Aquatic Macroinvertebrates

Introduction

This chapter reviews the literature of aquatic macroinvertebrates of the Hanford Site, and compares taxonomic findings of studies conducted between 1948 and 2002. The results of recent benthic (bottom dwelling) and light-trap sampling are presented in relation to the distribution of Trichoptera (caddisflies) in Hanford aquatic environments, and to the effects of wildfire on macroinvertebrates in two spring streams. A survey of the Hanford Reach of the Columbia River for a crayfish, *Pacifasticus leniusculus towbridgii*, and a mussel, *Margaritinopsis falcata*, is described. Newell (2003) provides details not included here.

Purpose and Scope

A tremendous amount of research has been conducted on the habitats and biota of the 560 square mile (1450 km^2) U.S. Department of Energy Hanford Site since it was established in 1943. A portion of the Hanford Site was designated the Hanford Reach National Monument in 2000. The Monument includes the Hanford Reach of the Columbia River, the Arid Lands Ecology (ALE) Reserve, which contains several spring streams, and other areas. Becker (1990) and Newell (1998) have summarized results of previous aquatic bioenvironmental studies of the Hanford Site. Many of the early Hanford aquatic studies began near the present Priest Rapids Dam site, which is approximately 10 miles (16 km) above the first reactor site, and extended downstream to the upper end of Lake Wallula (formed by McNary Dam) at Richland, Washington. This area, the last free-flowing stretch of the Columbia River, is known as the Hanford Reach.

The Hanford Reach of the Columbia River is a unique and valuable resource. It is a major spawning site for Chinook salmon and steelhead trout. It contains a diverse assemblage of fish and provides valuable nesting and feeding sites for many migratory (such as ducks, geese, and pelicans) and non-migratory birds. It is relatively undeveloped for most of its length, it provides water and cover to a large deer and elk herd, and is a favorite recreation area.

An objective of this study was to survey and compile all known records of aquatic macroinvertebrates of the Hanford Reach, its local tributaries, and three spring streams on the Hanford Reach National Monument in order to prepare a comprehensive literature review and to document changes to the taxa of aquatic macroinvertebrates in these environments over time. In 2002, this study also conducted benthic (bottom dwelling) sampling of Rattlesnake Spring and Snively Spring on the ALE Reserve. Catches were compared to those from light-trap sampling that recently had been conducted near the two springs, in the sand dunes area between the springs and the Columbia River, and on the Hanford Reach in order to evaluate the origin of several species of adult Trichoptera that had been captured in the light traps near the springs. The benthic sampling was also compared to similar sampling that had been conducted in spring 2000 in order to evaluate the effects on aquatic macroinvertebrates of the major wildfire that occurred in July 2000. Additionally, this study examined the current status of the crayfish, *Pacifasticus leniusculus towbridgii*, and the western pearl mussel, *Margaritinopsis falcata*, in the Hanford Reach.

Materials and Methods

COLUMBIA RIVER - HANFORD REACH

The Hanford Reach study area has previously been described in Newell (1998) and elsewhere. The width of the river varies from approximately 1000 ft to 3300 ft (305-1005 m) within the Hanford Reach (Battelle 1998). Flows through the Reach fluctuate significantly on a daily basis as well as seasonally and annually and are controlled by releases from Priest Rapids Dam. During the last ten years flows have averaged 120,000 ft^3/sec (340 m^3/sec). But in 1996-97 peak flows reached 415,000 cfs (1175 m^3/sec), far from the most recent flood of 1948 when peak discharge reached 742,000 cfs (2101 m^3/sec) (Battelle 1998). Large annual and diurnal flow variations can cause water level fluctuations of about 25 ft (7.6 m) that can be devastating to aquatic invertebrates. Even during the summer and fall, daily water levels may fluctuate by nearly 5 vertical feet (1.5 m) as hydroelectric generating needs dictate (personal observation).

Crayfish (*Pacifasticus leniusculus towbridgii)* and western pearl mussel (*Margaritinopsis falcata*) sampling occurred on the Hanford Reach during late winter (February-March 2002) and late spring (May 2002). Shorelines were walked looking for mussel shells and live mussels and rocks were randomly turned to search for crayfish. Crayfish traps were baited with fish and left overnight. Sampling areas were in the vicinity of the old Hanford town-site and one mile upstream from the Hanford 300 area. Several miles of shoreline were examined in both locations. The Washington Department of Fish and Wildlife was contacted for data on their recent snorkeling surveys. Current and historical records for *M. falcata* were tabulated.

SPRING STREAMS OF THE ALE RESERVE

Sampling was conducted in Snively Spring and Rattlesnake Spring to assess effects of the recent fire that burned areas around the spring streams. The study area, including a third spring, Benson Spring, has been described in Newell (1998), Pickel (2000), Newell et al. (2001), and elsewhere. Benson Spring is located in Bobcat Canyon and is composed of three small springs that seep out of the base of the foothills near the north end of Rattlesnake Mountain. The discharge for this spring is approximately 0.0023 cubic meters/sec. and it flows approximately 800-900 m before disappearing into the ground. Snively Spring originates from ground seeps about 5 km south of Rattlesnake Spring. Its perennial flow is approximately 3.6 km. Rattlesnake Spring originates from ground seeps and its perennial flow is approximately 2.5 km before it disappears into the ground. This stream is the largest of the three and average discharge is approximately 0.01 cubic meters/second. Prior to the recent wildfire Rattlesnake Spring had a luxuriant riparian zone that was heavily used by many animals during the hot summers, including the large elk herd present on the Monument.

Each of the spring sampling stations was visited during the winter of 2002. Four stations in Rattlesnake Spring and four stations in Snively Spring were sampled. Stations were approximately equidistant from one another along the entire flowing water stretch of each spring stream. Samples were taken with a D- ring aquatic net of mesh size 500 microns openings. The sampler waded into the stream and placed the net downstream. The substrate was disturbed by kicking, wiping, and brushing the rocks and substratum. The current then carried the thus dislodged organisms into the net. Typically, up to 6 linear feet (2 m) of bottom was disturbed at each sample point. The net contents were placed into an enamel pan. All large pieces of detritus were carefully cleaned of organisms and discarded. The contents of the pan were poured through a very fine mesh net to remove the excess water. All organisms were preserved with 70% ethyl alcohol, labeled and returned to the laboratory. Pickel (2000) used a quantitative sampler (0.093 m sq. area) of the same 500-micron mesh size and similar separation and identification techniques.

In the laboratory, the benthic samples were returned to a white bottom pan. The sample was checked under a dissecting microscope to ensure complete removal of organisms. All invertebrates were placed into vials filled with 70% ethyl alcohol and labeled. Adults were transferred to rubber stoppered 2-4 dram vials for permanent storage. Organisms were identified to the lowest possible taxon using the most current, regional, and complete references such as; Plecoptera (stoneflies), Baumann et al. (1977) and Stewart and Stark (1993); Odonata (dragonflies and damselflies), Paulson (1998); Trichoptera (caddisflies), Wiggins (1996); all other aquatic insects, Merritt and Cummins (1996); and other invertebrates, Smith (2001). A reference collection of all organisms is stored at the museum of the Washington State University/Tri Cities campus in Richland, Washington or at the Entomological Museum, Washington State University at Pullman, Washington. The Acknowledgements section of this paper lists taxonomists who identified organisms for this study.

Night collecting trips for adult insects were conducted at the laboratory building and near the road crossing, both on Rattlesnake Spring and near Snively Spring. Mercury vapor and ultraviolet lights were illuminated at dusk at ground level and sampling continued until approximately 2 hours after dark. Light trap sampling continued approximately twice monthly in 1998 and 1999, from March until adults failed to appear, usually in October (Newell et al. 2001). Some adult caddisflies were also collected from pheromone traps set to collect Lepidoptera. D. Strenge conducted additional unpublished sampling during 2001 near the springs and in a sand dunes area located between the springs and the Hanford Reach. This sampling provided some additional taxa and provided species names for some genera. Casual light-trap sampling was also conducted by Newell and others along the Hanford Reach between 1998 and 2002.

Results and Discussion

LITERATURE REVIEW

The first and possibly the most complete study of the benthic aquatic macroinvertebrates of the Hanford Reach was by Davis and Cooper (1951). This research was conducted during 1948. No one since this study has used a similar, intensive and comprehensive sampling approach. Davis and Cooper used a huge bottom dredge to collect samples during 1948 - 1950. This study began the same year as the most recent flood on the Columbia River (Battelle 1998). The principal objective was to survey radioactivity from the river aquatic organisms. Any resulting radioactivity would have originated from the nuclear reactors situated on the Columbia River along the northern boundary of the Hanford Site. The taxonomic treatment by Davis and Cooper (1951) was extensive given the date and state of the taxonomy of many western species of aquatic organisms at that time. The report by Davis and Cooper (1951), like many early reports prepared at Hanford, was classified as '*Secret*' for many years and was only declassified in the 1990's.

Coopey (1948, 1953) completed one of the first limnological studies of the Columbia River. He studied the abundance of benthic organisms and provided a list of phytoplankton and zooplankton. Coopey (1953) also studied other crustacea of the river and found an extraordinary number of crayfish, *Pacifasticus leniusculus* (39 /ft^2, 420 /m^2).

Battelle Pacific Northwest Laboratory, now the Pacific Northwest National Laboratory (PNNL), began research at Hanford in 1965. Battelle's researchers have published numerous papers on the fauna, flora, and ecology of Hanford. Annual reports in the 1960's contain numerous studies on Columbia River aquatic organisms. Coutant (1966), for example, studied phototaxis on the caddisfly, *Hydropsyche cockerelli* and determined the retention time of radionuclides in mollusks and algae. Coutant et al. (1967b) also examined upstream dispersal of some caddisflies, *Hydropsyche cockerelli, Cheumatopsyche campyla*, and *C. enonis.* The limpet, *Fisherola nutalli*, was a favorite study organism, (Coutant et al. 1967a, and Coutant 1968a, b).

Becker (1972a, b) examined effects of thermal discharges on aquatic biota such as the blackfly, *Simulium vittatum*, and thermal resistance of the crayfish. Wolf and Cushing (1972) published one of the earliest studies on Rattlesnake Spring. Their work provided some productivity estimates and records of the occurrence of periodic severe floods that had a devastating effect on the biota.

In the early 1970's, research on benthic organisms was stimulated by plans of the Washington Public Power Supply System (WPPSS) to build nuclear power plants on the Hanford Site near the Columbia River and to extract cooling water from the Hanford Reach (Battelle 1977, 1978, 1979a, b, c; Beak Consultants Inc. 1980; WPPSS 1977, 1984, 1985, 1986). One of these reactors operates today. These studies provide the bulk of river aquatic invertebrate data available in the published record.

Schwab et al. (1979) conducted a survey of all springs on Hanford and provided maps, water chemistry data, elevations, and drawings. Wolf and Cushing (1972) published one of the first studies on the ecology and environment around Rattlesnake Spring. Cushing and Rader (1982) investigated the food of *Callibaetis* sp. (Ephemeroptera) nymphs from Rattlesnake Spring. Cushing and Wolf (1982) provided an energy budget and water chemistry data. Gaines et al. (1992) and Gaines (1987a, b) calculated secondary production of benthic insects in Rattlesnake and Snively Springs. Gaines et al. (1989) studied trophic relations and functional group composition of some benthic insects in both springs. Pickel (2000) was the first to survey Benson Spring for macroinvertebrates.

COMPARISONS OF INVERTEBRATE COMMUNITIES OVER TIME

COLUMBIA RIVER-HANFORD REACH

Table 1 lists results of 11 previous studies covering a 50-year period. These studies utilized at least three very different sampling schemes and this would affect sampling results. Davis and Cooper (1951) utilized a large barge-mounted suction dredge and their study occurred prior to the construction of Priest Rapids Dam. Some studies emphasized certain taxa, e.g. the WPPSS studies found many taxa of Annelida and mollusca and resulted in the greatest number of taxa collected, 92. Some studies identified most taxa to genus while others stopped at order, while others identified to species. Differences in benthic assemblages are expected between the river suction dredge results gathered before Priest Rapids Dam was constructed and the wading sampling conducted by Newell (1998). Major taxa collected in all studies included Porifera, Mollusca, Ephemeroptera, Trichoptera, Lepidoptera, Diptera, and Aracnida. Some of the species identification was made from adult collections (Newell 1998). It is uncertain if the other studies collected adults. Major taxonomic revisions in the Mollusca make comparisons very difficult for this and other taxa. No reference collections remain for comparison.

TRIBUTARIES OF THE HANFORD REACH

Newell (1998) provided the first examination of Hanford Reach tributaries. The assumption that tributary streams might contain a microcosm of the river’s fauna or that the streams might function as refugia proved **not** to be true. However, some organisms were collected here and not in the nearby river in 1998 including: damselflies-*Argia* and *Enallagma* sp., flatworms, and riffle beetles of the family Elmidae.

A total of 21 taxa were collected in the tributaries compared to 52 from the Hanford Reach. The irrigation-return stream at Ringold had the most diverse fauna of the tributaries with 14 taxa collected. All taxa collected in these four locations are listed in Table 2. Newell (1998) noted several major taxa found in the Hanford Reach missing from the tributaries including: Porifera, Bryozoa, Decapoda, Lepidoptera, and Aracnida.

SPRING STREAMS OF THE ALE RESERVE

All aquatic macroinvertebrates collected in Rattlesnake Spring from all published studies are listed in Table 3. Gaines (1987a, b) collected 19 taxa while Newell (1998) found 30 taxa, and in 2002 Newell found 21 taxa. However, Gaines apparently did not collect or did not identify Odonata, Hemiptera, Amphipoda, Mollusca, and Oligochaeta but did identify Chironomidae to genus, while in 1998 and 2002 Newell identified all of these groups but only identified Chironomidae to family. When one compares only those groups collected and identified by both researchers, the results are, Gaines found 14 taxa, Newell (1998) found 11 and in 2002 Newell found 9 taxa.

All aquatic macroinvertebrates collected in Snively Spring from all published studies are listed in Table 4. Gaines (1987a, b) collected 17 taxa while Newell (1998) found 15 taxa, and in 2002 Newell collected 13 taxa. Gaines apparently did not collect or did not identify Coleoptera, Odonata, Hemiptera, Amphipoda or Decapoda but did identify Chironomidae to genus, while in 1998 and 2002 Newell identified all of these groups but only identified Chironomidae to family. Since Gaines identified Coleoptera in Rattlesnake Spring but not Snively Spring, there may not have been any beetles collected from Snively Spring. When only those groups collected and identified by both researchers are compared, the total taxon count is: Gaines 12 taxa, Newell (1998) 9 taxa, and Newell in 2002 11 taxa. The following taxa previously collected by Gaines (1987a, b) and/or by Newell (1998) were not found by Newell in the 2002 study: *Paraleptophlebia*, *Tricorythodes*, Elmidae, Hydrophilidae, *Argia tibialis*, *Dicranota* sp., Tabanidae, and perhaps some Chironomidae. The 2002 study found the previously undetected Diptera family Psychodidae.

Pickel (2000) sampled all three springs prior to the 24 Command Fire of June-July 2000 (Table 5). He noted 16 taxa in Benson Spring, 11 in Snively Spring and 15 in Rattlesnake Spring. When compared to Newell's (1998) pre-fire sampling, the results for Pickel's and Newell's results respectively are: Snively-11 and 15 taxa, Rattlesnake-15 and 13 taxa. Differences for the two studies at Snively Spring are: Pickel (2000) found new taxa of Curculionidae, Heptageniidae, and Sphaeriidae (Table 4). Pickel (2000) did not collect: *Cheumatopsyche*, *Parapsyche* sp., Elmidae, *Argia* spp., *Simulium* sp., *Dicranota* sp., nor *Pacifasticus leniusculus*.

For Rattlesnake Spring, the differences between Pickel (2000) and Newell (1998) are: Pickel found the following new taxa: Dryopidae, Tipulidae, *Fisherola* sp., *Parapsyche* sp., *Lepidostoma* sp., 2 genera in the family Elmidae, Dixidae, Psychodidae, and Acariformes, while Newell found the following taxa not noted by Pickel: *Baetis* sp., *Cheumatopsyche* sp., 2 species in the family Dytiscidae, Gyrinidae, adults of 2 species in the family Aeshnidae, *Argia* sp., *Belostoma bakeri*, 5 species of Corixidae, Gerridae, 2 species of Notonectidae, perhaps *Simulium* sp., *Physella* sp., *Radix auricularia*, and Oligochaeta (Table 3). Some of the Hemiptera are not technically benthic organisms, but are aquatic insects.

Overview of Several Aquatic Insect Orders

Ephemeroptera (Mayflies):

Several of the taxa of adult mayflies that were captured in 1998 in the vicinity of the Columbia River (within 1 mile/1.6 km) but not noted recently from the Hanford Reach are listed in Table 6. These catches were far enough from the river to raise questions as to their habitat and origin. These species may potentially occur in the Reach; other possible origins include the Yakima River and nearby irrigation ditches, ponds, etc.

Ephoron album is very abundant in the nearby Yakima River and was collected in the Columbia River by Davis and Cooper (1951). In late July and early August, huge numbers of adults of this mayfly are attracted to light sources in Richland, Washington during the evening hours. Newell has not caught nymphs of this species in the Hanford Reach, nor has he collected adults immediately adjacent to the Reach (personal communication). Davis and Cooper also collected nymphs of the largest U.S. mayfly, *Hexagenia*; Newell has collected this species in Lake Wallula but not in the Reach (personal communication). Since nymphs of both of these species are burrowers, their specialized habitat could have been missed in Newell's sampling of the Reach but collected by Davis and Cooper with their bottom-dredge sampling procedure.

Fourteen mayfly species in 8 genera were collected by Newell (1998) and Davis and Cooper (1951) listed 7 species in 6 genera from the river (Table 1). Three of the genera reported by Davis and Cooper (1951) were collected by Newell (1998): *Ephemerella, Stenonema*, and *Baetis*. Newell has collected *Paraleptophlebia bicornuta* in small streams in southeastern Washington but not in the Hanford Reach (personal communication) as Davis and Cooper did. The species *Ephemerella yosemite* is now known as *Drunella grandis* and is common in cold mountain streams in Washington and elsewhere in the west, although not caught by Newell in 1998. Newell's study found some previously unreported species from the river: *Acentrella insignificans*, *Baetis bicaudatus* and *B. tricaudatus, Ephemerella inermis, Ephemera simulans, Heptagenia solitaria* and *H.* sp., *Nixe simplicioides* and *N.* sp., *Stenonema terminatum*, and *Tricorythodes minutus.* During July-September in the Richland area, large numbers of adults of *Heptagenia, Nixe, Ephemerella, Stenonema*, and *Tricorythodes* are commonly encountered adjacent to the Reach shoreline. Adults of the burrowing mayfly, *Ephemera simulans,* were encountered only once by Newell in 1998, swarming near the river shoreline at Leslie Groves Park on a warm summer evening at dusk (personal communication).

Edmunds (1960) reported a record of a rare mayfly, *Baetisca columbiana,* from the Columbia River, collected near Pasco, Franklin County, Washington in 1948. No one else has collected or confirmed the presence of this species in the subsequent 50 years.

Hemiptera (True Bugs):

Table 7 includes Hemiptera collection records from R. Zack, Washington State University, from the Hanford Site (Benton County) during and prior to 1998, and from the current study. Adult Corixidae and Notonectidae are excellent flyers and their dispersive powers are excellent, thus they may appear in any suitable habitat. The immatures and/or adults of these species may or may not live in the Columbia River or other Hanford water bodies.

Odonata (Dragonflies and Damselflies):

Table 8 lists Odonata nymphs and adults captured by Newell (1998) or R. Zack in or near the Columbia River, Rattlesnake Spring, Snively Spring, and other locations on the Hanford site. Gaines (1987a, b) listed only *Argia tibialis* from both spring streams but Paulson (1998) does not list this species from Benton County. The list of taxa collected by Newell and Zack is more diverse than previously reported probably because other researchers did not sample for adult Odonata. Odonata adults are excellent fliers and can migrate great distances from larval habitats.

Plecoptera (Stoneflies):

This study collected no stoneflies in the river, tributaries, or the spring streams and no adults were captured anywhere on the Hanford site. Davis and Cooper (1951) found three species in the river. Only two other studies (Battelle 1979, WPPSS 1977) noted Plecoptera in their samples. No stoneflies have been captured in the Hanford Reach since 1979.

Diptera (Flies):

The Diptera are a difficult group to identify beyond the family level in most cases. Becker (1972) did identify one black fly to species, *Simulium vittatum*. Gaines (1987a, b) identified Chironomidae larvae to genus. Zack (1998) has compiled a list of shoreflies (family Ephydridae) of the Hanford Site from past years of sampling. The diversity of Diptera is great but only the Chironomidae and Simuliidae are abundant in the Hanford Reach and the springs of the ALE Reserve.

ORIGIN OF ADULT TRICHOPTERA (CADDISFLIES)

The caddisfly fauna of the Columbia River and Rattlesnake and Snively Springs is rich and varied. Gaines (1987a, b) has published the most complete benthic faunal list from these two springs. He reported two and three genera of caddisflies, respectively, from the spring streams' benthic sampling. Newell et al. (2001) and Strenge (personal communication) found 21 genera and 35 species of adults near Rattlesnake Spring and 2 genera near Snively Spring by light trapping. The increase in the faunal list from Rattlesnake Spring was due largely to the light trap sampling of adults after dark (Table 9). Davis and Cooper (1951) reported 17 taxa of caddisflies from benthic samples from the river, 11 of which were among the 13 taxa collected by Newell et al.

Larvae of many of the taxa of adults that were collected in light traps between 1998 and 2001 have never been collected from any of the spring streams. Immatures of many of the adult taxa collected near the springs are, however, common in the Columbia River. This leads to speculation that some of the adult specimens collected near the spring streams originated from the river. This was partially confirmed by sampling for adults in the dunes area between the river and the spring streams. Sixteen taxa of adult caddisflies were caught in the dunes, where no water is available, indicating that the adults were dispersing from their aquatic source of origin.

WILDFIRE EFFECTS ON SPRING-STREAM INVERTEBRATES

Visits to Rattlesnake Spring subsequent to the fire and 2 years later revealed a severely impacted stream and destroyed riparian zone. The wildfire burned much of the riparian vegetation and deposited ash and charred material into the stream. Vegetation not burned was killed by the heat and much of this material fell into the stream channel. With the surrounding soil unprotected and no riparian buffer zone, winds have blown sand, silt, ash, and dead vegetation into the stream. The result is a great increase in sediment, reduced flow velocities, and dramatic change in substrate composition. This detritus material cannot be flushed from the stream due to the large amount of dead vegetation now restricting stream flow. Bottom sampling revealed a tremendous amount of silt and large amounts of particulate organic matter. Bottom samples also revealed a decrease in diversity and a reduction in numbers of organisms compared to sampling conducted in 1998 and 2000 (Table 3), while some taxa such as the Chironomidae (midges), Simuliidae (black flies or buffalo gnats), Amphipoda (scuds, sandhoppers, beach fleas), and the fingernail clam, *Pisidium,* remained high. Chironomidae and Amphipoda are very tolerant of extreme environmental conditions and adaptable, but the high populations of filter feeders such as Simuliidae and *Pisidium* are unexpected because of the huge amounts of sediments that could disrupt their filter feeding habits. The huge sediment additions to the substrate, and reduced flows could smother the small *Pisidium* clams.

The benthic fauna of Snively Spring has changed little from the pre-fire studies, although no aquatic beetles were caught in 2002 sampling (Table 4). Snively Spring was apparently less impacted than Rattlesnake Spring by the fire. Newell (2003) attributes this to the location of the spring streams and their stream channel configuration. Snively Spring is located primarily in a steep canyon. This may have reduced the wind effects and lessened input of allochthonous detritus, i.e., fragments of material that originated outside the stream. The Snively stream channel is narrow and "V" shaped; this has prevented much of the dead vegetation from reaching and restricting stream flow. Thus, flows in Snively have been maintained much as before the fire. Silt, ash, and debris that might have reached the stream would have been washed downstream. This seems to be born out by the large amounts of silt and debris found in the lower 200 m of the Snively Spring channel.

STATUS OF *PACIFASTICUS LENIUSCULUS* (CRAYFISH) POPULATION

One objective of this small study in 2002 was to increase the sampling effort in an attempt to determine the status and condition of the *Pacifasticus leniusculus* (crayfish population) in the Hanford Reach. This concern arose from Newell's (1998) report that noted not a single intact crayfish specimen was captured or seen, although body parts were found, while previous studies noted an incredible abundance of crayfish in the Columbia River (Coopey 1953). This portion of the 2002 study was merely a few days in length but involved some sampling efforts that differed from previous studies. Sampling was conducted in the late winter prior to river fluctuations, late spring, and with traps. The traps failed to attract crayfish but sampling at low and steady river levels in late winter revealed large numbers of crayfish in many size classes. Nearly every rock harbored a crayfish beginning at the water's edge and out as far as one could wade. Sampling in May revealed no crayfish. Perhaps this crayfish has adapted to the daily river fluctuations by staying in deeper water except when flows are constant over long periods as during the winter.

Crayfish populations are present in both Benson and Snively Springs. Specimens caught in these springs do not achieve the large size of Hanford Reach specimens.

STATUS OF *MARGARITINOPSIS FALCATA* (WESTERN PEARL MUSSEL) POPULATION

Freshwater mussels are molluscs in the class Bivalvia (Stock 1996). There are seven species of native large freshwater bivalves in Washington State. Literature on ecology and distribution is limited. The seven species belong to the genera *Anodonta* and *Gonidea* (Unionidae) and *Margaritinopsis* (Margaritiferidae). Mussels will not occur in streams where the substrate is substantially disturbed by torrents (Toy 1998). Pearly freshwater mussels of the order Unionoida reproduce by releasing immature molluscs called glochidia into the stream. These glochidia must attach to the gills of a fish within a few days in order to survive. They eventually fall off of the host as a small mussel. Both of these events exhibit high mortalities, which are compensated for by production and release of huge numbers (millions) of glochidia and by long-lived adults.

Margaritinopsis is usually found in cold, well oxygenated, oligotrophic (low in nutrients) waters with a sand and gravel substrate. Distribution is affected by: current velocity, temperature, particle size of substrate, water chemistry, timing and nature of organic inputs (Toy 1998), floods and river stability (Vannote and Minshall 1982), and availability of suitable hosts for their glochidia (usually young fish of the family Salmonidae-trout, char, and salmon). Under optimal conditions, *Margaritinopsis* can form extensive beds. Murphy (1942) estimated over 20,000 individuals in a ¾ mile channel of the Truckee River in California. Unfavorable fluvial processes and lithology can work to confine *Margaritinopsis* to localized places in a river, such as in protected areas behind large boulders (Vannote and Minshall 1982) or behind large woody debris (logs) (Stock 1996). This mussel prefers areas of stable substratum, and current velocities sufficient to prevent deposition of silt and sand. Stock (1996) found mussels predominately in cobble substratum with large logs and boulders present, which provide substrate stabilization during flood events. Di Maio and Corkum (1995) also noted that Unionidae bivalves are adversely affected by unstable hydrologic regimes. Stock (1996) believed that mussel habitat corresponded to that of juvenile forms of their host fishes, primarily salmonids.

The western pearl mussel, *Margaritinopsis falcata* (Gould), is endemic to the North American states west of the Rocky Mountains, including California, Idaho, Montana, Nevada, Oregon, Washington, and British Columbia. Glochidia of *M. falcata* are highly host specific (Bauer et al. 1991) and are generally restricted to the salmonid family, especially Chinook salmon, cutthroat trout, steelhead, and coho salmon. Stream velocities affect this mussel with stream gradients of 1.4% containing mussels and those averaging 2.4% absent of mussels. Koenig (2000) determined that *M. falcata* can adjust to natural variable stream conditions but these adaptations may be inadequate to compensate for larger scale stream habitat degradation. *M. falcata* is one of the most common species of freshwater mussels in the Pacific Northwest. It is closely related to, and until recently was considered a subspecies of *Margaritifera margaritifera* (L.) (Burch 1972), which is a circumpolar species found in northern Europe, Russia, Great Britain, and the eastern United States and once was called *Margaritana margaritifera* (Elrod 1902). *M. falcata* is found in west coast drainages from California to Alaska, with a suspect disjunct population occurring in the upper Missouri drainage in Montana (Clarke 1981, Stober 1972). Smith (2000) elevated this species to a new genus, *Margaritinopsis*, for all specimens in Pacific Northwest coastal drainages.

M. falcata may be one of the longest living freshwater invertebrates. The oldest known specimens have been aged at greater than 90 years (Toy 1998), 100 years (Vannote and Minshall 1982), and >100 years old (Stock 1996).

Native Americans have been harvesting *M. falcata* from the Columbia River drainage for as long as 5000-7000 years (Toy 1998, and Marceau 2002). Lyman (1980) noted 13 archaeological sites along the Columbia and Snake Rivers, and Round Butte in Central Oregon. Many of these sites contained remains of *M. falcata* and dated from nearly 9000 years before present.

While once very abundant in this stretch of the Columbia River, recent collecting efforts suggest that the population of *M. falcata* has drastically declined in the Hanford Reach and probably in much of the Columbia and Snake Rivers inundated by dams (Table 10). Newell (2003) reports that he has sampled, fished, and recreated on the Hanford Reach for 15 years and has extensively observed aquatic life in and along the river. On only one single occasion, August 8, 2000, he discovered a dead specimen of *M. falcata* on the shore of the Columbia River at Leslie Groves Park in Richland, Benton County, Washington. This shell was recently dead since it had fresh muscle flesh attached to one of the unbroken shell halves. He searched the immediate area and found three live specimens in about 6-10 inches of water. All were about the same size, approximately 100 mm in length. The river flow this time of year was very reduced with little diurnal or diel fluctuations and relatively low discharge. This location is not far from the upper reaches of the influence of Lake Wallula. The substratum in this sidechannel is sand and gravel with relatively modest current flows. Based on other studies, these individuals could be 60+ years of age and would have hatched before any of the Columbia River dams were constructed. Newell believes that even if a modest population of these bivalves exists in the Hanford Reach, more shells and live specimens would have been found. Even in the presence of many young host specimens of Chinook salmon, some factor(s) has caused an apparent drastic decline in this species. Based on the substrate and flow requirements and given the huge and numerous daily and seasonal water level fluctuations, these flow conditions, and resulting substrate conditions, would be detrimental for the adults and probably more so for the young bivalves. It is possible that the huge population of the exotic mollusc, *Corbicula fluminea,* in the Reach may also have a detrimental influence.

Williams et al. (1993) listed this species as undetermined conservation status due to a lack of knowledge of this species. Anderson (2002) attributes the decline of *Margaritifera* and other molluscs to the presence of dams. Dams impound flowing habitat, reducing water velocities as well as inundating diverse substrates with fine sediments (Bogan 1993). Mussels downstream from dams are subject to scouring effects from the outflow, which can create unstable substrates as well as inundation.

Frest and Johannes (1995) list the following actions as threats to this species: extensive diversion of streams, hydroelectric and water supply projects, heavy nutrient enhancement, siltation, and unstable substrate. These and other factors likely have greatly reduced populations in the main stem Snake and Columbia Rivers (Frest and Johannes 1995). Frest and Johannes (1995) do not recommend federal or state listing at this point, although they believe the species should be considered sensitive. They recommend further work to document range changes. They note that populations showing repeated reproduction (at least several age classes) are now the exception rather than the rule. They also noted a new species of *Margaritifera* from the Pahsimeroi River, Idaho (Taylor 1988).

Summary

The macroinvertebrate fauna of the Hanford Reach has changed over the last 50 years. Records of aquatic invertebrate catches (Table 1) indicate that mayfly diversity has increased; stoneflies have disappeared; caddisfly diversity and abundance remain high; Odonata, Hemiptera, Lepidoptera and Coleoptera are rare; and Diptera diversity remains relatively constant. Recent surveys found that the population of the crayfish, *Pacifasticus leniusculus*, remains high but the western pearl mussel, *Margaritinopsis falcata*, seems to have nearly disappeared from its past high densities. Taxonomic revisions of the mollusks make it difficult to compare catches from numerous studies conducted over several decades, and no voucher specimens are available for study. The one healthy mollusk population is that of the introduced exotic Asiatic clam, *Corbicula fluminea,* which is extremely abundant in the Hanford Reach. Impacts of the huge population of this mollusk on other benthic fauna is unknown. One problem in comparing data from over 50 years ago is revision of taxonomy. Taxa have been split (e.g. mayfly families

Ephemerellidae and Baetidae) making some comparisons impossible without voucher specimens to examine. In some instances the early studies were only able to identify most benthic organisms to genus. Apparently adult specimens were not a priority and thus identification to species was not possible.

Benthic macroinvertebrate diversity in the spring streams of the ALE Reserve has changed over the last 15 years. In Rattlesnake Spring, the mayfly genera *Paraleptophlebia* and *Tricorythodes* and the caddisfly genus, *Limnephilus,* have not been captured since 1987, nor has any hydrophilid beetle or tabanid fly (Table 3). Similarly, *Paraleptophlebia* and *Tricorythodes* have not been caught since 1987 from Snively Spring, nor has any tabanid fly (Table 4). It is impossible to compare the status of some groups prior to Newell (1998) since previous studies did not collect some taxa (Hemiptera, Odonata, Amphipoda, and Mollusca). Pickle (2000) found some taxa previously unreported from Rattlesnake or Snively Springs and found diversity in Benson (Bobcat) Spring to be similar to the other two spring streams (Table 5).

The streams of both Rattlesnake and Snively Springs were impacted by the fire of July 2000 that engulfed most of the Hanford site, including much of the Monument land around the springs. Rattlesnake Spring was the most severely impacted by a combination of ash, silt, charred wood, dead and allochthonous detritus (wind-blown vegetation).

Recommendations

Recommendations for future research.

- Benthic sampling in Snively and Rattlesnake Springs should occur periodically to document any recovery from fire effects.
- Benson Spring benthic fauna sampling should occur every few years to document population status.
- Studies should be conducted that replicate the methods and season of earlier studies to better evaluate changes in benthic fauna over time.
- More intensive sampling of the river and shoreline should be considered to create a valid current species list. Appropriate taxonomic assistance should be utilized.
- Long-term, seasonal studies are needed to develop baseline data that can be used to monitor the effects of both natural and man-caused disturbances, such as unstable hydrological regimes, on benthic fauna over time.
- Comprehensive surveys for the western pearl mussel, *Margaritinopsis falcata*, should be conducted to determine whether isolated populations of this formerly abundant mussel exist within the Hanford Reach.

Recommendations for management:

- Rattlesnake and Snively Springs are fragile ecosystems that have been greatly disturbed by the wildfire of 2000. The springs are ecologically important in that they provide water and some remaining riparian habitat to animals, and they provide rare habitat for a diverse assemblage of benthic fauna in an otherwise arid environment. Additional disturbances to these fragile ecosystems should be avoided, while control of invasive non-native plants around the springs would give the native plant species greater opportunity to recover.

- Management plans designed to protect salmon should include measures to protect aquatic insects, which are the main food for young chinook salmon (Dauble et al. 19__).

Acknowledgements

The author thanks the following persons for their assistance in the completion of this study: Dr. James Hansen, for helping with collections; Dennis Strenge, for collecting adult insects at his light traps; and the following for identifying specimens: Dr. Boris Kondratieff and Dr. William Peters, Ephemeroptera; Dave Ruiter, Trichoptera; Dr. William Shephard and Dr. Curt Schmude, Coleoptera; Dave Nunnallee and Dr. Dennis Paulson, Odonata; Dr. Rich Zack, Coleoptera and Hemiptera; and Dr. Alyson Brigham, USGS, aquatic Lepidoptera. The author also thanks The Nature Conservancy for funding this study. Others who helped make this report possible are: Dr. Dennis Dauble and Dr. Duane Neitzel of Battelle Pacific Northwest National Laboratory, Betty Hodges of the WPPSS library, and Dr. Lee Rogers of WSU/Tri-Cities.

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Table 1. Summary of all benthic invertebrate taxa reported by the major benthic studies on the Hanford Reach, 1948-1998, including all organisms, immatures and adults. Current taxonomic names are provided when applicable. **PHYLUM/SUBPHYLUM** is in upper-case bold; CLASS/SUBCLASS is in upper case; **Order** is in lower-case bold.

Master List-Aquatic Invertebrates					
	Davis - Cooper, 1951 (1)	Battelle 1976-79 (2)	Beak, 1980 (3)	WPPSS 1977, 84-86(4)	Newell, 1998 (5)
PORIFERA-Sponges					
Spongilla lacustris	X	X	X	X	X
COELENTERATA-Jellyfish, hydroids, corals, sea					
Craspedacusta sowerbii				X	
Hydra sp.	X	X		X	
PLATYHELMINTHES-Flatworms, tapeworms, planarians					
Cura sp.			X		
Dugesia sp.		X			
Dugesia dorocephala				X	
Planaria sp.	X				
BRYOZOA-Moss animals					X
Plumatella sp.	X			X	
Pertinatella sp.	X			X	
NEMATODA-Nematodes, roundworms, eelworms	X	X	X		
ANNELIDA-Earthworms, marine worms, leeches		X		X	
HIRUDINEA-Leeches	X		X	X	
Erpobdella punctata				X	
Helobdella stagnalis				X	

Master List-Aquatic Invertebrates					
Illinobdella moorei				X	
Piscicola sp.				X	
Placobdella montifera				X	
Theromyzon rude				X	
OLIGOCHAETA-Earthworms, freshwater ringed worms			X	X	X
Chaetogaster sp.				X	
Triannulata montana				X	
Xironogiton instabilis				X	
MOLLUSCA-Mollusks: clams, snails, octopi					
BIVALVIA-Bivalves: clams/mussels				X	X
Anodonta californiensis				X	
Anodonta compressum				X	
Anodonta nuttalliana	X				
Corbicula fluminea				X	X
Cyclas fluminea (=*Corbicula*?)	X				
Margaritifera margaritifera (=falcata)				X	
Pisidium sp.					X
Pisidium columbiana	X			X	
Pisidium compressum	X				
GASTROPODA-Snails					
Fluminicola sp.				X	X
Fluminicola nuttalliana	X	X		X	
Gyraulus parvus					X
Gyraulus vermicularis	X			X	
Goniobasis plicifera	X				
Limnaea sp.		X	X	X	
Lymnaea stagnalis				X	
Lithoglyphus sp.			X		
Parapholyx sp.			X	X	
Parapholyx effusa costata	X			X	
Parapholyx effusa neritoides	X			X	
Parapholyx sp.			X	X	
Planorbis sp.				X	

Master List-Aquatic Invertebrates					
Physa sp.		X	X	X	
Physa nuttalla (=*nuttallii*?)	X	X		X	
Radix auricularia					X
Radix japonica	X			X	
Stagnicola apicina	X			X	
Stagnicola nuttalliana	X			X	
Vorticifex (Parapholyx) sp.					X
Basommatophora-Freshwater limpets, pond snails					
Fisherola sp.				X	
Fisherola nuttallii	X	X	X	X	
ARTHROPODA-Arthropods: crayfish, insects, spiders etc.					
CRUSTACEA-Crustaceans					
Cerophium spinicorne	X				
Decapoda-Crayfish, shrimp					
Astasus trowbridgii	X				
Pacifasticus leniusculus towbridgii		X		X	X
Amphipoda-Scuds, sandhoppers, beach fleas				X	
Gammarus sp.		X		X	X
Isopoda-Isopods: sow bugs, pill bugs					
FAMILY Asellidae					
Caecidotea sp.					X
UNIRAMIA-Insects, millipedes, centipedes, symphylans					
HEXAPODA (INSECTA)-Insects					
Hemiptera-Bugs		X			
FAMILY Corixidae-Water boatmen			X		X
Corixa sp.	X				
Sigara washingtonensis					X
FAMILY Gerridae-Water striders					
Gerris sp.				X	
FAMILY Notonectidae-Backswimmers					
Notonecta sp.				X	
Ephemeroptera-Mayflies		X	X	X	
FAMILY Baetidae			X	X	X

Master List-Aquatic Invertebrates					
Acentrella insignificans					X
Baetis sp.	X			X	X
Baetis bicaudatus					X
Baetis tricaudatus					X
FAMILY Baetiscidae					
Baetisca columbiana (6)					
FAMILY Ephemerellidae				X	
Ephemerella yosemite (=*Drunella grandis*)	X			X	
Ephemerella inermis					X
Ephemerella sp.	X			X	X
FAMILY Ephemeridae					
Ephemera simulans					X
Ephoron album	X			X	
Hexagenia sp.	X			X	
FAMILY Heptageniidae				X	
Heptagenia sp.					X
Heptagenia solitaria					X
Nixe sp.					X
Nixe simplicioides					X
Stenonema sp.	X		X	X	X
Stenonema terminatum terminatum					X
FAMILY Leptophlebiidae					
Paraleptophlebia bicornuta	X			X	
FAMILY Tricorythidae				X	X
Tricorythodes minutus					X
Plecoptera-Stoneflies	X	X			
Arcynopteryx parallela (= *Skwala americana*)				X	
Isogenus sp.	X				
Perlodes americana (=*Skwala americana*)	X				
Pteronarcys californica	X				
Trichoptera-Caddisflies	X	X	X	X	X
FAMILY Brachycentridae					
Brachycentrus sp.		X			

Master List-Aquatic Invertebrates					
Brachycentrus occidentalis	X			X	
FAMILY Glossosomatidae			X	X	
Glossosoma sp.					X
Glossosoma parvulum	X				X
Glossosoma velona (= *velonum*?)	X			X	X
FAMILY Hydropsychidae-Net-spinning caddisflies			X	X	
Cheumatopsyche sp.	X	X		X	X
Cheumatopsyche campyla	X	X		X	X
Cheumatopsyche enomis (= enonis)	X	X		X	X
Cheumatopsyche logani		X			
Hydropsyche sp.				X	X
Hydropsyche (=Ceratopsyche) cockerelli	X	X		X	X
Hydropsyche californica	X			X	X
FAMILY Hydroptilidae-Micro-caddisflies			X	X	
Hydroptila sp.	X			X	X
Hydroptila argosa	X			X	X
Leucotrichia pictipes	X			X	
FAMILY Leptoceridae-Long-horned caddisflies			X	X	
Athripsodes annulicornis	X			X	X
Lepidostoma strophis	X			X	
Leptocella sp.	X			X	
Mystacides alafimbriata	X			X	
Oecetis sp.		X			
FAMILY Limnephilidae-Northern caddisflies					
Limnophilus sp. (=*Limnephilus* ?)				X	
FAMILY Psychomyiidae-Tube making & trumpet-net			X	X	
Psychomyia flavida	X			X	X
FAMILY Rhyacophilidae-Primitive caddisflies			X		
Rhyacophila coloradensis	X			X	
Odonata-Damselflies and dragonflies		X			
FAMILY Gomphidae-Clubtails					
Ophiogomphus sp.					X
Lepidoptera-Moths and butterflies		X			

Master List-Aquatic Invertebrates					
FAMILY Pyralidae-Snout and grass moths			X	X	
Argyractis angulatalis	X			X	
Petrophila confusalis					X
Diptera-Flies		X			
FAMILY Chironomidae-Midges		X	X	X	X
Hydrobaeninae (=Chironomidae)	X				
FAMILY Simuliidae-Black flies or buffalo gnats		X	X		
Simulium sp.	X	X			X
Simulium vittatum				X	
FAMILY Tipulidae-Crane Flies				X	
Coleoptera-Beetles					
FAMILY Dytiscidae-Predacious Diving Beetles					X
Dytiscus sp.					X
FAMILY Elmidae-Riffle beetles			X	X	
FAMILY Gyrinidae-Whirligig Beetles					
Gyrinus sp.				X	
CHELICERATA					
ARACHNIDA-Arachnids: spiders, mites, ticks, scorpions					
Araneida-Spiders	X			X	
Hydracarina-mites	X	X	X	X	X
FAMILY Hygrobatidae			X		
TOTAL TAXA=	58	30	28	92	52

REFERENCES :
(1). Davis and Cooper (1951)
(2). Battelle (1976, 1977, 1978, 1979a, b, c)
(3) Beak Consultants Inc. (1980)
(4) WPPSS (1977, 1984, 1985, 1986)
(5) Newell (1998)
(6) Edmunds (1960)
NOTE: Taxa are listed and names are spelled as they appeared in the original documents. In some cases the current correct name has been added.

Table 2. Aquatic benthic invertebrate taxa collected from tributaries to the Hanford Reach of the Columbia River, February 1998 (Newell 1998). Location of tributaries are listed as a table footnote. **PHYLUM/SUBPHYLUM** is in upper-case bold; CLASS/SUBCLASS is in upper

case; **Order** is in lower-case bold.

Hanford Reach Tributaries-Taxa				
	Hatchery Outlet (1)	Ringold Spring (2)	Irrigation Return (3)	P.R. Hatchery (4)
PLATYHELMINTHES-Flatworms, tapeworms, planarians				
TURBELLARIA-Flatworms	X			
ANNELIDA-Earthworms, marine worms, leeches				
OLIGOCHAETA-Earthworms, freshwater ringed worms				X
MOLLUSCA-Mollusks: clams, snails, octopi				
Gyraulus sp.			X	
Vorticifex (Parapholyx) sp.			X	
ARTHROPODA-Arthropods: crayfish, insects, spiders etc.				
Amphipoda-Scuds, sandhoppers, beach fleas				
Gammarus sp.	X			X
Isopoda-Isopods: sow bugs, pill bugs				
FAMILY Asellidae				
Caecidotea sp.				X
HEXAPODA (INSECTA)-Insects				
Ephemeroptera-Mayflies				
Baetis tricaudatus	X	X	X	X
Tricorythodes minutus	X			
Trichoptera-Caddisflies				
Hydropsyche sp.	X	X	X	X
Hydroptila sp.			X	
FAMILY Limnephilidae-Northern caddisflies		X		
Odonata-Damselflies and dragonflies				
Argia vivida		X		
Argia sp.			X	

Hanford Reach Tributaries-Taxa				
Enallagma sp.			X	
Unknown			X	
Diptera-Flies				
FAMILY Chironomidae-Midges	X	X	X	X
FAMILY Empididae-Dance flies				
Hemerodromia sp.			X	
FAMILY Simuliidae-Black flies or buffalo gnats	X	X	X	X
FAMILY Stratiomyiidae-Soldier flies	X		X	
Coleoptera-Beetles				
FAMILY Elmidae-Riffle beetles				
Optioservus sp.	X	X	X	
Zaitzevia sp.			X	
TOTAL TAXA	9	7	14	7

1-Hatchery Stream=Outlet from the Ringold Fish Hatchery, river mile 355.
2-Ringold Spring=Spring stream originating from the hill east and across the road from the Ringold Fish Hatchery.
3-Irrigation stream=Irrigation return stream that enters the Columbia River adjacent to the Ringold Hatchery Land at river mile 354.5.
4-PR Hatchery Outlet stream from the Priest Rapids Dam fish hatchery. This stream enters the Columbia River approximately 1 mile (1.6 km) downstream from Priest Rapids Dam, east bank.
Note: The sampling points for all but the spring stream at the Ringold fish hatchery were below the river's high water mark and within 100 m of the river.

Table 3. Aquatic invertebrate taxa collected from Rattlesnake Spring. Cushing and Rader (1982) worked with a single taxon, *Callibaetis* (Ephemeroptera), and it is not listed in this table. **PHYLUM/SUBPHYLUM** is in upper-case bold; CLASS/SUBCLASS is in upper case; **Order** is in lower-case bold.

STUDIES	Gaines 1987 a,b	Newell 1998	Newell 2002	Pickel 2000
ANNELIDA-Earthworms, marine worms, leeches				
OLIGOCHAETA-Earthworms, freshwater ringed worms		X	X	
MOLLUSCA-Mollusks: clams, snails, octopi				
Physella sp		X	X	
Pisidium sp		X	X	X

Radix auricularia		X	X	
Fisherola sp.				X
ARTHROPODA-Arthropods: crayfish, insects, spiders etc.				
Amphipoda-Scuds, sandhoppers, beach fleas				
Hyalella azteca		X	X	X
HEXAPODA (INSECTA)-Insects				
Hemiptera-Bugs				
FAMILY Belostomatidae-Giant water bugs				
Belostoma bakeri		X		
FAMILY Corixidae-Water boatmen				
Cenocorixa bifida hungerfordi		X		
Corisella inscripta		X		
Graptocorixa californica		X	X	
Hesperocorixa laevigata		X		
Sigara alternata		X	X	
FAMILY Gerridae-Water striders		X		
FAMILY Notonectidae-Backswimmers		X	X	
Notonecta kirbyi		X		
Notonecta undulata		X		
Notonecta sp.			X	
Ephemeroptera-Mayflies				
Baetis sp.	X	X	X	
Callibaetis sp.		X		X
Paraleptophlebia sp.	X			
Tricorythodes sp.	X			
Trichoptera-Caddisflies				
Cheumatopsyche sp.	X	X		
Hesperophylax sp.		X	X	X
Lepidostoma sp.				X
Limnephilus sp.	X			
Parapsyche sp.				X
Odonata-Damselflies and dragonflies				
FAMILY Aeshnidae-Darners				X
Aeshna multicolor (adult)		X		

Aeshna umbrosa (adult)		X		
Aeshna sp.			X	
Archilestes californica		X		
FAMILY Coenagrionidae-Narrow-winged damselflies				
Argia sp.		X	X	X
Enallagma sp.			X	
Diptera-Flies				
FAMILY Chironomidae-Midges	X	X	X	X
Chaetocladius sp.	X			
Chironomus sp.	X			
Heleniella sp	X			
Polypedilum sp.	X			
Thienemannimyia sp.	X			
FAMILY Dixidae-Dixid midges	X		X	X
FAMILY Empididae-Dance flies	X		X	
FAMILY Psychodidae-Moth flies and sand flies			X	X
FAMILY Simuliidae-Black flies or buffalo gnats	X	X	X	X
Simulium sp.	X	X	X	
FAMILY Tabanidae-Horse flies and deer flies	X			
FAMILY Tipulidae-Crane Flies				
Dicranota sp.	X			
Coleoptera-Beetles				
FAMILY Dryopidae-Long-toed water beetles				X
FAMILY Dytiscidae-Predacious Diving Beetles		X		
Hydaticus sp.	X	X		
Unknown		X		
FAMILY Elmidae-Riffle beetles				
Optioservus sp.				X
Rhizelmis sp.				X
FAMILY Gyrinidae-Whirligig Beetles		X	X	
FAMILY Hydrophilidae-Water scavenger beetles	X			
ARACHNIDA-Arachnids: spiders, mites, ticks, scorpions				
Acariformes-Water mites				X
TOTAL TAXA	19	30	21	17

Table 4. Aquatic invertebrate taxa collected from Snively Spring. **PHYLUM/SUBPHYLUM** is in upper-case bold; CLASS/SUBCLASS is in upper case; **Order** is in lower-case bold.

STUDIES	Gaines 1987 a,b	Newell 1998	Newell 2002	Pickel 1999-2000
MOLLUSCA-Mollusks: clams, snails, octopi				
Pelecypoda				
FAMILY Sphaeriidae-Fingernail clams				X
ARTHROPODA-Arthropods: crayfish, insects, spiders etc.				
Decapoda-Crayfish, shrimp				
Pacifasticus leniusculus		X	X	
Amphipoda-Scuds, sandhoppers, beach fleas				
Gammarus sp.		X	X	X
HEXAPODA (INSECTA)-Insects				
Ephemeroptera-Mayflies				
Baetis sp.	X	X	X	X
Paraleptophlebia sp.	X			
Tricorythodes sp.	X			
FAMILY Heptageniidae				X
Trichoptera-Caddisflies				
Cheumatopsyche sp.	X	X	X	X
Parapsyche sp.	X	X	X	
Odonata-Damselflies and dragonflies				
Argia sp.		X	X	
Argia tibialis		X		
Diptera-Flies				
FAMILY Chironomidae-Midges	X	X	X	X
Chaetocladius sp.	X			
Chironomus sp.	X			
Heleniella sp	X			
Polypedilum sp.	X			
Thienemannimyia sp.	X			
FAMILY Dixidae-Dixid midges	X	X	X	X
FAMILY Empididae-Dance flies	X		X	

FAMILY Psychodidae-Moth flies and sand flies			X	
FAMILY Simuliidae-Black flies or buffalo gnats	X	X	X	X
Simulium sp.	X	X	X	
FAMILY Tabanidae-Horse flies and deer flies	X			
FAMILY Tipulidae-Crane Flies	X	X	X	X
Dicranota sp.		X		
Coleoptera-Beetles				
FAMILY Curculionidae-Weevils or snout beetles				X
FAMILY Elmidae-Riffle beetles		X		
FAMILY Hydrophilidae-Water scavenger beetles		X		X
TOTAL TAXA	17	15	13	11

Table 5. Aquatic Macroinvertebrates from Benson, Snively, and Rattlesnake Springs collected and identified by Pickel, (2000). **PHYLUM/SUBPHYLUM** is in upper-case bold; CLASS/SUBCLASS is in upper case; **Order** is in lower-case bold.

TAXA	Benson	Snively	Rattlesnake
MOLLUSCA-Mollusks: clams, snails, octopi			
FAMILY Lymnaeidae-*Fisherola* sp.			X
FAMILY Sphaeriidae-Fingernail clams	X	X	X
ARTHROPODA-Arthropods: crayfish, insects, spiders etc.			
Decapoda-Crayfish, shrimp			
Pacifasticus leniusculus	X		
Amphipoda-Scuds, sandhoppers, beach fleas			
Gammarus sp.		X	
Hyalella azteca			X
HEXAPODA (INSECTA)-Insects			
Hemiptera-Bugs			
FAMILY Corixidae-Water boatmen-*Graptocorixa* sp.	X		
Ephemeroptera-Mayflies			
Baetis tricaudatus	X	X	
Callibaetis sp.			X
Paraleptophlebia sp.	X		
FAMILY Heptageniidae		X	
Trichoptera-Caddisflies			
Cheumatopsyche sp.		X	
Parapsyche sp.			X
Lepidostoma sp.			X
FAMILY Limnephilidae-Northern caddisflies	X		
Hesperophylax sp.			X
Odonata-Damselflies and dragonflies			
FAMILY Aeshnidae-Darners			X

FAMILY Coenagrionidae-Narrow-winged damselflies-*Argia* sp.	X		X
Diptera-Flies			
FAMILY Chironomidae-Midges	X	X	X
FAMILY Dixidae-Dixid midges-*Meringodixa* sp.	X	X	X
FAMILY Psychodidae-Moth flies and sand flies-*Pericoma* sp.	X		
FAMILY Simuliidae-Black flies or buffalo gnats	X	X	X
FAMILY Tipulidae-Crane Flies	X	X	X
Coleoptera-Beetles			
FAMILY Curculionidae-Weevils or snout beetles	X	X	
FAMILY Dryopidae-Long-toed water beetles			X
FAMILY Dytiscidae-Predacious Diving Beetles	X		
FAMILY Elmidae-Riffle beetles-*Optioservus* sp.	X		
FAMILY Elmidae-Riffle beetles-*Rhizelmis* sp.			X
FAMILY Hydrophilidae-Water scavenger beetles	X	X	
TOTAL TAXA	16	11	15

Table 6. Taxa of adult Ephemeroptera (Mayflies) captured by Newell in 1998 in the vicinity of the Columbia River, Richland, WA.

Callibaetis fluctuans (Eaton)
Callibaetis montanus (Eaton)
Callibaetis pictus (Eaton)
Camelobaetidius sp.
Ephoron album (Say)
Heterocloeon sp.
Labiobaetis propinquus (Walsh)

Table 7. Hemiptera collected on or near the Hanford Site. Species are listed along with the closest water sources which are designated with the following codes: Hanford Reach of the Columbia River (CR), Rattlesnake Spring (RS), Snively Spring (SS), and Gable Mountain pond (GP), located in the north central part of the Hanford Site.

	CR	RS	SS	GP
FAMILY Belostomatidae-Giant water bugs				
Belostoma bakeri Montandon		X		
FAMILY Corixidae-Water boatmen				
Cenocorixa bifeda hungerfordi Landsbury	X	X	X	X
Cenocorixa wileyae (Hungerford)	X			
Corisella decolor (Uhler)	X			
Corisella inscripta (Uhler)	X	X		X

	CR	RS	SS	GP
Hesperocorixa laevigata (Uhler)	X	X	X	X
Sigara alternata (Say)	X	X		X
Sigara washingtonensis Hungerford	X	X		
FAMILY Gerridae-Water striders				
Gerris buenoi Kirkaldy		X	X	
Gerris incurvatus Drakes & Hottes		X	X	
Gerris remigis Say		X	X	
Limnoporus notabilis (Drake & Hottes)			X	
FAMILY Notonectidae-Backswimmers				
Notonecta kirbyi		X	X	
Notonecta undulata Say		X	X	
Notonecta unifasciata		X	X	
Total taxa	7	13	10	4

Table 8. Odonata (adults and nymphs) captured in or near the following locations by Newell (1998) and Zack (1998, personal communication): Columbia River (CR), Rattlesnake Spring (RS), Snively Spring (SS), or other locations on the Hanford (H) site.

Aeshna californica Calvert	H	CR		
Aeshna multicolor Hagen			RS	
Aeshna umbrosa Walker			RS	
Aeshna sp.			RS	
Ophiogomphus sp.		CR		
Amphiagrion abbreviatum (Selys)			RS	
Argia sp.			RS	SS
Argia vivida Hagen	H		RS	SS
Argia tibialis (Rambur)			RS	SS
Enallagma cyathigerium (Charpentier)			RS	
Enallagma carunculatum Morse			CR	
Ishnura cervula Selys			RS	
Ishnura perparva Selys			RS	
Libellula pulchella Drury			RS	
Archilestes californica McLachlan			RS	

Table 9. Caddisfly adults caught in and near Rattlesnake and Snively Springs using ultraviolet and mercury vapor light trapping, including data from Newell et al. (2001), Pickel (2000) for the

Benson Spring area, unpublished data from Strenge for 2001 from the springs and the dunes area, and casual sampling by Newell and others from the river. Footnotes provide more details on the sampling locations.

TAXA Family/Genus/Species	Springs* 1999 (1)	Springs* 2001 (1)	Dunes* 1999 & 2001 (2)	Benson Spring 1999-2000 (3)	Hanford Reach, Columbia River 1998-2002 (4)
FAMILY Brachycentridae					
Amiocentrus aspilus (Ross)	x				
Brachycentrus americanus (Banks)		x?			
FAMILY Glossosomatidae					
Culoptila cantha (Ross)	x	x	x		
Glossosoma parvulum Banks					x
Glossosoma velonum Ross	x	x	x	x	
Protoptila coloma Ross		x	x		
Protoptila erotica Ross	x	x	x		
FAMILY Hydropsychidae-Net-spinning caddisflies					
Cheumatopsyche campyla Ross	x	x	x	x	x
Cheumatopsyche gelita Denning			x		
Ceratopsyche oslari Banks			x		
Hydropsyche californica Banks	x	x	x		x
Hydropsyche cockerelli Banks	x	x	x	x	x
Parapsyche almota Ross	x	x			
FAMILY Hydroptilidae-Micro-caddisflies					
Hydroptila arctica Ross		x			
Hydroptila argosa Ross	x	x	x		x
Hydroptila modica Mosely	x				
Hydroptila xera Mosely		x			
Leucotrichia pictipes (Banks)	x				
FAMILY Leptoceridae-Long-horned caddisflies					
Ceraclea latahensis (Smith, S.D.)	x				
Ceraclea annulicornis (Stephems)					x
Oecetis avara (Banks)	x	x	x		
Oecetis immobilis (Hagen)	x				
Oecetis inconspicua (Walker)	x	x	x		
Trianedes baris Ross			x		
Trienodes tardus Milne	x	x			
Ylodes frontalis (Banks)	x	x			
Ylodes reuteri (MacLaughlin)		x			
Nectopsyche sp.	x	x			
Nectopsyche lahontanensis Haddock		x	x		
Polycentropus cinereus (Hagen)		x	x		
FAMILY Limnephilidae-Northern caddisflies					
Hesperophylax designatus (Walker)	x	x			

Limnephilus abbreviatus Banks	x				
Limnephilus aretto Ross		x			
Limnephilus assimilis (Banks)	x	x			
Limnephilus diversus (Banks)		x			
Limnephilus frijole Ross	x	x			
Limnephilus sitchensis (Kalenati)	x				
Limnephilus spinatus Banks	x	x			
FAMILY Psychomyiidae-Tube making & trumpet-net caddisflies					
Psychomyia flavida Hagen	x	x	x		x
FAMILY Lepidostomatidae					
Lepidostoma cinereum (Banks)	x	x			
TOTAL TAXA	26	28	16	3	7

1- Springs= Rattlesnake and Snively Springs, ALE Reserve, Hanford, Benton Co., WA.
2- Dunes = sand dune area about 5 miles west of Columbia River near Energy NW nuclear power plant.
3- Benson Spring= Benson Spring, Bobcat Canyon, ALE Reserve, Hanford, Benton Co., WA.
4- Columbia River = Columbia River from Priest Rapids Dam to Richland, Benton Co., WA.

Table 10. The Western Pearl Mussel,-*Margaritinopsis falcata,* state of knowledge, current and past distribution in the Columbia River drainage, and ancient shell middens and data sources.

1-Current distribution-modern records <50 yrs. before present:
Salmon River, Idaho; (Vannote and Minshall 1982)
Middle Fork of the Salmon River, Idaho (M. Haddix, personal Correspondence, 2001)
Bitteroot River, Missoula, Co. Montana (R. Newell, personal Observation, 1968)
Columbia River, @ Richland, Benton Co., WA (R. Newell, personal Observation, 2000)
Wenatchee River (R. Stevens 2000)
Yakima River, north of Yakima, Yakima R. Canyon, WA (R. Newell 1998)
Yakima River near Ellensburg, WA (B. Leonard, 2000 pers. obs, WDF&W)
Columbia River near Energy NW nuclear Power Station, Benton Co, WA (WPPSS 1977)
Kettle River, Stevens Co., WA (Roscoe and Redelings 1964)
Nason Creek,(trib. of Wenatchee River) nr. Leavenworth, WA (Stock 1996)
Pole Cat Creek, Yellowstone Nat. Park, Wyoming (Van der Schalie 1970). There is uncertainty if this stream is in the Yellowstone R. or Snake River drainage.
Steele Creek, Blackjack Creek, Battle Cr. Kitsap Peninsula, WA (Koenig 2000)
Bear Creek and Battle Creek, Kitsap Peninsula (Toy 1998)
Upper Flathead River drainage, 9 small tributaries (McGuire and Marshall 2001)
W. Fork Sanpoil River, WA
Wenatchee River, WA
Myrtle Creek, OR
Williamson River, OR

Canyon Creek, OR
Blackfoot River, ID
St. Joe River, ID
Yaak River, MT
Monture Creek, MT (The above 9 locations studied by Anderson 2002)
Coeur d' Alene River, ID
St. Maries River, ID
Blackfoot River, ID (The above 3 sites reported by Frest and Johannes 1995)

2-Distribution - old records > 50 yrs.before present:
Snake River at Weiser, Idaho (Henderson 1936a)
Weiser River at Midvale, Idaho (ibid)
Little Salmon River 16 mi. north of New Meadows, Idaho (ibid)
Bitteroot River, Montana near Missoula, Montana (ibid; Elrod 1902)
Post Creek, 6 mi north of St. Ignatius, Lake Co., Montana (Henderson 1936a)
Yakima River near Yakima, WA 1934 (Eyerdam 1934)
Walla Walla River, Walla Walla Co., WA 1842 & 1892 (Gould 1842 and Stearns 1892 IN Walker 1910)
Most of the branches of the Columbia River1867 & 1892 (Cooper 1867 and Stearns 1892 IN Walker 1910)
Spokane River, ID, and Coeur d'Alene River, ID (Bland 1861, Cooper 1867, and Stearns 1892 IN Walker 1910)
Snake River, ID and Weiser River, ID (Hannibal 18?? and Walker 1909 in Walker 1910)
Crow Creek, Flathead Indian Reservation , Montana, Lake Co., and "in all of the western mountain streams." (Elrod 1901, 1902 in Walker 1910).
Mud Creek, Flathead County, near Mud and Echo Lakes, Flathead Co.,MT (Elrod 1902)
Deschutes River, Klamath Co., OR (Walker 1909 in Walker 1910).
Yakima River, near Yakima, WA. 1924 (Eyerdam 1934)
Crow Creek, Flathead Indian Reservation, Lake Co., MT (Elrod 1902)

3-Ancient archeological shell middens:
Salmon River, Idaho (Vannote and Minshall 1982)
Snake River, Washington (Brauner 1976 in Stevens 2000)
Upper Columbia River, Washington (Chance and Chance 1985 in Stevens 2000)
Wenatchee River, 38 sites above Levenworth, Chelan Co., WA, (Stevens 2000)
Columbia River, Hanford Nuclear Site, Benton Co., WA (Tom Marceau [BHI] pers. Correspondence, 2002, age 4000-7000 years)
Columbia River near Vantage, WA age up to 9000 years BP, (Ingram 1948)
Columbia River, several sites, WA (Lyman 1980)
Snake River, several sites, WA and ID (Lyman 1980)
Round Butte, Oregon, (Lyman 1980).

4-UNKNOWN STATUS

Yakima River at Benton City, Benton Co., WA, many broken and bleached shells following a flood, 1998 (R. Newell, personal observation)

Columbia River, Hanford Reach near White Bluffs, many shells, 2001 (B. Leonard, WDF&W, personal observation)

Snake River, except for some tributaries-extinct; extinct from many coastal streams; extinct in the Okanogan River; rare in the mainstem Columbia River (Frest and Johannes 1995)