

Long-Lived Taxa Attribute List: Documentation of methods for deriving the list

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Karr's Benthic Index of Biotic Integrity (BIBI) for benthic macroinvertebrates uses the total number of long-lived taxa as one of 10 metrics to evaluate the biological health of streams (<http://www.pugetsoundstreambenthos.org/>). For the second iteration of this index for Puget Sound Lowland streams, the classification of long-lived taxa is being updated and refined.

Long-lived benthic invertebrate taxa are those **where a significant portion of individuals require more than one year to complete their life cycle**. While some aquatic invertebrates always display a fixed number of generations per year, many aquatic invertebrates are plastic in regards to the length of time required to complete a life cycle from egg to adult. Depending on environmental factors such as water temperature and the seasonal accumulation of degree-days, populations or individuals develop at varying rates.

Voltine refers to the number of broods or generations a year that a species exhibits, typically in reference to arthropod life history. Prefixes are appended to voltine to describe generation time, e.g. univoltine refers to a species that has one generation per year, bivoltine for two generations per year, and trivoltine for three generations per year. Application and meaning of prefixes for voltinism in the literature is inconsistent and confusing. For example, Huryn et al. (2008) refer to semivoltine as a life cycle requiring a fixed two years. Poff et al. (2006) consider a semivoltine life cycle to be anything greater than one year.

We use "long-lived" to avoid confusion around terminology associated with voltinism, and to have broader application to non-insect freshwater invertebrates. **Long-lived species are those where a significant portion of individuals require more than one year to complete a life cycle**. Within a species range it is not uncommon for populations occurring at lower elevations or more southern latitudes to have shorter generation times than higher elevation or more northerly populations. For example, the caddisfly *Heteroplectron californicum* displays a one-year (univoltine) life cycle in the southern part of its range in coastal California (Beche and Resh 2005), but requires 2 years to complete a generation throughout the northern part of its range in Oregon and Washington, and at higher elevations throughout its range (Anderson 1976, Wisseman unpublished). A significant portion of individuals and populations for this species requires greater than one year to complete a life cycle and is classed as long-lived.

Classifying long-lived or not for some taxa is problematic. For example, Hauer and Stanford (1982) found that the large ubiquitous western montane caddisfly, *Dicosmoecus gilvipes*, required two years to complete a life cycle in the cold headwaters of the Flathead River in Montana. Besides these higher elevation populations, *Dicosmoecus gilvipes* is univoltine (1 year life cycle) throughout its range and in Puget Sound Lowland rivers and streams. Since a significant portion of individuals and populations has a single generation per year, we do not class this species as long-lived.

The level of detailed life history information currently available for most western North American aquatic invertebrates is meager, generally not at the level cited above for *Heteroplectron californicum* and *Dicosmoecus gilvipes*. In constructing our list of long-lived taxa for Puget Sound Lowland streams we relied on published references on life histories when available and best professional judgment when lacking. Evidence from biomonitoring samples collected throughout western North America has led us to the tentative conclusion that certain cold-water taxa are long-lived. Encountering two or more distinct development stages (cohorts) in samples suggests that a taxon requires more than a single year to mature and reproduce. If this pattern is seen repeatedly through much of the range the taxon has been classed as long-lived.

Hury et al. (2008) and Poff et al. (2006) summarize life history and voltinism for a number of North American aquatic insects. Stewart and Stark (2002)(Plecoptera), Wiggins (1996)(Trichoptera), Pennak (1989)(non-insects), Thorp and Covich (2001)(non-insects), Mackie (2007)(corbiculid and sphaeriid clams), Dillon (2010)(mollusks), and other authors were consulted in classifying Puget Sound Lowland aquatic invertebrates as long-lived.

Listed below are the major ways that this updated version of the long-lived taxa differs from the version originally used to construct and calibrate the Karr BIBI:

Mollusca: Bivalvia: Freshwater bivalves include the very long-lived mussels and clams in the families Corbiculidae and Sphaeriidae. Mackie (2007) reviewed the life histories of the freshwater clams and concluded that nearly all species live and are reproductively active for more than one year. The original Karr BIBI listed the mussels and *Corbicula* (asiatic clam) as long-lived and the Sphaeriidae (pea- and fingernail clams) as not. We have changed the Sphaeriidae to long-lived. Sphaeriidae (e.g. *Pisidium*) are common in Pacific Northwest streams.

Mollusca: Gastropoda (snails): In the freshwater snail families Planorbidae, Lymanidae and Physidae most individuals appear to die within a year and thus are not long-lived (Dillon 2010). *Juga* (Pleuroceridae) is a long-lived snail that is very common in lowland streams of western Oregon and Washington (Furnish 1989). We also consider the Hydrobiidae snails to be in general long-lived (Terrence Frest, personal communication; Dillon 2010). The only original classification for the Karr BIBI that has been changed is Hydrobiidae at the family level is now classed as long-lived.

Hirudinea (leeches): Most leeches (e.g. Hirudinea, Erpobdellidae, etc.) live and reproduce for more than one year and are newly designated here as long-lived (Pennak 1989). The exception is the very common and cosmopolitan leech *Helobdella stagnalis* which appears to have one or more generations a year and is not classed here as long-lived (Pennak 1989). Identification of this ubiquitous species in Puget Sound Lowland benthic samples is encouraged. Otherwise we recommend identifying leeches to the family level.

Oligochaeta (segmented worms): Pennak (1989) suggests that most of the larger species of segmented worms often live for more than one year. Steve Fend (personal communication) suggests that most individuals of small species in western North America probably live for a year or less. The duration of the life cycle of most oligochaets is not well known, except that it varies considerably. Most of the segmented worms encountered in Puget Sound Lowland benthic biomonitoring samples are identified to class only (Oligochaeta), and we are not classifying them here as long-lived. However, when worms are identified to the family or lower level, we classify the large megadrile taxa (Lumbriculidae) as long-lived.

Dytiscidae (predaceous diving beetles): Though classed as long-lived in the original Karr BIBI, we do not class them as such for this BIBI update. Poff et al. (2006) list the Dytiscidae as semivoltine, however in the tabular review of North American studies conducted by Huryn et al. (2008), the species studied are either univoltine or bivoltine. We follow the conclusion of Huryn et al. for this update and classify the Dytiscidae as not long-lived.

Elmidae (riffle beetles): In the original Karr BIBI several genera and species of riffle beetles were classified as long-lived, while others were not. In his review of riffle beetle biology, Brown (1987) suggests that most of the riffle beetle genera found in northern and cooler, montane waters require more than one year to complete a generation. Following Brown's lead, we are newly classifying all the riffle beetle taxa found in Puget Sound Lowland streams as long-lived. *Lara*, whose larvae are common in Pacific Northwest streams is particularly long-lived, requiring 6+ years to complete a life cycle (Steedman and Anderson 1985).

Haliplidae (crawling water beetles): *Brychius* was classified as long-lived in the original BIBI. Huryn et al. (2008) and Poff et al. (2006) list the Haliplidae as uni- or bivoltine. We newly designate *Brychius* here as not long-lived.

Hydrophilidae (water scavenger beetles): The hydrophilids were classed as long-lived in the original BIBI. Evidence suggests that they are not (Huryn et al. 2008), and we newly classify them here as not long-lived.

Chironomidae (midges): Midges are generally short-lived in temperate zone streams (Huryn et al. 2008). However, at high latitudes and elevations some species require multiple years to complete their life cycle (Butler 1982). Extensive studies would be required to determine the life cycle duration of midge taxa that are present at each site. Since this is unrealistic, the average condition for the family is applied to all taxa. All Chironomidae are considered to be not long-lived in either the original Karr BIBI or this update.

Empididae (dance flies): Huryn et al. (2008), Poff et al. (2006) and the original Karr BIBI designation for all genera in this family is not long-lived. We retain the not long-lived designation for this update with the exception of *Oreogeton*, a cold water empidid

fly that experience has shown is probably long-lived in Pacific Northwest streams (Wisseman, unpublished).

Glutops (Diptera: Pelecorhynchidae): This is another cold water fly genus that experience has shown that most individuals may require more than one year to complete a life cycle in Pacific Northwest streams (Wisseman, unpublished). Multiple, distinct cohorts of larvae are typically found at sites where they occur.

Tipulidae (crane flies): Few studies on the life cycles of freshwater crane flies have been published. Both Huryn et al. (2008) and Poff et al. (2006) in their reviews consider them to not be long-lived. The designation in the original Karr BIB was not long-lived for all tipulid taxa. We newly designate for the BIBI update *Pilaria* and *Tipula* as long-lived, based on their large size, affinity for cool water, and the presence of multiple cohorts of larvae found at many Pacific Northwest sites (Wisseman, unpublished). Other cold water genera (e.g. *Hesperoconopa* and *Rhabdomastix*) may be long-lived in many streams, but there is not currently enough circumstantial evidence to class them as such.

Sialis (Megaloptera: Sialidae): *Sialis* was classified as not long-lived in the original Karr BIBI. Azam and Anderson (1969) found that the common Pacific Northwest stream species has a two-year life cycle, and we classify *Sialis* as long-lived in this BIBI update.

Chloroperlidae (Plecoptera): The original Karr BIBI classed all the chloroperlids as not long-lived. In our update we classify the following genera as long-lived: *Kathroperla* (Wisseman, unpublished), *Paraperla* (Stewart and Stark 2002), and *Sweltsa* (Huryn et al. 2008, Poff et al. 2006, Stewart & Stark 2002).

Leuctridae (Plecoptera): The original Karr BIBI classed all the leuctrids as not long-lived. In our update we classify *Moselia infuscata*, a cold-water species common in higher elevation Pacific Northwest streams, as long-lived (Wisseman, unpublished).

Nemouridae (Plecoptera): The original Karr BIBI classed all the nemourids as not long-lived. In our update we classify the following cold water genera, species groups and species as long-lived: *Visoka cataractae* (Stewart and Stark 2002, Wisseman unpublished), *Zapada columbiana* (Huryn et al. 2008, Poff et al. 2006, Stewart & Stark 2002, Wisseman unpublished), *Zapada frigida* (Wisseman unpublished), and *Zapada oregonensis* group (Stewart & Stark 2002, Wisseman unpublished).

Peltoperlidae (Plecoptera): The original Karr BIBI classed all the peltoperlids as not long-lived. In this update we classify all genera and species found in the Pacific Northwest as long-lived (Stewart and Stark 2002, Wisseman unpublished).

Perlodidae (Plecoptera): The original Karr BIBI classed all the perlodids as not long-lived. In this update we classify *Megarcys* as long-lived (Stewart and Stark 2002, Wisseman unpublished). When more life cycle information becomes available on other

Pacific Northwest perlodids found in cold-water habitats more genera may be found to be long-lived.

***Brachycentrus* (Trichoptera: Brachycentridae):** The original Karr BIBI classified the *Brachycentrus* species found in the Pacific Northwest as long-lived. Though some populations may be semivoltine, the detailed life history studies conducted to date indicate they are univoltine over much of their range (Hury et al. 2008, Poff et al. 2006, Wisseman unpublished) and are classified in this update as not long-lived. This classification needs to be re-evaluated when more information becomes available,

***Rhyacophila* (Trichoptera: Rhyacophilidae):** The original Karr BIBI classified all species groups and species of *Rhyacophila* as not long-lived. The presence of multiple cohorts of larvae and multiple life stages at many western montane stream sites strongly suggests that most *Rhyacophila brunnea/vemna* group and *Rhyacophila vofixa* group individuals require more than one year to complete a life cycle over most of their range, and are thus reclassified as long-lived in this Karr BIBI update. Some other *Rhyacophila* species and groups not included in the Puget Sound Lowland BIBI update are undoubtedly long-lived.

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