Springs and the minute snails that inhabit them in the Puget Sound region: Searching for the concealed
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As part of a phylogenetic study with Dr. David Campbell, Gardner-Webb University, NC on *Juga* and *Pristinicola*, I have been surveying springs for the latter snail in the Puget Sound basin. Permanent springs (by springs I also include seeps) are ones running year round for thousands, if not a million years or so, may occur singly or in groups and are not only an important habitat for freshwater mollusks, in particular snails, but for many other animals and plants, especially in arid areas. Springs have a disproportionate occurrence of rare or endemic species, some found at one or a few springs (Sada et al., 2001). Springs also serve as a thermal refugia for many species including springsnails, especially those that were unable to migrate rapidly enough as the climate warmed during the end of the last ice age (Late Pleistocene). I have found cold springs in the Puget Sound basin ranging from 11 to 13 ºC, approximately the current mean annual ambient air temperature in the region, indicating they are coming from a relatively shallow groundwater sources. Hopefully human caused climate change will not increase water temperatures of these springs above the tolerance threshold of springsnails or other taxa. In the opposite temperature spectrum, hot springs (actually warm springs, above 46 ºC is too hot) support freshwater snails and other animals that cannot exist at cooler temperatures and have deep seated groundwater sources (Sada et al., 2001; Clarke, 2014). I have found no thermophile snail species occurring in the Puget Sound region; only two cold-water taxa, *Pristinicola hemphilli* (Pilsbry, 1890) (pristine pyrg) and *Colligyrus* n. sp. (coastal duskysnail) have been found during my surveys of springs here and elsewhere (Figure 1; Johannes, 2015). Recent DNA analysis suggest placement of the coastal duskysnail under a new genus (Liu et al., 2015). Both snails occur mostly in seeps to small-medium sized springs though on rare instances *Pristinicola* is found in small spring influenced creeks and bigger springs. To me, how these snails migrate from one spring, whether hot or cold, to another is a very interesting biogeographic problem, especially in the recently deglaciated Puget Sound basin. If you are inspired by finding new molluscan species, as I am, springsnails are by far the easiest way to go in the western U. S. Many have been scientifically described (mostly in the genus *Pyrgulopsis*) from this region within the last decades, with an unknown number yet to be found or named, including the aforementioned coastal duskysnail. Of the freshwater mollusks that occur in the western U. S., the few listed under the Endangered Species Act (ESA) include a significant number that are either spring dwellers or found in habitats influenced by springs or groundwater. Neither springsnail that occurs in the Puget Sound region are listed under the ESA. Despite the relative small size of the habitat, I have found searching for springs in the open arid lands of the western U. S. relatively easy. From a distance the green strip of vegetation surrounding the source and run of springs can be readily seen on hillsides or valleys (Figure 2). Even U. S. Geological Survey (USGS) 7.5-minute topographic maps, also known as 7.5' quadrangle, often have springs indicated in such areas, which are easily seen in areal photos, the basis for these maps. But areas with dense forest and vegetative cover, such as in the Puget Sound region, searching for spring habitats are extremely difficult (Figure 3). Often the USGS 7.5' quadrangles in this region do not show them—even large ones with names, like Crystal Springs (N.-most site for *Pristinicola* in Puget Sound) occurring a half mile from my house, are missed. So what is one to do?

From experience I know that most springs emanate from the side or base of hillsides, or along drainages often in small stream ravines or gulches. These are good geographic features to narrow searches. Permanent springs in the Puget Sound basin depend on a big enough upland (catchment) area for rain to fall on, that are underlain mostly by permeable geologic units largely glacially deposited allowing infiltration to a sufficient depth before hitting impermeable layers to store enough underground water volume for year round flow even during the dry summer months. But searching (crashing through) all
these well-vegetated slopes and ravines for springs would be slow going. If they exist, looking at geologic maps may help whittle down the search area, but is dependent on prior knowledge of which units produce springs. Even then it does not tell you where the springs will occur in these units that could cover many square miles. Once again we are back to vegetation, obscuring the geology of this region further hindering searches. There seems to be a consistent theme here, vegetation. Instead of considering it a barrier, why not use it. That is exactly what I do. Instead of looking for springs, I look for specific kinds of vegetation on slopes and in ravines, ones that are wetland indicators (for practical guide see Cooke, 1997). This is especially useful while tooling along roads both in the actual sense or virtually when using Google Earth street view, as plants are easier to see than the springs they obscure. Another method I use is to watch for water in ditches during the dry summer months as a possible indicator of springs. But ditches are not always present along roads and during the rainy season are not as helpful indicator as is the presence of wetland plants.

I am not the first to use plants as indicators. Having a background in geology, I was aware that miners have known since medieval times particular plants could be used as indicators to the presence of ore bearing deposits. Both *Lychnis alpina*, a small pink-flowering plant in Scandinavia, and *Haumaniastrum katangense*, a white-flowered shrub in central Africa, were known associates of copper mother lodes. Recently, a tree, possibly *Pandanus candelabrum*, in Liberia was noticed to occur...
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