The conservation status of the freshwater crayfish, *Pacifastacus leniusculus*, in British Columbia

by

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ABSTRACT

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The signal crayfish, *Pacifastacus leniusculus*, is native to BC; however, few studies have been done in the province and little is known about its conservation status. This report provides such information in three parts. We reviewed aspects of reproduction, development, and food and habitat choice of the signal crayfish, compiled from studies done in the United States, Canada, and Europe. The species exhibits enormous variation between populations in terms of age at first reproduction (1 to 3 years), longevity, and fecundity. Food choice appears to be largely dependent on what is available in the surrounding environment, although an emphasis on vascular detritus is commonly reported. Considerable variation in habitat preference is noted both between populations and between ontogenetic stages of the same population. We compiled reported sightings and historical records to describe the possible distribution range of *P. leniusculus* in BC. In BC the species is found in the southern quarter of the province from Vancouver Island east to the Kootenays (118°W) and as far north as Okanagan Lake (51°N). Sightings were reported from a variety of freshwater ecosystems from lakes, rivers, to streams, typically smaller systems. We also outline the details of previous crayfish fisheries and regulation in BC. There is a lack of research on almost all aspects of population biology and ecology of *P. leniusculus* in BC, and this must be addressed in order to prevent the demise of this organism in this area of the world. Some of the information needs for successful management of this organism in BC include estimates of densities, reproductive rates, and other demographic information that would indicate the potential rate of harvest that is sustainable or needs for conservation.

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PART I: BIOLOGY OF *Pacifastacus Leniusculus*

Pacifastacus leniusculus (Dana 1852), the signal crayfish, is a member of the family Astacidae, superfamily Astacoidea. The genus *Pacifastacus* refers to all Astacinae crayfish native to North America, west of the Rocky Mountains (Bott 1950). The natural range of *P. leniusculus* extends from the southern part of British Columbia (Hamr 1998) to the northern part of California (Elser 1994) and east to parts of Utah and Montana (Johnson 1986, Sheldon 1989); however, this organism has been widely introduced to many parts of Europe and Asia to compensate for the devastating loss of native European and Asian species caused by the crayfish plague earlier this century (Svardson 1995, Abrahamsson 1970). *Pacifastacus leniusculus* has been described as the most successful of the five North American *Pacifastacus* species (Hogger 1988).

There are three sub-species of *P. leniusculus*: *P. leniusculus leniusculus, P. leniusculus trowbridgii,* and *P. leniusculus klamathiensis* (Miller 1960), which are discernable from one another through differences in the morphology of the rostral postorbital, carpal and meral spines and chellipeds (Hamr 1998). However, few records are available as to the distribution and/or abundance of any of the sub-species in British Columbia. In fact, according to Hamr (1998, p8), "the gap in knowledge for this species is quite real as there has been very little crayfish research done in the province to date". It is suggested that the signal crayfish populations in Canada may be in danger of extirpation, and that the status and distribution of these organisms in British Columbia should be clarified in order to appropriately assess their conservation status (Hamr 1998). To adequately manage crayfish populations, knowledge about the basic biology, life history, population structure, and habitat and food preferences is required.

This literature review will attempt to address the latter topics with studies done on American and European *P. leniusculus* populations; however, it should be stressed that management regulations on signal crayfish should be population specific (Lewis and Horton 1997), as they have been shown to adapt life history and population parameters to a wide variety of environments (see Flint 1975, Cukerzis 1978, Kossakowski 1988, Westman et al. 1993a, b). This idea is also stressed by McGriff (1983), who suggests that life history data for signal crayfish populations in a wide range of environments should be obtained in order to predict population parameters based on environmental characteristics.

HABITAT PREFERENCE

Signal crayfish are found in several freshwater habitats, including streams, rivers, lakes, ponds, and estuarine areas (Miller 1960, Goldman and Rundquist 1977, Shimizu and Goldman 1983). They have been found to tolerate salinities up to 21 ppt (Holdich et al. 1997), and have displayed the capability to regulate body ions over a large range of salinities (Kerley and Pritchard 1967). Signal crayfish are tolerant of a wide temperature range, successfully inhabiting areas as far north as Finland, and as far south as Spain. Generally they prefer temperatures lower than 25º C (Hogger 1988), although they have been reported to survive in temperatures up to 33ºC (Becker et al. 1975). Coastal populations are generally more heat-tolerant than lake-dwelling inland populations (Goldman 1973). Optimum growth occurs at 22.8ºC (Firkins and Holdich 1993, Westman et al. 1993), though they thrive at temperatures as low as 4-5ºC in winter (Shimizu and Goldman 1970). *Pacifastacus leniusculus* requires high levels of dissolved oxygen (Nystrom 2002), and has a weak ability to survive in temporary habitats (Huner and Lindquist 1995). These organisms, as with most crayfish, are sensitive to calcium and pH levels (Lodge and Hill 1994, Kirjavainen and Westman 1999). Calcium in excess of 5 mg/L is required for adequate re-calcification of the exoskeleton subsequent to molting (Lowery and Holdich 1988), and ambient pH should always exceed 6.0. Signal crayfish have also been shown to be sensitive to high NO_2^- levels, but not to increased levels of SO_4^{-2} (Rallo and Garcia-Arberas 2002).

Substrate heterogeneity strongly influences both the density and size of crayfish inhabiting certain areas. In fact, it has been stated that substratum is the single most important variable related to total crayfish abundance in an area (Kirjavainen and Westman 1999). Signal crayfish generally prefer a rocky substrate (Flint 1977, Klosterman and Goldman 1983, Shimizu and Goldman 1983, Lewis and Horton 1997), and avoid flat, soft bottoms (Goldman and Rundquist 1977, Elser 1994). In addition, high numbers gather around rocky areas and submerged trees (Lowery and Holdich 1988, Guan and Wiles 1996, Kirjavainen and Westman 1999). Mason (1978) notes that current velocity and direction may also be involved in habitat choice of *P. leniusculus.* Although not generally classified as a burrowing species, many authors report finding deep *P. leniusculus* burrows when the substrate is appropriate (Kirjavainen and Westman 1999, Guan 1994).

Several researchers have documented a distinct ontogenetic shift in spatial distribution. Lewis and Horton (1997) found that juveniles preferred boulder/cobble areas, whereas adults preferred sandy, silty areas in an Oregon lake. In addition, the results of Abrahamsson and Goldman (1970), Mason (1974), Goldman (1973), Skurdal et al. (1988), and Englund and Krupa (2000) suggest that juvenile crayfish are often restricted to shallow areas with heterogeneous substrates to be used as shelters, whereas adults are often found in deeper water, presumably to avoid terrestrial predators. In large lakes the depth at which adult crayfish are found is strongly dependent on temperature, as hatching of eggs is generally prohibited at temperatures below 6.8º C (Abrahamsson and Goldman 1970). Decreased light levels at increased depths also restrict food availability, and therefore crayfish distribution (Abrahamsson and Goldman 1970).

Populations of signal crayfish in lakes are generally larger than populations in streams and rivers, although population sizes reported for different areas are highly variable (e.g. Abrahamsson and Goldman 1970, Goldman and Rundquist 1977, Elser 1994 (Table 5.1), Nystrom 2002). Crayfish tend to be clumped around areas of favorable habitat (Hogger 1988), which may seriously affect density estimates.

DIETARY PREFERENCES

As with most crayfish, *Pacifastacus leniusculus* is an omnivorous organism, feeding on a wide variety of items including algae, benthic insects, other crayfish, vascular detritus and woody debris (Mason 1974, Guan and Wiles 1998). Most signal crayfish consume between 0.22 and 6.02% of their body weight per day (Mason 1975, Guan and Wiles 1998). Many researchers have described an ontogenetic shift in dietary preference of several crayfish species (Westman et al. 1986, Lodge and Hill 1994, Momot 1995), and specifically for *P. leniusculus* (Mason 1975, Guan and Wiles 1998). Adults feed primarily on vascular detritus, preferring alder and maple leaves to oak or ash leaves (Mason 1975). According to Guan and Wiles (1998), cannibalism also increases with increasing adult size, specifically during and immediately after ecdysis (moulting). Juveniles and young of the year are primarily carnivorous on benthic insects, although vascular detritus makes up part of their diet as well.

Although a large number of studies have documented the ontogenetic shift in dietary preference, diet is also influenced by what is accessible in the surrounding environment, and will therefore shift according to what is most readily available. The results of Flint (1975) do not reflect the aforementioned ontogenetic dietary shift, potentially for this reason.

MATURATION, REPRODUCTION, AND FECUNDITY

There is considerable variation among populations of signal crayfish from Oregon, Washington, California, Nevada, British Columbia, Sweden and Finland with respect to maturity, growth and fecundity (see table 5, McGriff 1983, table 13.1, Lewis 2002). There are accounts of maturation occurring as early as the first year (Miller 1960, Kirjavainen and Westman 1995, Soderback 1995 (males)); however, most studies report sexual maturity at age 2+ (Abrahamsson 1971, Shimitzu and Goldman 1983, McGriff 1983, Reynolds et al. 1992, Soderback 1995 [females], Lewis and Horton 1997) or 3+ (Abrahamsson and Goldman 1970, Flint 1975, Kirjavaienen and Westman 1995). Size at maturity also varies considerably, from 60mm to 90mm total length (Miller 1960, Abrahamsson 1971, Mason 1975, McGriff 1983, Hogger 1986, Kirjavainen and Westman 1999). Sexually mature females may be discerned through visibly white cement glands on their ventral side, whereas maturity in males may be detected through the presence of white sperm in the gonads (Abrahamsson 1971). In addition, at maturity the abdomen of female crayfish becomes wider, creating a protective cavity for eggs (Goellner 1943), and the chellipeds of the males start to exhibit allometric growth (Mason 1975).

There are conflicting accounts on whether sexually mature adults spawn every year. Some studies (Abrahamsson and Goldman 1970) claim that mature adults spawn each year, whereas other studies (Miller 1960) do not document this same phenomenon. Mason (1975) claims that females spawn a total of 3-4 times during their lifespan.

Copulation usually begins in October in most American and European populations studied (Svardson 1965, Abrahamsson 1971, Flint 1975, Mason 1975, 1977, Shimizu and Goldman 1983, Soderback 1995, Lewis and Horton 1997), although lotic populations have been reported to initiate spawning up to 3 weeks later than lentic populations (Lewis 2002). Mason (1970) provides a detailed look at the copulatory behaviours of *P. leniusculus trowbridgii*, which may continue over a period of a few weeks. Some researchers (Mason 1975, Shimizu and Goldman 1983, Westin and Gydemo 1986, Reynolds et al. 1992) suggest that a drop in temperature to between 10 and 15ºC is what indicates the beginning of the reproductive season, whereas others (Lewis and Horton 1997) report that a change in photoperiod is the most important cue. Eggs are usually extruded within a few weeks of mating and, as previously mentioned, held on the under side of the female abdomen.

There is great variation in fecundity of mature females, from 100-400 eggs per individual (Kirjavaienen and Westman 1999). In general, egg counts increase as body size increases (see figure 2, Mason 1975, figure 2, Soderback 1995). An average of 105 +/- 12 eggs for females with a carapace length of greater than 30mm is reported by Lewis and Horton (1997), similar to the average of 110 reported by Abrahamsson and Goldman (1970); however, Momot and Gowing (1977) note that there is a negative correlation between the number of pleopod eggs and population density.

HATCHING / GROWTH / LIFE EXPECTANCY

Ovigerous females usually carry eggs for a period of approximately 7 months (Mason 1975), with hatching occurring in most populations around April-May (Miller 1960, Mason 1963, Abrahamsson and Goldman 1970, Shimizu and Goldman 1983, Soderback 1995, Lewis and Horton 1997). However, in cooler climates hatching may be delayed until late June or July (Flint 1975, McGriff 1983), as has been observed in some populations of signal crayfish in British Columbia streams (personal observation). It has been postulated that approximately 2200 degree-days are required for hatching of *P. leniusculus* eggs (Mason 1977, Lewis and Horton 1997). Body mass of hatchlings was found by Soderback (1995) to be between10 and 16 mg.

Immediately subsequent to hatching, stage 1 juveniles are lecithotrophic and immobile (Lewis 2002). After 1-2 moults, stage II juveniles begin to forage away from the mother at increasing intervals, returning if threatened (Reynolds et al. 1992). In their first year of life, juveniles moult 13-14 times (Mason 1974), resulting in a total growth of approximately 20.3 mm (Kirjavainen and Westman 1999). In subsequent years the number of moults is significantly decreased: 5-6 in the second year, 3 in the third year, and 1-2 in the fourth year. The moult increment is hypothesized to be between 2.5 and 4.5mm (Mason 1974), although McGriff (1983) suggests a moult increment of 6.6 mm for crayfish greater than 64 mm total length. Moult increment may also be influenced by temperature, increasing at higher temperatures (Shimizu and Goldman 1983).

There are sex-related differences in molt frequency, with adult females often molting only once per year (Kirjavainen and Westman 1999), resulting in a slightly lower growth rate for females. Of the two molts undergone by most adult males, the first usually takes place before July, and the second takes place in mid-August to September (Shimizu and Goldman 1983, Soderback 1995). Berried females (carrying eggs under their abdomen) undergo one molt subsequent to juvenile hatching, usually in July or August. Adult signal crayfish of both sexes may attain a maximum size of approximately 150-180 mm total length (Miller and Van Hyning 1970, McGriff 1983).

There is great diversity in growth rates for different populations of signal crayfish (Abrahamsson and Goldman 1970, Table 5 McGriff 1983). It is stressed by Hogger (1988) and Lowery and Holdich (1988) that density of crayfish determines not only rate of growth, but also age and size at maturity, fecundity, and lifespan. Therefore, these forms of density dependence should be of great importance in modelling crayfish population dynamics.

Estimates of the possible lifespan of signal crayfish are quite varied. According to Mason (1974), the maximum lifespan is 5-6 years; however, Shimitzu and Goldman (1983), Lowery and Holdich (1988), and Huner and Lindquist (1995) report that the lifespan may be up to 9 or 10 years. Belchier et al. (1998) used a lipofuschin derived technique to conclude that the maximum *P. leniusculus* lifespan in a British population was 16 years. It is suggested that populations of crayfish in cool environments and at high latitudes have a longer lifespan than those in warmer climates (Momot 1984).

Survival of juveniles to maturity is estimated at between 21-33%, and this percentage declines subsequent to maturation (Abrahamsson and Goldman 1970, Abrahamsson 1973). However, Lowery and Holdich (1988) note that it is very difficult to obtain estimates of survival rate in the field.

CATCH DYNAMICS

There are seasonal changes reported in the distribution and abundance of crayfish caught in traps (Miller and Van Hyning 1970, Klosterman and Goldman 1983). Fluctuation in trap catches (kg/trap) is a result of temperature fluctuations as well as the moulting period (Shimizu and Goldman 1983, Lowery and Holdich 1988). It has been found in Oregon that catches in winter are generally low due to the decrease in feeding with decreased water temperature (Miller and Van Hyning 1970).

Although *P. leniusculus* populations generally have a stable sex ratio of 1:1, there are seasonal differences in the catches based on sex (Miller 1960). Spring catches are more biased towards males, but may be generally low because the males are in their moulting period. Berried females are reluctant to enter traps (Abrahamsson 1971, Mason 1975, Kirjavainen and Westman 1999), but are often caught in traps subsequent to the hatching period, when they are aggressively seeking food to replenish reserves lost while carrying eggs (Lewis 1998).

PART II: CRAYFISH DISTRIBUTION AND HISTORIC EXPLOITATION IN BC

CRAYFISH DISTRIBUTION

Although *P. leniusculus* is widely distributed in western North America except Alaska, the distribution information of this organism is limited to a small range of B.C. (Hamr 1998, Taylor et al. 1996). One of primary goals of this section is to detail our knowledge of the distribution of *P. leniusculus*, and to provide baseline information for its future management and protection in B.C.

In this study, we found that the range of *P. leniusculus* is much broader than previously reported (Hamr 1998). The northern range of the distribution in B.C. is located approximately at latitude 51°N, and the eastern range is near to longitude 118°W (Figure 1). The total distribution area could reach 138000 km^2. *Pacifastacus leniusculus* has been found in the Lower Mainland, the Okanagan, and on parts of Vancouver Island.

Seventy-six crayfish records were collected in southern B.C., and raw data are shown in appendix I. Forty records come from lakes, and thirty-six records from streams and rivers. *Pacifastacus leniusculus* is distributed over a wide range of freshwater habitats from coastal to inland areas. The spectrum of these habitats ranges from small headwater streams (for example, Spring Creek, 1.3 km long) to large rivers (Fraser River), and from tiny lakes (an unnamed lake, 3.2 hectares) to large lakes (Okanagan Lake, 35008 ha). The majority of records on lake-dwelling *P. leniusculus* populations (62.5%) come from Vancouver Island (Region 1), while 17.5% of the reports are sites in the Lower Mainland (Region 2), and 20% in the Okanagan (Region 8). For stream and river distribution, the majority of reported sites are in the Lower Mainland (63%), with 34% on Vancouver Island, and 3% in the Okanagan.

The lake sites can be classified into three categories: small lakes (< 100 ha), medium lakes (100 – 1000 ha), and large lakes (> 1000 ha). The streams and rivers can be defined as small streams (length < 10 km long), medium rivers (length: 10 – 50 km), and large rivers (length > 50 km). *Pacifastacus leniusculus* shows a higher proportion of occurrence in small lakes than in medium and large lakes (Figure 4a). This may reflect the large number of small lakes compared to larger ones in B.C. A similar pattern is seen in stream and river systems, with more frequent reports of *P. leniusculus* populations in small and medium streams (Figure 4b).

Figure 1. Geographic distribution of *Pacifastacus leniusculus* in freshwaters of British Columbia. City names are shown for reference only, and symbols indicate the localities where crayfish were recorded.

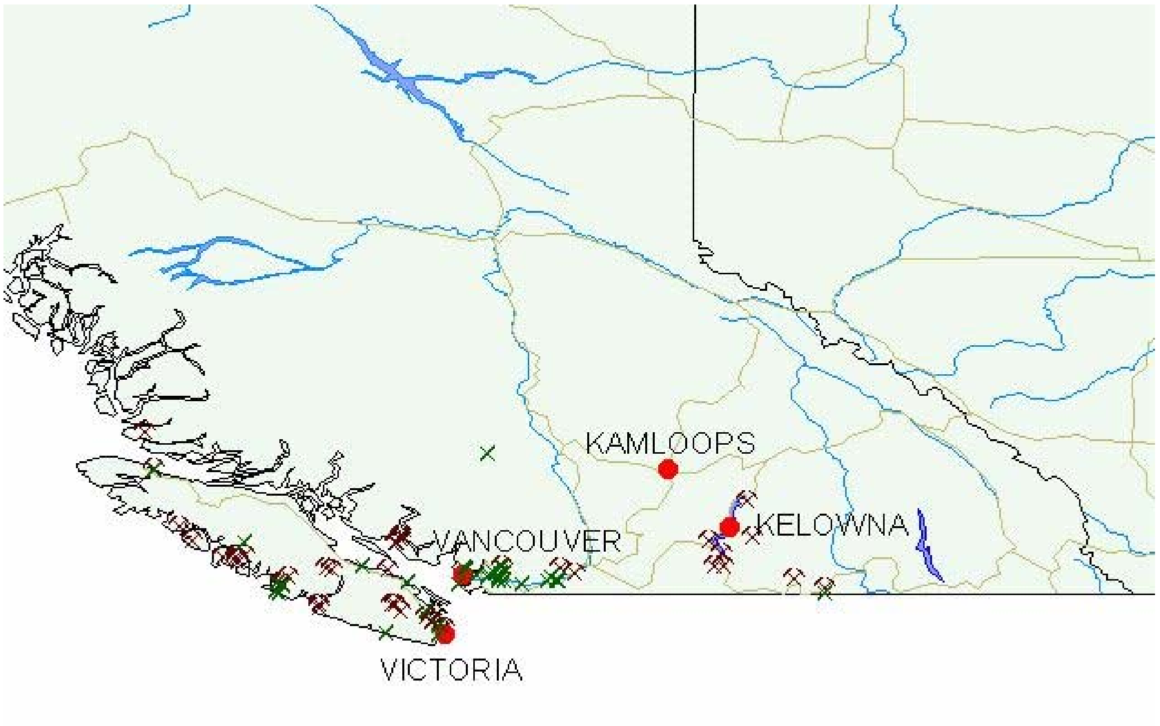
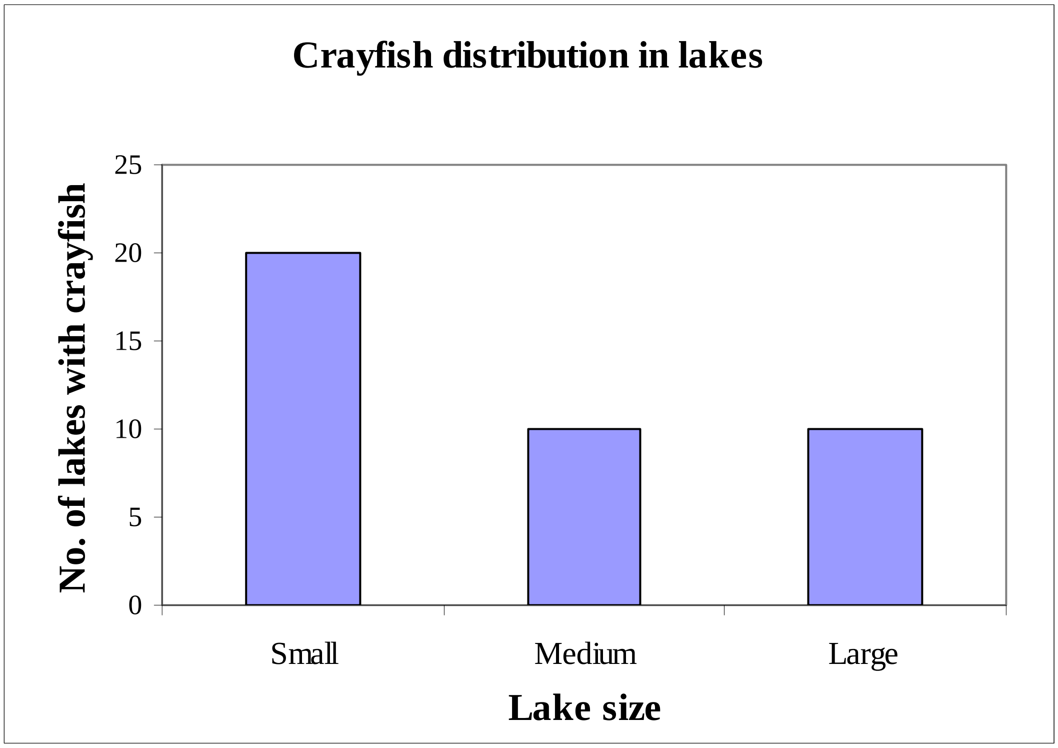


Figure 2. Geographic distribution of *Pacifastacus leniusculus* in lakes of British Columbia. City names are shown for reference only, and the symbol indicates lake localities where crayfish were recorded.

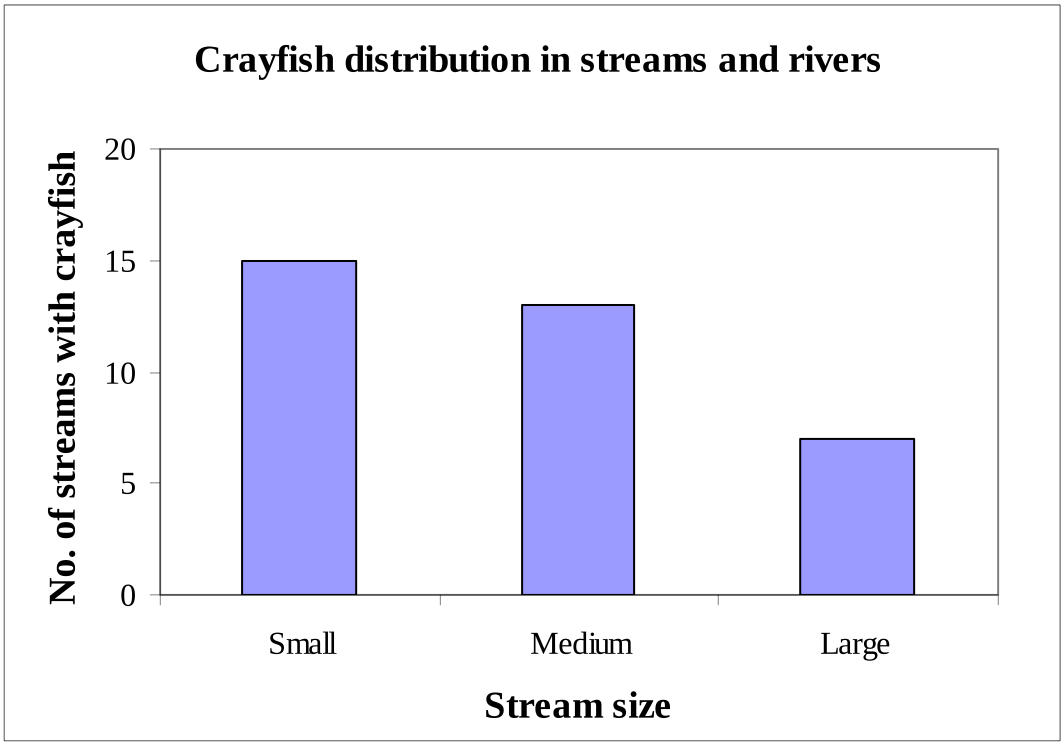
Figure 3. Geographic distribution of *Pacifastacus leniusculus* in streams and rivers in British Columbia. City names are shown for reference only, and the symbol indicates stream and river localities where crayfish were recorded.

Figure 4. The signal crayfish (*Pacifastacus leniusculus*) distribution in (**a**) lakes, and (**b**) streams with different categories in British Columbia, viz. small lakes (< 100 ha), medium lakes (100 – 1000 ha), and large lakes (> 1000 ha); small streams (length < 10 km long), medium rivers (length: 10 – 50 km), and large rivers (length > 50 km).

a.



b.



Historic Exploitation

Pacifastacus leniusculus has been harvested commercially in this province. The Ministry of Water, Land and Air Protection of B.C. issued twenty-six commercial crayfish licenses from 1994 to 1996. Eleven licenses (ten in the Lower Mainland, one on Vancouver Island) were granted in both 1994 and 1995. Five licenses (all on Vancouver Island) were issued in 1996. In 1994, only two licenses (Harrison River and Harrison Lake) captured 4602 pounds of crayfish and the other nine reported zero capture. In 1995, total catch record of 9 licenses (of the 11 issued) was 5859 pounds, in which 96% of the harvest amount was from Harrison River and Harrison Lake. There was zero capture in 1996.

Pacifastacus leniusculus has also been exploited by freshwater sport fishing. The 2002-2003 Freshwater Sport Fishing Regulations Synopsis informs that the regional daily catch quota is twenty-five crayfish in five southern regions, i.e. the Vancouver Island, the Lower Mainland, the Thompson-Nicola, the Okanagan, and the Kootenay. Crayfish less than 9 cm in total length and those carrying eggs or young individuals must be released. In addition, provincial regulations allow the use of aquatic invertebrates, including crayfish, as bait while angling in streams, unless a bait ban applies.

PART III: Information needs for management of freshwater crayfish in B.C.

There are few published studies of freshwater crayfish in British Columbia, and a high degree of uncertainty associated with their status. In order to effectively manage crayfish populations for conservation or for harvesting purposes, there are some urgent information needs that should be addressed to reduce uncertainty before harvesting is allowed on some populations.

Population size and age structure

There are no estimates of population sizes from anywhere in British Columbia. The absence of a programme for population estimation means that the only source of information on sustainability of management practices would be a measure of catch per unit effort (CPUE) from harvesting. This is not an adequate means for management given that the measure is only available in hindsight and does not allow for the anticipation of population declines or even extirpation. CPUE can be used as a component in a population monitoring plan, but alone it will not be sufficient. Development of some sort of measure of population size is needed for use in monitoring the responses of populations to any form of management.

There are several kinds of population estimates that could be applied to crayfish. One could use some measure of CPUE without harvesting to determine relative abundance. This measure would potentially be comparable across seasons, years, and between sites. To use this kind of an index would still require calibration to ensure that the “catchability” of crayfish doesn’t vary across habitat types or with density. Calibration would likely require a detailed mark-recapture study. Various methods of marking crayfish have been attempted. In the short term any kind of mark on their exoskeleton (paint, nail polish, white-out) can be used, but as crayfish moult that mark is lost. If estimates were made based on capture-mark-recapture in a short period of time the assumption could be met that marks are not lost by moulting during the sampling interval. Another method is the implantation of PIT (passive integrated transponder) tags into crayfish, but this is expensive and is not appropriate for the younger individuals. The use of freeze-branding has been used on juvenile fish and appears to be possible for use on crayfish, but still requires further testing, especially for juveniles. The use of visible implant elastomer (VIE) tags has shown to be effective in marking both juvenile and adult crayfish for long periods of time (Parkyn et al. 2002), and may be the most appropriate marking method for studies of crayfish.

The age structure of a population is valuable for determination of any shifts associated with age-specific changes, such as selective harvesting or other mortality of adults. If a population begins to lose a large portion of its breeding individuals it is obvious that reproductive rates for the population will decline. Age structure can be a very obvious way to detect imminent changes. These kind of data, coupled with mark-recapture can yield vital information on survival rates of different age classes and genders, which can shift in response to management activities. Age structure in *Pacifastacus leniusculus* is typically based on a simple measure of the length of the carapace and can separate out age classes from the size-frequency data.

DEMOGRAPHIC RATES

Age structure information and capture-mark-recapture data can be used to develop demographic models. Demographic models based on age-specific (and gender-specific) survival and fecundity rates can be used to assess future management actions and make predictions. The kinds of factors within populations that strongly affect population growth rates are fecundity, age at first reproduction, survival rates of juveniles and adults, and longevity (e.g. number of years reproducing). The available literature summarized in the sections above indicate that the demography of *P. leniusculus* is highly variable between sites and that there is no clear pattern associated with occurrence in lakes or rivers, with latitude, or with any currently measured variables. Some estimates from within B.C. should be made. However, this kind of information is time-consuming (and labour intensive) to collect. A couple of studies of this sort would provide a “ballpark” estimate that could be used in demographic projections. Tests of the sensitivity and elasticity of demographic models can be used to refine this approach to determine which factor(s) is critical to measure. In some cases the models can make robust predictions if the variation in demographic rates does not result in large differences in reproductive rates.

In harvested populations there can often be density compensation that affects demographic rates. For instance, reduction in the numbers of adults might free up resources resulting in higher survival or growth rates of juveniles, or higher reproductive output from the remaining adults. The extent to which this can happen is unpredictable without further study. If there is strong competition amongst crayfish then limited harvesting could result in no net loss of numbers or productivity, but the level of harvest would be impossible to predict in the absence of well-defined studies.

TEST FISHERY ON CRAYFISH

One of the clearest ways to determine the rates of harvesting of crayfish that are sustainable would be a well-defined experimental fishery. An experimental fishery would require harvesting at specified rates on at least two populations with at least two control (reference) populations, and the age-class distributions and population sizes estimated through time. The design of this would have to be scientifically rigorous, but would provide several benefits, such as harvesting by interested parties. One, an experimental fishery would allow for some harvesting by interested parties. Detailed, well-designed studies associated with the test fishery would provide density estimates and demographic information as outlined above.

A test fishery would also provide an indication of whether or not *P. leniusculus* populations could be seriously depleted. In most instances it would not be prudent to overfish a population, but in the case of the current conservation issue surrounding the Enos Lake stickleback pairs, it is feasible to ask the question of whether it is possible to provide the effort to reduce numbers to alleviate the putative pressure on sticklebacks from crayfish impacts.

Another aspect of a test fishery that could be tested with further effort would be the value of a male-only harvest. In many harvested populations females are left with the intent that the breeding females continue to contribute to the populations. This depends upon what actually limits population productivity, something unknown for this species of crayfish.

DISTRIBUTION PATTERNS

We are lacking any systematic survey for crayfish in B.C. Coastal areas of the mainland and Vancouver Island apparently have a high concentration of populations (as discussed above). One area that could use more detailed survey is the Kootenay-Boundary region of the province. Another consideration around distribution patterns is the degree to which populations are "connected". Persistence of many local species' populations depends upon a metapopulation structure, whereby local losses in a population may be made up by immigration from nearby populations. We know very little about the ability of *P. leniusculus* to move amongst habitats, however, the rapid spread of this species of crayfish since it was introduced to Europe suggests some capacity for dispersal (a lot of movement within Europe can be explained by intentional transplants). It would be valuable to know the degree to which populations are connected by dispersal, since one possible outcome of a fishery (test or operational) would be to reduce local numbers and "suck" in individuals from adjacent populations that would obscure local, unsustainable impacts. Metapopulation structure often conveys an ability to populations to recover from declines more effectively.

If surveys for crayfish in B.C. are undertaken, it would be important to collect habitat information on site productivity and other features. To date we have no way to determine if population sizes or productivity are related to particular habitat features, such as nutrient status or aspects of water chemistry.

LAND-USE IMPACTS

We know nothing about the impacts of land-use on crayfish populations in B.C. There are several ways that land-use could affect populations. Water quality and habitat may be influenced by forest practices. Crayfish in streams live in deeper, depositional areas and may be vulnerable to siltation. As omnivores they consume smaller invertebrates and detrital materials, the latter of which may be reduced in abundance if riparian canopy is removed. Changes in water quality and system productivity by chemical changes may have impacts, but again, there is no information available for this species. Agricultural and urban landscapes may introduce barriers to movements of crayfish, but for this species it is not known how much they move overland, as is known for other crayfish species.

Other impacts such as modification of temperature, flow regulation and water abstraction, and even climate change are unpredictable for this species, a source of large uncertainty.

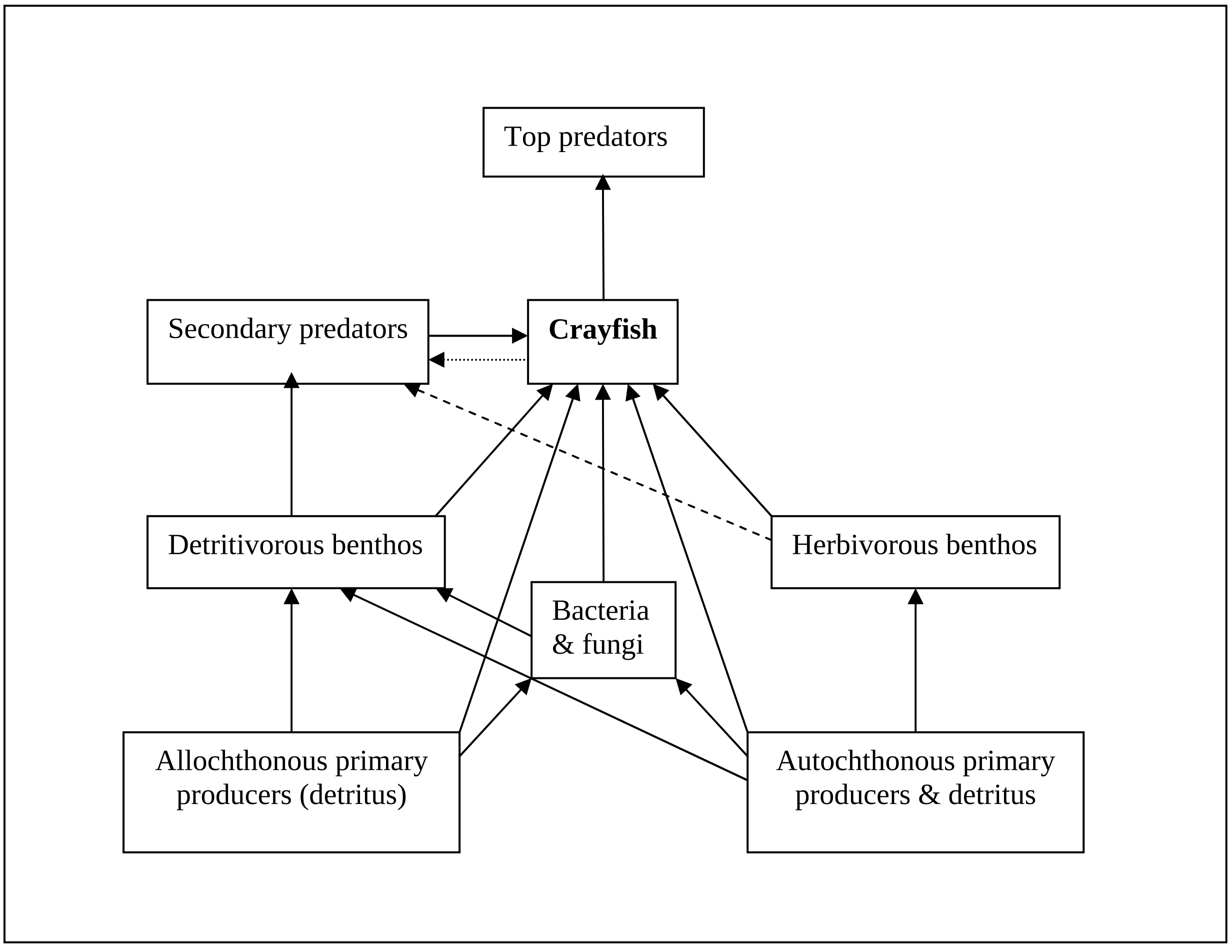
FOODWEB INTERACTIONS AND GENERAL ECOLOGY

We can hypothesise where the crayfish fits in the foodwebs of streams and lakes in B.C. (Figure 5), but there is very little information to describe its quantitative role as consumer or prey. Such fundamental questions as what does it eat and what eats it are not currently answerable for *P. leniusculus* in B.C. There are some indications it is much more detritivorous than is often thought (personal observation). However, the crayfish has been implicated in the demise of the Enos Lake sticklebacks, but the mechanism(s) is unknown. Crayfish could be capable of eating eggs, juveniles, and even adults. They may also disrupt mating biology of the species by affecting turbidity, and thereby recognition of conspecifics, or disturbing the building of nests in the lake bottom. These basic ecological questions need some answer before there is a large effort in trying to control the species if indeed it is responsible for this looming conservation issue over the sticklebacks.

SUMMARY: PRIORITIES FOR INFORMATION ON *PACIFASTACUS LENIUSCULUS* IN B.C.

The most imminent management needs for the species are population estimates and demographic data, perhaps along with a test fishery. The need to develop a method to determine how many individuals there are in populations and to properly calibrate some form of index is a very high priority. Demographic data (including age structure) based on capture-mark-recapture methods through time is also a high priority in order to generate useful predictive models that can be used in management, whether for harvesting or for control purposes. Finally, a test fishery with a well-designed experimental approach would be valuable to test demographic predictions and the sustainability of a fixed rate of harvest. There are many other information needs as outlined above, but the three here are our assessment of the current status of the uncertainty surrounding management of this species in B.C.

Figure 5. Hypothesised food-web interactions of crayfish.



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APPENDIX: DISTRIBUTION DATA FOR CRAYFISH IN B.C.

A preliminary list of forty lakes, and thirty-six streams and rivers found with the signal crayfish (*Pacifastacus leniusculus*) in British Columbia. Abbreviations: L = lake; S = stream; UTM East, North = Universal Transverse Mercader NAD 83 co-ordinates for the mouth of the stream or the outlet of the lake as determined from the 1:50,000 Watershed Atlas digital map; WSA Area = Lake surface area in hectares; WSA Perimeter = Lake perimeter in kilometers; Length = Stream length in kilometers, excluding lakes.

Name	Waterbody Code	Waterbody Identifiers	Type	UTM east	UTM north	UTM zone	Primary Region	WSA Area (ha)	WSA Perimeter (km)	Map	Source
Unnamed Lake	930-053800	00086SANJ	L	427903	5396640	10	1	3.2	1	092B12	Duane Jesson
Trout Lake	310-568600-52500	01470OKAN	L	302851	5469598	11	8	5.3	1	082E05	Ian R. Walker
Park Lake No. 1	930-616200	00185TAHS	L	644278	5527722	9	1	3.8	1.2	092E15	Duane Jesson
Spectacle Lake	920-222200	00153VICT	L	458043	5380619	10	1	3.5	1.2	092B12	Jack Nickolichuk
Calamity Lake	930-085500-298	01965ALBN	L	345895	5409364	10	1	14.3	2.1	092C14	Duane Jesson
North Lake	900-152008	00331JERV	L	429628	5511095	10	2	35.5	2.8	092G12	Commercial crayfish Licenses
Enos Lake	920-440400	00356PARK	L	415490	5459874	10	1	14.7	3.3	092F08	Jack Nickolichuk
Mesachie Lake	920-257700-68500-02300	00503COWN	L	417813	5407494	10	1	58.4	3.8	092C16	Commercial crayfish Licenses
Oliphant Lake	920-228800	00113VICT	L	457727	5383605	10	1	22.7	4.2	092B12	Duane Jesson
Clayoquot Lake	930-306400-13900	01141CLAY	L	315969	5451861	10	1	48.7	4.5	092F04	Duane Jesson
Beaver Lake	920-079700	00247VICT	L	470931	5372844	10	1	39.9	4.5	092B11	Royal BC Museum
Black Lake	930-081200	01977ALBN	L	345584	5403078	10	1	69.5	5.7	092C14	Duane Jesson
Idabel Lake	320-520100-42900-40600-5170	00377KETL	L	342714	5510526	11	8	40.2	5.7	082E11	Ian R. Walker
Sugsaw Lake	930-101400	01951AKBN	L	616725	5615301	9	1	58.8	5.9	092L11	Duane Jesson
Cecilia Lake	930-422000	00713CLAY	L	702169	5479084	9	1	44.7	6.1	092E08	Duane Jesson
Ellen Lake	930-426600	00627CLAY	L	700667	5483011	9	1	97.5	6.2	092E08	Duane Jesson
Jewel Lake	320-407300-34400-32300	01221KETL	L	381703	5446819	11	8	72	6.2	082E02	Duane Jesson
Garden Bay Lake	900-147300-18900	00553JERV	L	426145	5500270	10	2	59.2	6.4	092F09	Eric B. Taylor
Garnet Lake	310-671700	01171OKAN	L	299843	5507351	11	8	39.5	7.5	082E12	Duane Jesson
Megin Lake	930-413500	00532CLAY	L	709892	5486809	9	1	167.4	8	092E08	Duane Jesson
Riley Lake	935-374000-462	00822CLAY	L	702261	5473369	9	1	77.6	8.1	092E08	Duane Jesson
Easter Lake	930-422000	00706CLAY	L	702941	5479634	9	1	202.9	11.4	092E08	Duane Jesson
Muriel Lake	930-306400-02600	01219CLAY	L	309206	5444398	10	1	161.8	12.8	092F04	Kim D. Hyatt
Wahleach Lake	100-101800	00338HARR	L	601597	5456081	10	2	446.9	14.1	092H04	Marvin Rosenau
Crawfish Lake	935-483000-08800	00629GOLD	L	657602	5505233	9	1	416.2	14.5	092E10	Royal BC Museum
Hesquiat Lake	930-461400	00387CLAY	L	688232	5483549	9	1	470.9	16.1	092E08	Duane Jesson
Ruby Lake	900-147300	00341JERV	L	429738	5506845	10	2	449.3	18.4	092G12	Commercial crayfish Licenses
Shawnigan Lake	920-235800	00091VICT	L	453765	5389484	10	1	527	28	092B12	Duane Jesson
Pack Lake	900-975900	00375SEYM	L	606898	5670165	9	1	698.2	29.9	092M03	Commercial crayfish Licenses
Skaha Lake	310	01367OKAN	L	312572	5469417	11	8	1958.5	29.9	082E05	Royal BC Museum
Sakinaw Lake	900-147300	00435JERV	L	423132	5500638	10	2	681.3	35.3	092F09	Commercial crayfish Licenses
Kalamalka Lake	310-939400	00209OKAN	L	338228	5566843	11	8	2574.2	44.7	082L03	Duane Jesson
Christina Lake	320-160600	01206KETL	L	411678	5432962	11	8	2548.9	45.6	082E01	Duane Jesson
Pitt Lake	100-026700	00288LFRA	L	528068	5466523	10	2	5348.2	70.9	092G07	John Mason
Great Central Lake	930-137400-99500	00587ALBN	L	355052	5465312	10	1	5327.8	90.5	092F07	Commercial crayfish Licenses
Sproat Lake	930-137400-99100	01128ALBN	L	360729	5461297	10	1	4233.3	99.1	092F07	Stephanie Sylvestre
Cowichan Lake	920-257700	00408COWN	L	422270	5408526	10	1	6213.9	106.8	092C16	Commercial crayfish Licenses
Kennedy Lake	930-306400	01168CLAY	L	310126	5441129	10	1	6542.4	133.5	092F04	Kim D. Hyatt
Harrison Lake	110	00081HARR	L	586953	5462858	10	2	22192.4	211.7	092H05	Commercial crayfish Licenses
Okanagan Lake	310	00078OKAN	L	310901	5486610	11	8	35008	282.1	082E12	Ian R. Walker

Name	Watershed Code	Waterbody Id	Type	UTM east	UTM north	UTM zone	Primary Region	Length (km)	Map	Source
Thain Creek	900-069000-06300-26300	00000SQAM	S	493620	5463248	10	2	1.24	092G06	Alana Hilton
Spring Creek			S	530958	5457728	10	2	1.3	092G02	Yixin Zhang & John Richardson
East Creek			S	531375	5457676	10	2	1.56	092G02	Yixin Zhang & John Richardson
Munday Creek	100-033300-48400	00000LFRA	S	525603	5447000	10	2	2.46	092G02	Alana Hilton
Clinch Creek	930-041300	00000SANJ	S	412897	5367317	10	1	2.93	092C08	Allan B. Costello
Colwood Creek	920-040500	00000VICT	S	465389	5364254	10	1	5.38	092B06	Jack Nickolichuk
Hyde Creek	100-026700-07200-97700	00000LFRA	S	519313	5459205	10	2	5.72	092G07	Alana Hilton
Lajoie Creek	100-241900-55400-055	00000SETN	S	514201	5639531	10	3	5.88	092J15	Duane Jesson
Dunville Creek	100-074100-68900	00000CHWK	S	585414	5447167	10	2	6.52	092H04	Stephanie Sylvestre
Sandhill Creek	930-264800	00000ALBN	S	303651	5434395	10	1	6.68	092F04	Allan B. Costello
Still Creek	100-020100-95100	00000LFRA	S	503238	5454971	10	2	7.08	092G02	Royal BC Museum
Yorkson Creek	100-033300	00000LFRA	S	525167	5449309	10	2	7.17	092G02	Alana Hilton
Mackay Creek	900-069300	00000SQAM	S	492483	5462365	10	2	7.76	092G06	Alana Hilton
Brothers Creek	900-071100-03400	00000SQAM	S	490502	5463946	10	2	8.02	092G06	Alana Hilton
McLennan Creek	100-053600	00000LFRA	S	548119	5439652	10	2	9.36	092G01	Stephanie Sylvestre
Blaney Creek	100-026700-06000-06400-0860	00000LFRA	S	526678	5457684	10	2	10.34	092G07	Alana Hilton
Elk Creek	100-074100-59019	00000CHWK	S	583680	5447779	10	2	11.85		Stephanie Sylvestre
Staghorn Lake	930-306400-11900	00000CLAY	S	308700	5440100	10	1	12.87	092F04	Jordan Rosenfeld
Lost Shoe Creek	930-260600	00000ALBN	S	306959	5431131	10	1	13.37	092F04	Allan B. Costello
Clayburn Creek	100-054300	00000LFRA	S	549470	5440000	10	2	13.56	092G01	Stephanie Sylvestre
Widgeon Creek	100-026700-19300	00000LFRA	S	526759	5467026	10	2	18.17	092G07	Stephanie Sylvestre
Little Qualicum River	920-481800	00000PARK	S	391063	5469206	10	1	18.24	092F08	Eric Demers, snorkeling
Harrison River	110	00000HARR	S	576816	5452277	10	2	18.47	092H04	Commercial crayfish Licenses
Hope Slough	100-074100	00000CHWK	S	574309	5447911	10	2	22.12	092H04	Stephanie Sylvestre
Alouette River	100-026700-06000	00000LFRA	S	521242	5456901	10	2	31.63	092G07	Colin Levings
Salmon River	100-038800	00000LFRA	S	530138	5447266	10	2	31.75	092G02	Marvin Rosenau
Coquitlam River	100-024500	00000LFRA	S	514183	5452610	10	2	32.5	092G02	Marvin Rosenau
Knogh River	920-866900	00000NIMP	S	616725	5615301	9	1	32.86	092L11	Duane Jesson
Cowichan River	920-257700	00000COWN	S	453212	5400219	10	1	50.09	092B13	John Mason
Kennedy River	930-306400	00000CLAY	S	305372	5446142	10	1	50.11	092F04	Kim D. Hyatt
Gold River	930-511600	00000GOLD	S	708243	5507098	9	1	54.83	092E09	Duane Jesson
Nanaimo River	920-384400	00000COWN	S	434665	5443222	10	1	64.61	092G04	Eric Demers, snorkeling
Pitt River	100-026700	00000LFRA	S	516936	5452970	10	2	74.15	092G02	Commercial crayfish Licenses
Kettle River	320	00000KETL	S	412483	5428164	11	8	237.7	082E01	Royal BC Museum
Fraser River	100	00000TABR	S	486005	5440487	10	2	1387.85	092G03	Marvin Rosenau
Todd Inlet (Central Saanich)				465321	5378652	10	1		092B11	Royal BC Museum