lepitzki 2002, Wethington and Dhillon 1997). However, evidence suggests that this generation time for the snails may be accelerated in a warmer environment (McMahon 1975). However, when considering life history patterns, there are two distinctive habitat features between physids that inhabit hot springs and pools and the other studied physid species: (1) the temperature regime of hot springs species likely has much narrower temperature fluctuations year-round and the snails would not subject to the widely varying seasonal temperature shifts experienced by other species, and (2) the habitat of the hot springs species is limited by the amount of habitat that includes the viable temperature for that particular species. For example, egg capsules and small snails (around 1mm shell length) are observed year-round at Banff Springs, suggesting reproduction may be ongoing throughout the year (Lepitzki 2002), which is not commonly seen in other physid habitats.

Temperature has been shown to affect directly life history traits such as growth rate, age of maturity, and fecundity levels in freshwater pulmonates (McMahon 1983, Britton and McMahon 2004). There is limited information on captive Hotwater physa indicating relatively low fecundity (6-18 eggs/egg mass)(Lee and Ackerman 1999). Hotwater physa has not undergone the same intensive monitoring as the Banff Springs snail, although egg capsules were documented during the August 2006 survey (COSEWIC 2008a).

In order to better understand and interpret the observed population dynamics of Hotwater physa in the Liard River hot springs complex, knowledge gaps on life history parameters need to be addressed. This will assist in understanding the vulnerabilities of the population; assess the amount of risk that would be acceptable in maintaining the population, as well as mitigating potential threats and managing allowable harm activities. Given the high intrinsic rates of increase as well as apparently high reproductive rates of related species, even though limited information showed a relatively low fecundity rate (Lee and Ackerman 1999), a small portion of the snails could be sampled and removed for observational studies and experimental work to fill in the information gaps on basic life history parameters. Monthly abundance estimates at established index sites are needed to evaluate the seasonal population fluctuations, as potential threats would have more serious impacts during the seasonal lows seen in other *Physella sp*. (Lepitzki 2002, Gillespie 1969)

<u>Habitat requirements and habitat use patterns</u>

Habitat needs for Hotwater physa are both terrestrial and aquatic. Physids are aquatic snails requiring air to breathe and occupy substrate near the water/air interface, with a water temperature between 23-40ºC year round. Further information on habitat characteristics of the Alpha stream were noted in the 2008 survey (Appendix B, Table B-1).

Hotwater physa have been observed on various substrates both above and below the water level. Substrates included mats of green alga, *Chara,* decaying leaves, woody debris (logs, bark), and soil/stream bed substrates such as sand, silt and mud. From the visible counts (Appendix B, Table B-1), preferred stream bottom substrates appear to be sand, silt and mud in quiet water outside the influence or sheer zone of the main stream flow. The importance of *Chara* mats as a preferred Hotwater physa substrate is difficult to evaluate due to the cryptic nature of the snails within *Chara* mats. Decaying leaves and other vegetation also supported large numbers of snails. Observations from the 2008 survey, as well as previous surveys (COSEWIC 2008a), indicate Hotwater physa likely graze on the aufwuchs, the algal and bacterial growth covering the submerged substrates where they were most frequently found.

Previous studies (Lee and Ackerman 1999) have found large numbers of snails in the *Chara* mats. It forms dense, floating mats along the Alpha stream bank and appears to be the preferred substrate for Hotwater physa. When the spring water (high in calcium) cools, calcium precipitates out onto the surface of the *Chara* and results in significant calcification of the plant, particularly those plants floating along the edges of the stream. As calcification of the algal mats and other surfaces proceeds, tufa is formed with crumbly porous rock surfaces. Hotwater physa are likely not directly grazing on tufa surfaces, but on aufwuchs, the organic material that encrusts submerged substrates (Heron 2007).

Hotwater physa appear to require a secure anchoring surface in areas of little or no water flow, although the exact flow rate parameters that they can tolerate are not known. Water enters Alpha stream over the weir at a rate of 80-81 litres/second (annual average) (Peepre *et. al.* 1990). Consistent flow rates and water levels are important for a species that inhabits the margins of streams and pools. Sudden changes in water levels may expose Hotwater physa to the ambient air or may dislodge them from the streambed substrate.

As a pulmonate, Hotwater physa likely has a wide tolerance range for changes in dissolved oxygen levels, due to its ability to extract oxygen from the air, and its capacity for limited gas exchange in water with a rudimentary gill (McMahon 1983). The percent saturation of dissolved oxygen (DO) varied from 39.6% in the Alpha Pool to 80.4% in the Alpha stream (Table 1, Table 2). In the Alpha pool the water was relatively stagnant and a very low proportion of the observed snails were seen below the water/air interface in the pools, with most observed snails just above the water surface on the bank or structure substrates. This may be due both to the relatively high water temperatures in both pools as well as the decreased DO saturation. The water in the stream became aerated and cooled as it moved over and through the weir and over the riffles and structures of the stream bed, which resulted in higher DO levels. In the Alpha stream in September 2008, the majority of observed snails were just below the water surface, which was likely closer to their optimum temperature. Dissolved oxygen saturation may affect the aufwuchs community as a food source for physa. Egg development would likely not be affected by low DO levels, as visible Hotwater physa egg masses are deposited just above the water line both in captivity and in situ (Lee and Ackerman 1999), as is the case with Banff Springs snails (Lepitzki 2002).

The mineral composition needs of the Hotwater physa are also not well understood. *P.wrighti* normally inhabits waters of extremely high salt levels and one could assume that its blood salt levels are correspondingly high as well (Salter 2001). The water in Liard hot springs is slightly alkaline and contains high amount of calcium sulphate. Total dissolved solids, or conductivity of the Liard hot springs has been measured at concentrations around 1100 ppm (Table 1, Table 2). About 3/4 of this concentration is accounted for by Ca^{++} and $S0_4^{--}$ ions, with lesser amounts of Mg^{++}, Na^+, K^+, $HC0_3^-$, Cl^-, and $Si0_2$. (Peepre *et. al*., 1990)

Previous observations have noted that there may be seasonal migration of snails above and below the water line, dependent on the ambient air temperature. Lee observed most snails and egg cases above the water/air interface in August 2006 when the ambient temperature was 20°C compared to observations of mostly submerged snails in September 1997 when the ambient temperature was much cooler. Thus, *P.wrighti* appears to instinctively position itself and its eggs at optimal temperature to facilitate life history requirements (COSEWIC 2008a).

The terrestrial habitat requirements include the riparian zone of the pools and stream. Salter (2001) observed snails occurring in a ~5cm band both above and below the surface of the water. The extent of the effect and the importance of the riparian vegetation and shade it provides have on the Hotwater physa and aquatic plants such as *Chara* has not been closely studied or quantified. Vegetation provides woody debris and leaf matter to the stream. Once this material enters the stream it becomes a substrate for algal and bacterial growth, as seen in the September 2008 survey, by the aggregations of snails grazing on semi-submerged leaf matter as many sites, especially at the lower end of the stream. At present the light reaching the outlet stream and the margins of the warm water swamp where the snails are found can be described as deep shade to dappled shade. The effect of direct sunlight from an open tree canopy on the snails is not known.

Habitat availability for this species has likely changed with the construction of the weir and dam structure and the creation of the lower and upper Alpha pool. It is not possible to estimate the available habitat before alteration of the pools and construction of the weir and dam, but the most likely scenario is that the weir and dam has provided moderating flows and stability to the outlet stream reducing the frequency and degree of streamflow fluctuations that would be harmful to the snail. The log dam also provides a barrier to hot springs pool bathers that may be tempted to wade in the small outlet stream.

Population and distribution targets

Due to the unusual circumstances of this endemic data-limited species, this is not a recovery situation in the usual sense, but an assessment to ensure protection and preservation of a unique small population with a very limited and restricted distribution within LRHSPP. The population and distribution targets for Hotwater physa are to maintain the current variation of abundance within both the Alpha and Beta pools and along the Alpha stream.

Expected population trajectories and time to recovery

Expected population trajectories and time to recovery parameters do not apply to Hotwater physa. There is no current or historic evidence of Hotwater physa population decline and therefore the expected population trajectories would be to maintain the current variation of abundance. This is an attempt to protect and preserve a unique population that exists within an area of periodically intense human use that has potential risks to catastrophic effects on the existing population.

Residence requirements

The term residence – as defined in *SARA* s.2(1) is “a dwelling-place or 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 2002). This concept of residence is not applicable to Hotwater physa.

Surveys in 2006 estimated the extent of occurrence and area of occupancy along 95m of the Alpha stream were estimated to be 16,310m² (0.02km²) and 4.6m², respectively (COSEWIC 2008a). However area of occupancy should include the both the Alpha and Beta pools as well as the Alpha stream extending all the way to the warm marsh, as shown by Salter (2007). The extent of occurrence should include 60-100cm on both sides of the streambank edge (e.g. both into the stream and into the riparian area).

PHASE II: SCOPE FOR MANAGEMENT TO FACILITATE RECOVERY

Probability that the recovery targets can be achieved

Hotwater physa recovery goal is to maintain and protect the population(s) of Hotwater physa within its natural geographic range and within its current variation of abundance at Liard River Hot Springs. (Heron 2007) Hotwater physa will likely remain listed as endangered, due to the fact that it is an endemic to the Liard River Hot Springs. There is no current or historic evidence of population decline. The habitat specificity of this species makes it vulnerable to human disturbance and stochastic events. To ensure success in the maintenance and protection of Hotwater physa, appropriate mitigation steps must be drafted, implemented and monitored, thus providing ideal conditions for survival at present population levels.

Magnitude of each major potential source of mortality

Recreational Use

Recreational activities pose the greatest threat to Hotwater physa through both direct and indirect mortality.

- Bathers may contribute to a gradual population decline (indirect mortality) through the introduction of foreign chemicals through toiletry products (e.g. mosquito repellent, shampoo, body lotions, antibacterial soap). The presence of these substances on the waters surface may limit the snail's access to air and/or coat them with materials that could interfere with life processes, such as egg-laying.
- Direct mortalities may be caused by bathers playing with large woody debris found within the pools (e.g. bathers playing with floating logs and potentially crushing or dislodging snails from the pool banks or the log itself).
- Visitor's venturing off the boardwalk and trampling the habitat adjacent to Alpha stream and surrounding swamp area of the park could also crush or remove snails from their substrate and increase mortality rates.
- Liquor consumption by bathers was evident during the September 2008 survey. Heavy use of the Alpha pool by bathers at peak times may be a source of stress for snails not only residing in the lower Alpha pool, but especially in the outlet Alpha stream. According to the B.C. Regulations defining bathing loads in treated pools outlined in the Park Master Plan (Peepre 1990), the Alpha pool should be able to accommodate 50 bathers at a time without health risk. The estimated outflow to the Alpha stream outlined in the same report is approximately 80 l/s, with an overnight flushing rate, thereby reducing health risks to bathers. However, any contaminants or effluent from human use of the pools is in direct contact with the snails in the outlet stream and swamps, and the mitigating effect of 80 l/s as a dilution rate is unknown on the snails. In contrast, the Beta pool has less flushing than the Alpha pool and was closed due to high coliform counts from the mid-1970's until the late 1980's (Peepre 1990).

An invasive species could disrupt the delicate ecology of the hot springs. Although the likelihood that an invasive species would be introduced to this remote ecosystem is low, the potential risk to its' endemic populations would be very high. For example, the introduction of a mosquito fish (*Gambusia affinis*) into Banff Hotsprings for mosquito control resulted in the extinction of the Banff longnose dace *(Rhinichthys cataractae smithi)* in 1987 (COSEWIC 2000, SARA 2011). Two known introductions of turtles have taken place in the past at Liard Hot Springs. Fortunately the animals were found and quickly removed.

Collection of snails by visitors is considered low risk.

Diversion of or fluctuations in the outflow of Alpha stream

Prior to documentation of Hotwater physa the Alpha pool was modified to create a large pool for recreational bathing. Cool water from an unnamed creek was diverted into the incoming springs to moderate the water temperature. Alpha pool was artificially created through the installation of a dam and weir (Heron 2007). The dam separates the water into the upper and lower Alpha pools. The weir holds back the water in the lower Alpha pool at the outlet to the Alpha stream. It is difficult to assess the how these past modifications have altered the habitat and distribution of Hotwater physa, but the moderated temperature of the lower Alpha pool and outlet to the Alpha stream is well within the temperature tolerance of Hotwater physa. A collapse of the dam or weir structure would cause a change in the flow regime of the water entering the Alpha stream and on the water level of the Alpha pool. A flash flood of water would have a devastating effect on the population of Hotwater physa.

Land-use of the surrounding area

Large scale changes to the water flow through the region would include potential development of the Liard River Hydroelectric Project (Devil's Gorge Project). This project would flood the entire hot springs complex with cooler water. Drilling activities for oil and gas exploration outside the park could potentially interfere with the underground thermal source of the hot springs. The source of the hot springs has not been mapped but is believed to be located outside of the park boundaries. Drilling into the source water at any point may markedly affect the flow of hot water within the Park (Heron 2007).

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

The Liard River hot springs were used by humans for bathing since prospectors and trappers first came to the area at the end of the 19^{th} century and during the building of the Alaskan Highway during World War II. In 1957 the area was set aside as a park in order to manage the continued public use of an ecologically unique area. Hotwater physa was not discovered until 1983, therefore there are no pre-development Hotwater physa population estimates, estimates of habitat quantity or quality, nor are there any Hotwater physa distributional data from the source springs, streams and warm-water swamps. The weir and dam were installed to create the lower and upper Alpha pools altering the flow, shape, and depth of the hot springs to accommodate bathers. It is difficult to measure the impact these activities had on the Hotwater physa population before it was discovered and before any population monitoring was in place. Anecdotal accounts suggest that in the early years as a Provincial park, and during the construction of the Alaskan Highway, individuals using the pools often washed with soaps and shampoos.

Likelihood that the current quantity and quality of habitat is sufficient

Due to the lack of pre-development data, setting realistic biological restoration goals to pre-development levels or complexity is not possible. Despite the pool development activities and associated human recreational use, the continued presence of Hotwater physa in the hot springs complex shows that it has been able to survive and persist with a perceived reduction to habitat quantity and quality.

Since this is not a usual recovery situation, the goal of a draft recovery plan is to maintain current population and protect a unique/endemic species and the habitat that supports the species (Heron 2007). In order to preserve and maintain the existing habitat that supports the Hotwater physa, critical habitat of the Hotwater physa could be defined as the hot water springs sources as well as the present area of occupancy, including the occupied pools, the upper portion of the Beta Stream above the tufa cliffs and the Alpha Stream (including a 5 cm buffer riparian strip) and the downstream marsh with water temperature greater then 22˚C. Additional action steps to maintain the current population and protect the supporting habitat are: to monitor the current relative population levels at appropriate time levels, and to implement mitigation measures to decrease risks to mortality and protect the unique habitat supporting Hotwater physa.

PHASE III: SCENARIOS FOR MITIGATION AND ALTERNATIVE TO ACTIVITIES

Inventory of mitigation measures

The purpose of mitigation measures is to reduce the stress imposed on the snails through the recreational use of the hot springs and to reduce the risk of mortality.

Recreational Use

While efforts to protect the fragile ecosystem, hot springs marsh and aquatic habitat are ongoing, habitat destruction, disruption or deterioration can be avoided by providing and maintaining elevated boardwalks, limiting access to hot springs waters to a maximum bathing capacity, and no further expansion of the camping facilities within LRHSPP. Improved signage is needed to inform the public that the hot springs are a delicate ecosystem susceptible to human misuse. There are currently only two signs, one in the parking lot and one at the change rooms that list a number of rules for pool use. These signs contain a multitude of messages regarding user conduct at the pools. Signs should be added that specifically describe the hot springs as a unique ecosystem and that misuse by visitors will have an impact on the sensitive flora and fauna of the area. Signage requesting that visitors not put on mosquito repellent before entering pools would be helpful, though difficult to enforce. A greater level of supervision by Parks staff would improve compliance to established rules. Closer monitoring of the Alpha pool by Parks staff during peak use times would advise Parks managers on the risk of exceeding suggested or recommended maximum bathing capacity. The Liard River Hot Springs Provincial Park Master Plan proposes the development of interpretation programs for park users. Implementation of these proposals would foster stewardship by park users. It would be ideal to have all bathers shower in freshwater before entering the pools, but given the remote location of the park and the lack of running water this is not feasible option at this time. Park users are requested not to use soaps and shampoos within the pools. Some of the risk to the snails from deleterious material may be alleviated by the relatively high volume of water being flushed through the Alpha pool, but the effect on the snails is unknown.

The removal of large woody debris from the lower Alpha pool on a regular basis would reduce mortality rates and minimize the damage that can be caused by children playing with the logs and collisions with the pool margins where the snails are found. Large woody debris blocking the weir has also been a problem in the past. In September 2005 water levels within the stream fell below the level of data loggers because of alterations made to the dam (Heron 2007).

Diversion of or fluctuations in the outflow of Alpha stream

Since the development of the Alpha pool in 1973, the Hotwater physa appears to be stable in the current habitat created by the pool development. It is not clear if any modifications to the weir or dam would result in any positive habitat restoration or enhancement, providing a net benefit to the Hotwater physa. The implementation of a weir and dam maintenance schedule is a proactive preventative measure to maintain the integrity of the Alpha pool and stream. The development of a weir maintenance schedule and inclusion of this schedule in the Park Master Plan would minimize the likelihood of structural failure. Structural failure of the weir or dam would cause a large mortality event in the snail population. A sudden flash flood could dislodge individuals, while a sudden drop in flow could expose the snail to ambient air temperature that might be lethal during the winter.

Land-use of the surrounding area

An assessment to determine the route of the geothermally heated water from its underground source to the hot springs would provide greater certainty to the level of risk associated with the sources location. It is believed that the underground source of the hot spring is located outside the Provincial Park boundary. This information would be useful in determining if additional land protection should be considered.

To reduce risk consideration should be given to obtain the water rights for the hot springs even though it is groundwater and there is pending legislation on groundwater rights.

Alternatives to human activities and threats to habitat

The Liard River hot springs were developed for public use before the discovery of the Hotwater physa. It is not feasible to alter the parks use due to its unique features and high demand. Since biological surveys indicate the Hotwater physa population and habitats appear to be stable under current conditions, and are not negatively impacted by the present recreational use pressures, the continued recreational use of LRHSPP is feasible with continued and possibly enhanced protective measures to ensure the viability of the Hotwater physa population. Focus should be directed towards mitigating human impacts. Effort should be made to inform and educate park users of the ecological sensitivity of the area and that continued access to the area is dependent upon compliance. Information should be provided so the public can minimize their impact on the environment when they use the hot springs. This information can be in the form of better signage, interpretive programs, and greater monitoring by park staff at the pool.

Additionally, any activities that directly impact Hotwater physa, including research activities, such as population assessments or habitat assessments have the protection of requiring Section 73 Allowable Harm Permits under *SARA*, as well as BC Provincial Parks Park Use Permits, with the conditions of use accompanying these permits.

Suggested research activities

1. The development of a survey schedule and the implementation of the survey protocol outlined in Appendix A. Surveys should be completed annually at a minimum due to the short life span of Hotwater physa. Banff Springs snail has been surveyed four times per year (as a minimum) over the past fifteen years (Lepitzki, pers. comm., 2011).

Consistent survey methodology for the Alpha stream and both the Alpha and Beta pools would increase the understanding of population dynamics.

2. Monthly snail counts by the park staff of the lower Alpha pool and permanent index sites along the Alpha Stream would provide invaluable information regarding the population fluctuations during the course of the year. This information could be obtained quickly and easily and would increase the understanding of seasonal fluctuations, and productivity or survivorship parameters.

3. Studies are needed to better understand the biological parameters of physids (growth rates, fecundity etc.) in order to better assess the risks and vulnerabilities of the Hotwater physa population exposed to human activities.

4. A geological assessment should be completed to identify the underground route water takes to be thermally heated.

5. Determine through genetic studies whether there are other populations of Hotwater physa outside LRHSPP that may provide a possible rescue source.

CONCLUSIONS AND RECOMMENDATIONS

1. Annual (minimum) or quarterly (optimal) surveys of the Alpha stream and both the Alpha and Beta pools should be conducted to monitor the population and document changes in the area of occupancy. Surveys should follow the protocol outlined in Appendix A to minimize risk and disruption to the resident population, yet provide a realistic minimum relative abundance estimate. Monthly counts at permanently fixed index sites should be conducted to evaluate seasonal population fluctuations and determine the extent and vulnerability of annual lows. Further surveys in unoccupied areas need to be completed.

2. Hotwater physa critical habitat is recommended as hot water springs sources as well as the present area of occupancy, including the occupied pools, the upper portion of the Beta Stream above the tufa cliffs and the Alpha Stream (see Figure 3) (including a 5 cm buffer riparian strip) and the downstream marsh with water temperature greater then 22˚C.

3. Observational studies are needed to fill in the gaps in basic life history knowledge, and experimental work is needed to better understand the effects of deleterious substances, (e.g. soaps and mosquito repellent) on Hotwater physa and their habitat. The level of deleterious substances in the Alpha stream under varying bathing loads in the Alpha pool, along with a better understanding on the effects of those deleterious substances would provide a foundation for setting biologically based bathing capacity in the Alpha pool to reduce the stress and risk of mortality to Hotwater physa. Further research on the cellular disruption and/or hormonal impacts to Hotwater physa from introduced chemicals is also required. Given the high intrinsic rates of increase of populations of related species, and an assumed equilibrium population size of 10,000, the removal of 5-10% or 500-1000 snails per year for scientific study would be a precautionary measure to assist in providing needed information for sustaining this species at the present abundance levels and distribution.

4. A review of the Liard River Hot Springs Provincial Park Master Plan is recommended with consideration of additional options to protect and restore habitat within the park, if

required, to improve and implement mitigation measures to reduce the impact of deleterious substances, and to develop guidelines to protect the geothermally heated water from its source to where it surfaces in the park

5. Address knowledge gaps by determining through genetic studies whether there are other populations of *P. wrighti* outside the Liard River hot springs that may provide a possible rescue source if it is ever required and by providing support to the identification of new threats in the event there is a decline in the population from unknown causes.

SOURCES OF INFORMATION

B.C. Parks. 2008. Liard River Hot Springs Provincial Park. http://www.env.gov.bc.ca/bcparks/explore/parkpgs/liard_rv_hs/

Britton, D.K. and R.E. McMahon. 2004. Seasonal and artificially elevated temperatures influence bioenergetic allocation patterns in the common pond snail (*Physella virgata*). Physio. And Biochem. Zool. 77(2) 187-196

Brown, K.M. 1991. Mollusca: Gastropoda. pp 285-314 in Ecology and Classification of North American Freshwater Invertebrates. (Thorp, J.H. and A.P. Covich, eds.) Academic Press, San Diego, CA

COSEWIC. 2000. Species Database: Dace, Banff longnose. http://www.cosewic.gc.ca/eng/sct1/searchdetail_e.cfm?id=71

COSEWIC 2008a. Status of Hotwater Physa, *Physella wrighti* (Te and Clarke, 1985). Report prepared by J. S. Lee and accepted by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in April 2008. 41pp.

COSEWIC. 2008b. COSEWIC assessment and update status report on the Banff Springs Snail *Physella johnsoni* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 53 pp. http://www.sararegistry.gc.ca/virtual_sara/files/cosewic/sr_banff_springs_snail_0808_e.pdf.

DeWitt, R.M. 1954. The intrinsic rate of increase in a pond snail (*Physa gyrina* Say). The American Naturalist. 88(842): 353-359

DeWitt R.M. and W.C. Sloan. 1959. Reproduction in *Physa pomilia* and *Heliosoma duryi*. Animal Behaviour 7(1-2):81-84

DFO, 2007. Revised Protocol for Conducting Recovery Potential Assessments. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2007/039.

Dhillon, R.T. Jr. 2000. The Ecology of Freshwater Molluscs. Cambridge University Press, Cambridge, UK. 509 pp

Gillespie, D.M. 1969. Population studies on four species of molluscs in the Madison River, Yellowstone National Park. Limnology and Oceanography. 14(1):101-114

Heron, J. 2004. A Summary of Terrestrial and Freshwater Invertebrate Conservation in British Columbia In T.D. Hooper, editor. Proceedings of the Species at Risk 2004 Pathways to

Recovery Conference. March 2-6, 2004, Victoria, B.C. Species at Risk 2004 Pathways to Recovery Conference Organizing Committee, Victoria, B.C.

Heron, J. 2007. Recovery strategy for the Hotwater Physa (*Physella wrighti*) in Canada. *Species at Risk Act* Recovery Strategy Series. Fisheries and Oceans Canada, Vancouver. Vii + 27pp. http://dsp-psd.pwgsc.gc.ca/Collection/En3-4-17-2007E.pdf

Lee, J.S. and J.D. Ackerman. 1999. Status of Hotwater Physa, *Physella wrighti* (Te and Clarke, 1985). Report accepted by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in April 1998.

Lepitzki, D.A.W. 2002. Status of the Banff Springs Snail (*Physella johnsoni*) in Alberta. Alberta Sustainable Resource Development, Fish and Wildlife Division, and Alberta Conservation Association, Wildlife Status Report No. 40, Edmonton, AB. Vii + 29pp.

McMahon, R.F. 1975. Effects of artificially elevated water temperatures on the growth, reproduction and life cycle of a natural population of *Physa virgata* Gould. Ecology 56: 1167-1175.

McMahon, R.F. 1983. Physiological ecology of freshwater pulmonate. Pp.359-430 in Mollusca (W.D. Russell-Hunter, eds.), Volume 6, Ecology. Academic Press. San Diego, CA.

Peepre, J.S., P. Jordan and J. Nathan. 1990. Liard Hot Springs Provincial Park Master Plan. Ministry of Parks, British Columbia.

Rupert E.E., R.S. Fox and R.D. Barnes. 2004. Invertebrate Biology: A Functional Evolutionary Approach. Seventh Edition. Thompson Brooks/Cole. 989 p + xvii

Salter, S.P. 2001. Management of Hot Water Physa (Physella wrighti) in Liard River Hot Springs. Report submitted to British Columbia Parks Peace-Liard District, Ministry of Environment, Lands and Parks. 23 p.

Salter, S.P. 2003. Invertebrates of selected thermal springs of British Columbia. Habitat Conservation Trust Fund, Victoria, B.C. 90 p.

Salter, S.P. 2007. Report of Population Observations of *Physella wrighti* in Liard Hot Springs Provincial Park, July 13, 2007. Report submitted to British Columbia Parks Peace-Liard District, Ministry of Environment, Lands and Parks.. 4 p.

SARA. 2002. Canada Gazette Part III. Volume 23, No.3. Chapters 24-29.

SARA. 2011. Species at Risk Act Registry accessed 2011 http://www.sararegistry.gc.ca/default_e.cfm

Te, G.A. and A.H. Clarke. 1985. *Physella* (*Physella*) *wrighti* (Gastropoda: Physidae), a new species of tadpole snail from Liard Hot Springs, British Columbia. Canadian Field-Naturalist 99:295-299.

Wethington, A.R. and R.T. Dhillon. 1997. Selfing, outcrossing and mixed mating in the freshwater snail *Physa heterstropha*: lifetime fitness and inbreeding depression. Invertebrate Biology. 116(3):192-199

Personal Communication:

Barbara Bunting, Independent biological consultant, J.S. Lee and Associates, Vancouver, B.C.
Dana Haggarty, Parks Canada biologist, Fort Simpson, NWT
Sue Salter, Independent biological consultant, invertebrate specialist, Summerland, B.C.

Figure 1. Total known extent of P. wrightii global distribution confined within Liard River Hot Springs Provincial Park (Salter 2003).

Figure 2. Hotwater physa on emergent vegetation (J. Heron)

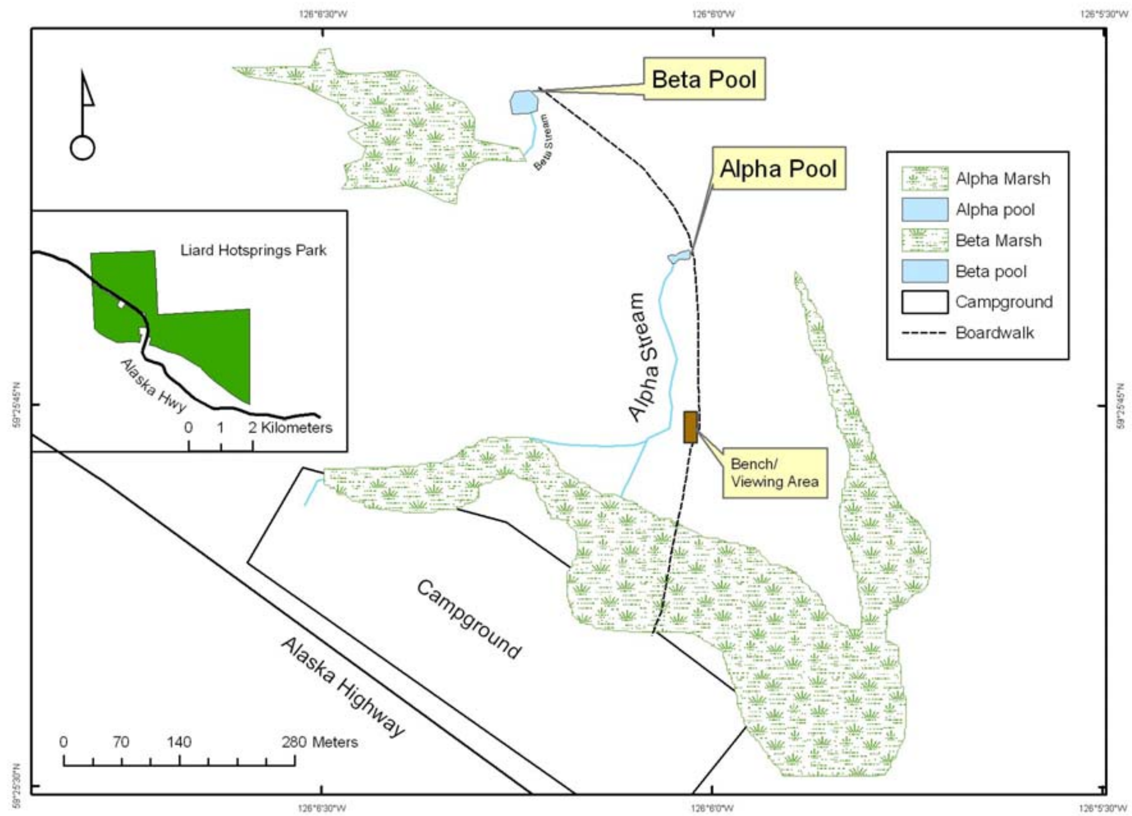

Figure 3. Hot springs pools and outlet streams with resident Hotwater physa in Liard River Hot Springs Provincial Park

Table 1. Summary of recent and past survey data for Alpha and Beta Pools

Surveyors	Count	pH	Temperature Range (˚C)	Conductivity µS/cm^2	DO (%)
Alpha Pool					
DFO & MOE, Sept 2008[1]	97	7.64	32.3-45.0	1177	39.6
Salter, July 2007[2]	0	-	-	-	-
Lee, Aug 2006[3]	23	-	36.0-48.0	-	-
Salter, Jan 2001[4]	2100	-	-	-	-
Beta Pool					
DFO & MOE, Sept 2008[1]	17	6.84	39.4	1175	52
Salter, July 2007[2]	0	-	-	-	-
Lee, Aug 2006[3]	910	-	36.0-41.5	-	-

Table 2. Summary of recent and past survey data for Alpha and Beta Streams

Surveyors/Sample Date/Reference	Distance (m)	Count	pH	Temperature Range (˚C)	Conductivity µS/cm^2	DO (%)
Alpha Stream						
DFO & MOE, Sept 2008[1]	100	6212	7.1	35.6-36.7	1144-1150	80.4
Salter, July 2007[2]	12 Sites, 0-171m	observed	-	34.0-37.0	1150	-
Lee, Aug 2006[3]	95	1426	-	35.5-40.0	-	-
Salter, 2003[5]	-	observed	-	28.9-36.3	-	-
Salter, Jan 2001[4]	-	7000	-	33.0	-	-
Salter, Aug 2000[4]	200	5186	-	23.0-36.0	-	-
Lee & Ackerman, Sept. 1997[6]	50	2127	7.8	23.5-36.5	1155	67
Te & Clarke, 1979[7]	-	observed	7.9	23.0-35.0	1310	-
Beta Stream						
DFO & MOE, Sept 2008[1]	20	3	6.9	38.8	-	-
Salter, July 2007[2]	-	0	-	40.9	-	-

[1]This report; [2]Salter, 2007; [3] COSEWIC, 2008a; [4]Salter, 2001; [5]Salter, 2003; [6]Lee and Ackerman, 1999; [7]Te & Clarke, 1985

Table 3. Number of Snails Observed Along the Alpha Stream on September 23-25 2008

		First Count	Second Count	Difference Between Counts		
				Number	%	P=
East Bank	Obs. Total	1,749	4,181	2,432	58.2	<0.0001
	Max Obs./meter	227	415	188	45.3	<0.0001
West Bank	Obs. Total	1,044	2,017	973	48.2	<0.0001
	Max Obs./meter	198	319	121	37.9	<0.0001
Island	Obs. Total	6	14	8	57.1	<0.0001
Alpha Stream Total		2,799	6,212	3,413	54.9	<0.0001

Table 4. Comparison of Number of Snails Observed Between West Bank and East Bank of Alpha Stream on September 23-25 2008

		West Bank	East Bank	Difference between West Bank and East Bank		
				Number	%	P=
First Count	Observed Total	1,044	1,749	705	40.3	<0.0001
	Max Obs./Meter	198	227	29	12.8	<0.0001
Second Count	Observed Total	2,017	4,181	2164	51.8	<0.0001
	Max Obs./Meter	319	415	96	23.1	<0.0001

APPENDIX A – HOTWATER PHYSA SURVEY METHODOLOGY

This survey protocol was developed to ensure minimal risk and minimal harm to Hotwater physa (*Physella wrighti*) found in Liard Hot Springs Provincial Park. Since this species is has been designated endangered under *SARA*, and resides within B.C. Provincial boundaries, permits are required to collect any biological samples and to disturb the animal or its habitat. The survey protocol was developed to ensure minimal intrusion and disturbance of the natural habitat for Hotwater physa. Classical sampling techniques of transect placement and/or quadrat placement to satisfy the requirements for parametric statistical analysis should not be used because of the potential increased risk of harming or disturbing the snail.

The stream length of each bank is determined by carefully laying out a survey tape along the riparian vegetation next to the margin of the stream. At each metre measure on the tape, a pre-marked page of water-proof paper with the number of the metre measure is clothes-pinned to the vegetation, over-hanging branch or thin stake. Care must be taken to ensure the tape does not go into the water and is not caught by the wind and twisted to disturb the vegetation, surface of the water or bottom sediment. As the metre markers are placed, noticeable aggregations of snails should be denoted by placing an irrigation flag (a small plastic flag on a long thin pin-stake) in the stream sediment or along the bank close to the observed aggregation. Care must be taken when wading the stream to avoid stepping on any snails in the mid-stream riffles, islands or banks. Care must also be taken to reduce the frequency and magnitude of wave wake caused by wading in the stream, as this has been seen to cause dislocation of snails above and below the water-air interface.

The bottom end of the stream survey will be determined by the depth and softness of the stream sediment. Persistent cloudiness in slower water from disturbing the sediment makes it impossible to enumerate the snails, and the effect of the suspended silt on the snails is unknown. A surveyor having difficulty moving or staying upright in deep and soft sediment poses a risk to any snails on the sediment, in the margins or along the vegetation.

Snails are enumerated with direct visual counts. While counts along the stream banks could be done immediately after placement of the bank metre markers and the irrigation flags, there should be a count the following day when there as been no disturbance to the stream or stream bank immediately preceding the count. There should be at least two complete counts at different times of the day to ensure as many snails as possible are seen under different light conditions. The maximum counts should be used as the minimum relative abundance estimate. Snails are found both in the water relatively close to the surface, and above the water surface in close proximity to the water surface. All substrates above and below the water near the water-air interface should be examined, including vegetation, wood debris, dead leaves and open shallow bays sheltered from the mainstream flow. The underside of submerged dead leaves should also be examined by carefully turning over for a visual count, and returning to their original position. Direct visual counts between metre marks of each bank should be recorded, as well as any islands, riffles or structures in the mid-stream for each metre of stream length and delineated by east bank, west bank or mid-stream.

The substrate, water velocity water temperature and bank configuration should be noted where aggregations are found, where the irrigation flags were originally placed, and at each metre mark along the stream bank whether or not snails are observed.

The margins along the pools are counted by swimming/wading surveyors, slowly and carefully moving along the margins and closely examining the substrate above and below the water-air interface. This is best done when with the fewest possible bathers in the pools, which reduces wave action along the margins, and reduces the chances of bathers picking or disturbing the snails when they become aware of the individual appearance and location.

The goal of the surveys is to determine the minimum population estimate of the Hotwater physa in the pools and outlet streams for a given year. Since the snails are cryptic, easily disturbed, relatively fast moving for their size and it is impossible to sample all their known habitat without irreparable harm, the highest overall count of two or more counts would be the minimum population estimate.

APPENDIX B – 2008 HOTWATER PHYSA SURVEY RESULTS

Table B-1 Hotwater Physa 2008 Survey Counts and Habitat Characteristics

Dist. (m)	East Bank Counts 1st	East Bank Counts 2nd	East Bank Habitat Features	West Bank Counts 1st	West Bank Counts 2nd	West Bank Habitat Features
Dam	9	0	undercut bank	0	0	
1	12	2	snails on bark	0	1	mud with a lot of debris & veg - hard to see
2	0	0		3	5	again hard to see
3	12	8	along the side of log at interface, on the leaves	33	220	all sizes of snails, on mud/sand bank
4	17	71	on the leaves	90	95	on mud/sand, moving around under water
5	27	59	on the leaves	58	54	mud/sand flat
6	9	51		14	12	getting swift next to CWD
7	1	11		9	6	swift
8	8	7		49	87	top of mud grazing, likely more
9	64	66	aggregation on sand, undercut bank	30	70	grazing on mud/sand and leaves
10	43	111	chara clump	7	0	missed by observer?
11	64	181		29	49	grazing ~2cm below water line on mud/sand
12	76	204	1st large Chara mat	198	319	on mud/sand
13	53	121	Chara mat	57	86	very small, likely more but snails small & under leaves
14	13	130	Chara mat	10	30	water gets more swift
15	36	114		11	33	water swift, snails on mud/sand lip
16	9	47	fast water, no undercut bank	6	24	swift, snails clinging to mud lip, roots & leaves @ interface
17	15	21	fast water, no undercut bank	13	25	on vegetation (rotten) or plant roots/leaves that are dragging in water & are brown w/algal etc
18	15	24	fast water, no undercut bank	32	34	vegetation overhanging & dipping into water, swift water, snails grazing on leaf litter & sticks
19	4	27		12	12	vegetation overhanging, start of undercut bank, bits of mud w/leaves, snails sitting - not grazing
20	0	5		7	17	undercut but small ledge w/snails
21	0	2		0	0	undercut, no ledge
22	1	4		0	0	undercut, no ledge
23	3	8		5	1	on ledge, undercut begins to stop, island starts 1/2 along
24	25	30		3	1	mud/sand, undercut

25	10	12		1	0	undercut, island ends just after
26	3	8		6	1	moss over bank to H2O
27	25	58	slow water, sand bay	3	14	start of swift water by bank
28	13	42	bay with small flat	2	4	veg to water, not much "mud-flat"
29	23	34		4	0	overhang of vegetation
30	5	19	fast water	2	1	overhang of vegetation, swift water
31	0	8		2	6	overhang of vegetation, swift water, wintergreen
32	2	17		0	2	overhang of vegetation, swift water, wintergreen
33	1	28		3	2	overhang of vegetation, wintergreen
34	0	13		2	0	overhang of vegetation, wintergreen
35	0	1		0	1	overhang of vegetation, swift water
36	0	0		9	14	overhang of vegetation, swift water
37	0	7		0	0	overhang of vegetation, fast - incut water
38	3	3		3	2	beginning of moss mat flat end swift water, overhang of vegetation
39	31	38		22	101	mudflat extends 1m to moss then edge of bank
40	36	133	mud/sand	28	120	mud/sand
41	6	63	mud/sand	8	48	end mud/sand
42	24	65	mud/sand	4	6	beginning of undercut veg hangs off moss; start of overhang
43	19	15		0	3	overhang vegetation, undercut bank
44	12	21		0	3	missed by observer?
45	6	2		0	0	undercut bank
46	2	4		0	0	undercut bank; end of overhang
47	0	0		0	1	
48	7	28	mud/sand bank	2	1	sand/mud bank
49	9	10		5	0	moss covered mud/sand
50	2	4		5	0	wintergreen
51	3	4		0	0	swift water
52	1	6		0	0	swift water, starting to round a corner
53	19	10		4	12	wintergreen, overhanging vegetation in water
54	0	8		2	6	wintergreen, overhanging vegetation in water
55	2	3	large Chara mat	0	1	wintergreen, overhanging vegetation in water
56	3	9	large Chara mat	3	1	wintergreen, overhanging vegetation in water
57	0	3		0	1	

58	2	0		0	1	water covered moss & wintergreen, too swift over log?
59	0	41		1	0	
60	1	13		0	12	mud/sand flat, but swift
61	4	26	start of silt zone	3	8	start of overhang with moss
62	11	33	silt/mud, slow water	0	0	
63	5	30	silt/sand, slow water, small bays	0	0	
64	16	42		0	0	
65	61	52		7	8	cinquefoil
66	0	4		8	23	little sheltered mud flat
67	6	23		4	4	
68	5	30		3	41	wintergreen covering edge, touching swift water
69	8	27		4	0	
70	11	28		2	2	
71	18	46		0	1	undercut bank
72	36	42		0	0	undercut bank
73	13	32		0	0	undercut bank
74	4	8		0	1	
75	0	7		2	2	small sand bank
76	7	77		0	5	undercut bank
77	39	47		0	0	
78	0	4	fast water next to bank	2	3	
79	11	4	fast water next to bank	2	1	
80	0	6	fast water next to bank	0	1	
81	5	19		0	4	
82	0	20	small sand/silt embayments, overhanging veg'n	3	2	
83	5	58	small sand/silt embayments, overhanging veg'n	3	2	
84	4	26	small sand/silt embayments, overhanging veg'n	1	4	
85	18	53	small sand/silt embayments, overhanging veg'n	3	18	
86	0	16		2	7	
87	16	84	small sand/silt embayments, overhanging veg'n	3	25	
88	4	12		8	12	

89	6	50		14	4	
90	7	51		10	5	
91	0	1		63	76	
92	5	53		1	66	
93	101	87	under leaves Chara mat	0	32	
94	20	170	Chara mat & bays, silt bottom, dead leaves	2	27	
95	90	415	large Chara mat, silt bottom, dead leaves	2	20	
96	227	283	large Chara mat, silt bottom, dead leaves	8	20	
97	68	10		74	7	
98	125	151		10	4	
99	7	20	thick silt with snails	3	37	
Total	1749	4181		1044	2017	

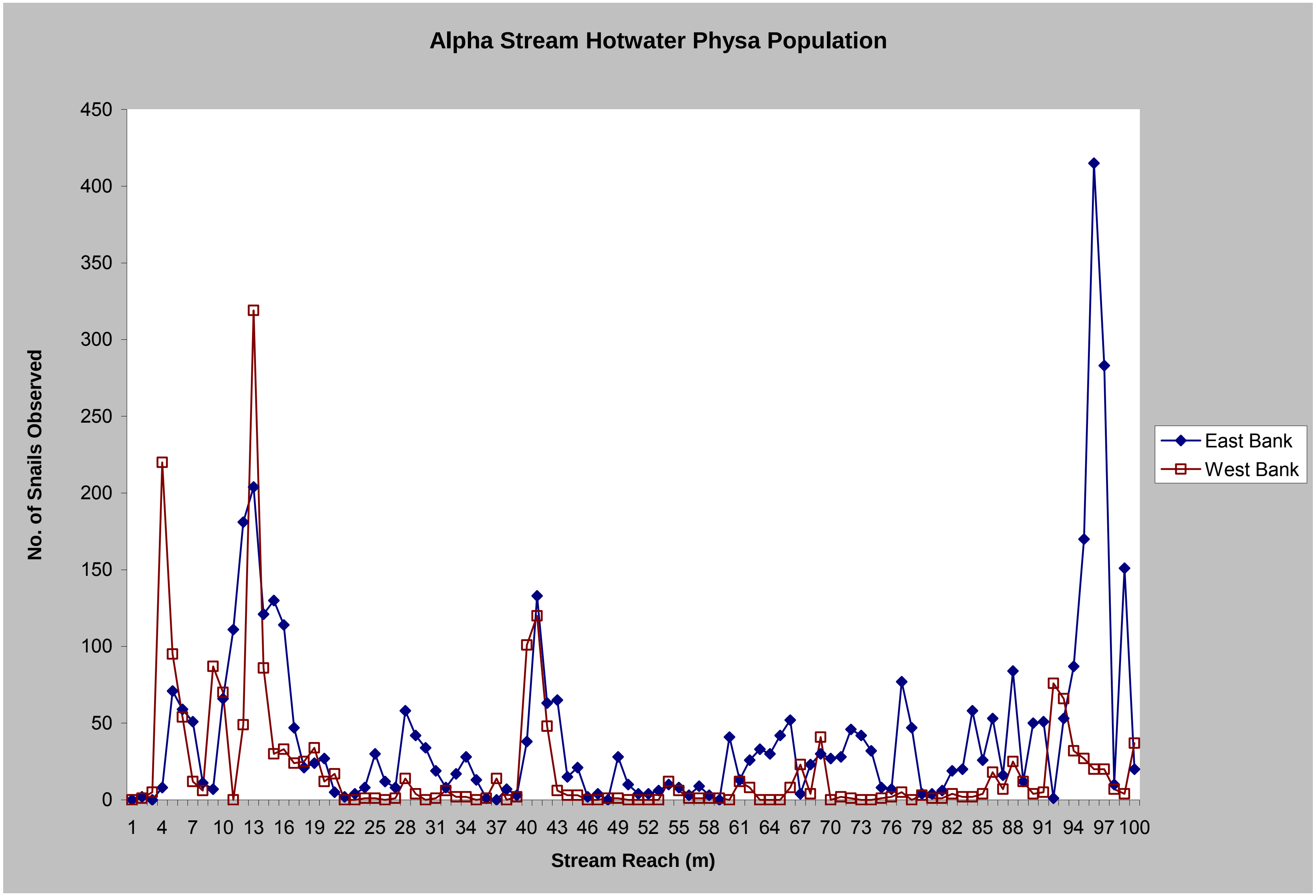

Figure B-1. Hotwater physa counts along each meter section of the Alpha Stream, DFO & MOE, September 2008