Temperature Assessment Methodology for Use III(-P) Streams in Maryland

Last Revised on October 8, 2013
Approved by EPA with the 2014 Integrated Report

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Background

Code of Maryland Regulations (COMAR) Section 26.08.02.08 assigns use classes and the corresponding designated uses for water bodies throughout Maryland. Designated uses define the water quality goals for a water body. At a minimum, the Maryland Department of the Environment (MDE) must provide water quality for the protection and propagation of fish, shellfish, and wildlife, and provide for recreation in and on the water, where attainable (Clean Water Act (CWA) Section 101(a)(2)). Where numeric thresholds are available, MDE adopts these as water quality criteria to protect designated uses. Such criteria must be scientifically defensible and relate, directly or indirectly, to attainment of the designated use.

Studies have shown that temperature is a key parameter for protecting aquatic life and Maryland has adopted numeric temperature criteria. Temperature is a physical property of water that affects most biological and chemical processes that occur in water (Bogan et al., 2003). Water temperature is an important measure of water quality and influences the overall health of aquatic ecosystems (Kelleher et al., 2011; Caissie, 2006; Coutant, 1999). In many cases, the geographic distribution of aquatic species (e.g., fish and benthic macroinvertebrates) is determined by the thermal regime of streams in the region. Anthropogenic activities can alter the temperature regime of streams and rivers causing changes (sometimes permanent) in the biological community (Allan 1995). For example, if the thermal tolerance of a fish species is exceeded in a stream reach, it can result in direct fish mortality (Easton and Scheller, 1996; Caissie et al., 2001). Since temperature can affect the attainment of designated uses, it is necessary to assess and protect stream temperature as an essential component of the total aquatic environment to achieve and maintain designated uses.

Code of Maryland Regulations groups waters of the State into four main use classes according to the unique water body types and the specific designated uses that apply. The four main use classes are listed below.[1]

- I(-P) - Water Contact Recreation, and Protection of Nontidal Warmwater Aquatic Life,
- II(-P) - Support of Estuarine and Marine Aquatic Life and Shellfish Harvesting,
- III(-P) – Nontidal Cold Water, and
- IV(-P) - Recreational Trout Waters

Each of these use classes has a numeric water temperature criterion. However, this temperature assessment methodology will focus only on assessing Use Class III(-P) Nontidal Cold Waters and the associated temperature criterion. A temperature assessment methodology for Use Classes I(-P), II(-P), and IV(-P) waters may be developed in the future.

Certain waters of the State possess water quality suitable to support cold water community assemblages. To protect the conditions necessary for cold water community survival and persistence, Maryland's regulations (COMAR 26.08.02.02B(5)) establish Use Class III: Nontidal Cold Waters. Use Class III(-P) is defined in COMAR Section 26.08.02.02 as follows:

[1] Each of these use classes can potentially have a "-P" suffix if the public water supply designated use applies to the water body.

“Use III: Nontidal Cold Water. This use designation includes all uses identified for Use Class I and waters which have the potential for or are:
(a) Suitable for the growth and propagation of trout populations and other coldwater obligate species including, but not limited to the stoneflies tallaperla and sweltsa.
(b) Capable of supporting self-sustaining trout populations and their associated food organisms.”

The temperature criteria associated with Use Class III(-P) (see COMAR 26.08.02.03-3 D. (3)) are:

“(a) The maximum temperature outside the mixing zone determined in accordance with Regulation .05 of this chapter or COMAR 26.08.03.03—.05 may not exceed 68°F (20°C) or the ambient temperature of the surface waters, whichever is greater.
(b) Ambient temperature—Same as Use Class I.
(c) A thermal barrier that adversely affects salmonid fish may not be established.
(d) It is the policy of the State that riparian forest buffer adjacent to Use Class III waters shall be retained whenever possible to maintain the temperatures essential to meeting this criterion.”

Up until the 2014 Integrated Report cycle, Maryland did not have an established methodology for assessing water temperature. Before that time, stream temperature data was rarely assessed as assessments were focused on other parameters with more robust assessment methodologies. Prior to 2014, the State recognized that monitoring and assessing temperature was a critical component in evaluating and protecting Maryland’s cold water streams. Eventually, with the advent of the Maryland Biological Stream Survey’s (MBSS) temperature monitoring program, more data was gathered and consistent protocols were developed. This greatly enhanced the reliability of temperature data and helped to provide the basis for many of the protocols and analysis methods discussed herein. Created in collaboration with Maryland DNR, this document describes the temperature assessment methodology to be used for evaluating Use Class III(-P) non-tidal cold water streams.

Rationale for Temperature Analysis Thresholds

Recent analysis by the University of Maryland Center for Environmental Science (UMCES) and DNR confirm the appropriateness of the current Use Class III(-P) temperature criterion (68°F/20°C) in protecting healthy populations of Maryland’s cold water obligates. However, these studies also noted that even in streams holding healthy populations of brook trout (*Salvelinus fontinalis*), a cold water obligate, that water temperatures do occasionally exceed 68°F/20°C. The following paragraphs describe the results from those studies.

Hilderbrand (2009) analyzed stream temperature data, from 236 Maryland Biological Stream Survey (MBSS) sampling records from 2001 to 2008 and recorded during the critical summer period (June 1 through August 31). Hilderbrand’s study found that brook trout-bearing streams exceeded 68°F/20°C approximately 10.7% of the time. In addition, the average daily mean for brook trout-bearing streams was 16.8°C.

Table 1: Temperature Statistics for Streams with brook trout (Hilderbrand, 2009).

Temperature Statistic	Mean
Percent of Time Temperature > 20C	10.7%
Average Daily Mean (degrees C)	16.8°C

One limitation of this study was that it included all streams containing brook trout, including those streams that had only one individual. As a result, these statistics were calculated on a population of brook trout-bearing streams that likely included streams with a degraded (warm) thermal regime. To further clarify, some of these streams may have had a remnant or transient brook trout at the time of sampling, but for all intents and purposes, have an impaired thermal regime.

In order to overcome this limitation, DNR developed a more appropriate reference condition to effectively describe the thermal regime for healthy/persistent cold water streams. To be considered a non-degraded cold water site (i.e., reference condition), DNR chose locations sampled in July and August (generally the hottest months of the year) that had 25 or more brook trout[2] and which demonstrated multiple year classes. In all, thirty-eight sites qualified as reference sites. From this vetted dataset, DNR found that stream temperature still exceeded 68°F/20°C approximately 10% of the time (Table 2).

Table 2: Temperature Statistics for Non-impaired Cold Water Streams.

Temperature Statistic (n = 84,950 temperature measurements)	Empirically Derived Value
Percent time >20°C	10.9%
Mean Temperature (°C)	17.3
90th Percentile Temperature (°C)	20.1

Since both the UMCES and DNR studies' arrived at nearly an identical result, the Department decided to use the 90th percentile of temperature measurements to help determine[3] whether a Use Class III(-P) stream is meeting temperature criteria. Therefore, the 90th percentile temperature of a Use Class III(-P) stream must be equal to or less than 68°F/20°C, outside of any mixing zone established by the Department, to be considered not impaired. In so doing, this assessment rule is consistent with EPA's 10% rule as described in EPA guidance for the development of state's 305(b) reports (EPA 1997 and Regas 2005).

[2] Self-sustaining brook trout populations were effective indicators of healthy cold water conditions as their thermal regime matches very closely with *Tallaperla* and *Sweltsa*, two other cold water obligate taxa.
[3] This assessment methodology includes another step that incorporates an assessment of coldwater obligate populations to help confirm the temperature assessment results. This is explained later in the section titled "Temperature Assessment Process".

The Department will also utilize a secondary assessment threshold, that being an upper limit of 23.8°C, to help identify potential impairments. The purpose of this secondary threshold is to help identify those Use Class III(-P) streams that are impacted by short duration, high temperature events. In effect, this secondary threshold ensures that monitored Use Class III(-P) streams will not experience extreme increases in temperature beyond the thermal limit of cold water obligates without being identified as impaired. This value is based on literature by Embody (1921), Kendall (1924), Bean (1909), McAfee (1966), and MacCrimmon and Campbell (1969).

Temperature Assessment Process

Under Section 303(d)(1) of the federal Clean Water Act (CWA), MDE is required to develop a list of those waters that do not meet applicable water quality standards and are therefore considered "impaired" (placed in Category 5 of the Integrated Report). To achieve this, MDE considers all existing and readily available water quality data and information, and develops methods to interpret these data for each impairing substance. An impairment is identified when water quality monitoring data suggest that a water body does not meet or is not expected to meet water quality standards or applicable criteria. When a water body is assessed as impaired, the cause (pollutant or pollution) and priority of the impairment is identified.

EPA provides guidance on making 'use support determinations' for the State Water Quality Assessments 305(b) Report (EPA 1997) (referred herein as the Integrated Report). Maryland's 303(d) list and 305(b) report are combined as the Integrated Report (IR) which describes waters using five unique categories, including: Category 1 – waters attaining all standards; Category 2 – waters attaining some standards; Category 3 – waters with insufficient information to determine if water quality standards are attained; Category 4 – impaired or threatened waters that do not need or have an already completed TMDL; and, Category 5 – impaired waters for which a TMDL is required.

This assessment methodology provides the decision framework, including data collection requirements and analysis techniques, used to determine if a Use III(-P) stream or river is meeting the required temperature criteria or otherwise supporting the cold water aquatic life use. The Maryland Department of the Environment considers all current and readily available stream and river temperature data to determine if a water body should be assessed as impaired for temperature on the Integrated Report. MDE evaluates the monitoring plans, quality assurance and quality control programs of any data provided to determine what data can be included in assessments. The rules below describe how water temperature data assessed for Use Class III(-P) will be used in Integrated Reporting. As a general rule, there are three potential outcomes of the assessment of a water body, these include: Category 2 – waters attaining some standards; Category 3 – waters with insufficient information to determine if water quality standards are attained; Category 5 – impaired waters for which a TMDL is required. Categories 1 and 4 may be assigned, but are contingent on other Department actions not covered within this assessment methodology (e.g. assessment of other criteria, development of a TMDL).

Assessment Scale

The data collected by a single water temperature logger will generally be considered representative of a single stream segment, from the location of the logger upstream to the next confluence, according to the 1:100,000 scale National Hydrography Dataset (NHD). In this case, the upstream confluence is defined as either the next upstream confluence with a perennial stream or, if no upstream confluence exists, the headwaters of the stream itself. This geographic scale will therefore be the default assessment scale for the Integrated Report of Surface Water Quality (IR). However, this methodology recognizes that unforeseen environmental settings may complicate the assessment scenario and thereby require adaptability of the assessment scale. For that reason, State biologists reserve the right to use best professional judgment when specifying the final scale of assessment. It is worth noting, that regardless of using a stream segment as the defaulting listing scale, upstream waters must protect downstream uses, and all upstream sources of thermal pollution will be considered during the assessment process.

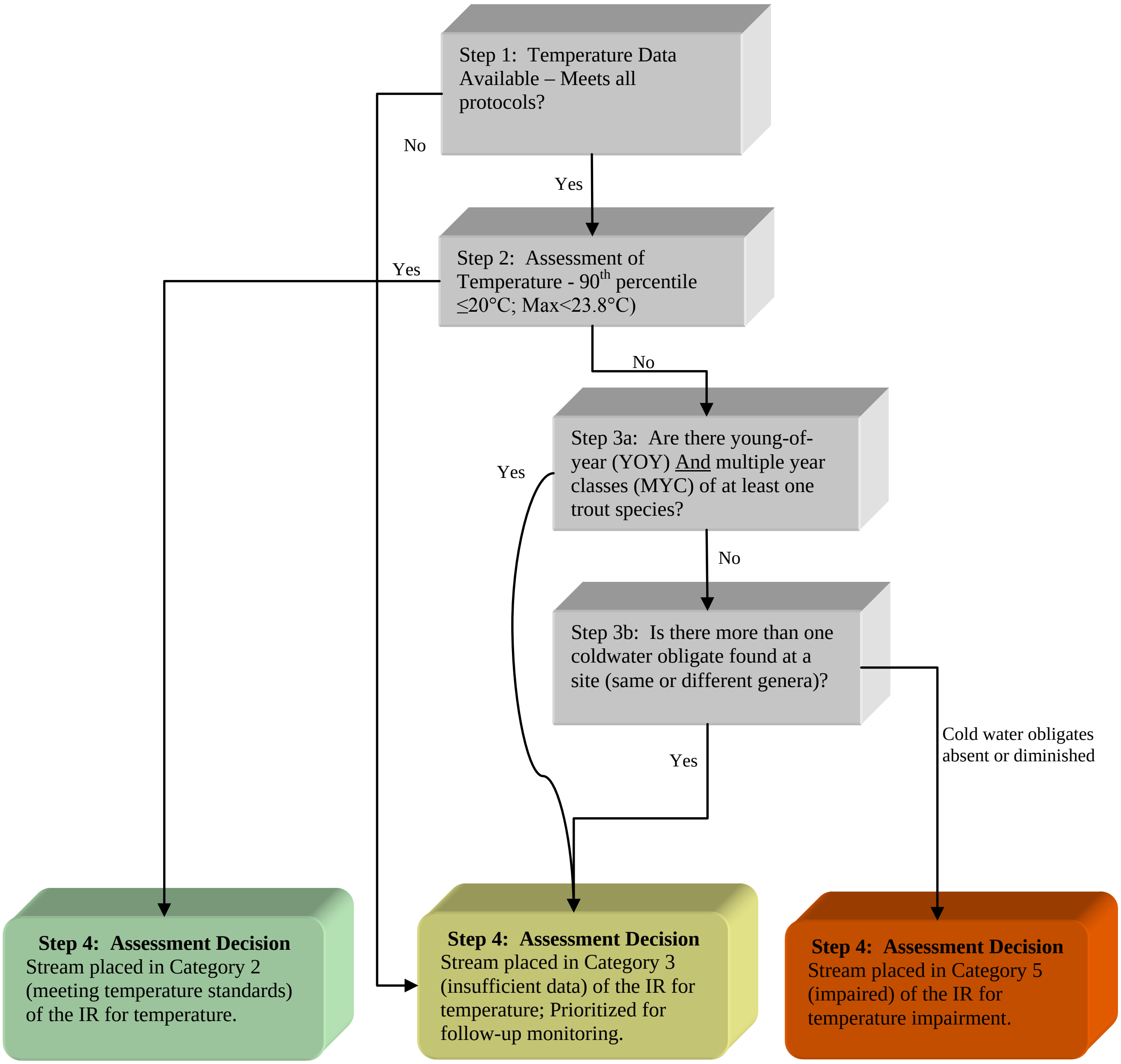

Figure 1: Decision diagram for Use III(-P) Non-tidal Cold Water attainment decisions.

<u>Decision Diagram Step 1: Temperature Data</u>

All data used for temperature impairment determinations must meet Maryland's stream temperature measurement protocols as detailed in Maryland's Temperature Measurement Protocols for Wadeable Streams. This document describes the procedures for measuring water temperatures in 1st through 4th order lotic systems (as defined by Strahler 1952 and 1964) that are well mixed and have nearly constant temperatures from surface to bottom (Allan 1995). This document provides information on temperature equipment, the time period and frequency for measurements, logger deployment and retrieval, quality assurance/quality control procedures, and data management. For Use Class III(-P) waters, the critical period for temperature measurement is defined as June 1 through August 31. In all cases, data should be collected with the use of continuous temperature loggers deployed in streams/rivers to record water temperature at 30 minute intervals or less. Data collected outside the critical period can be used for assessment purposes, however, temperature criteria violations are unlikely to occur at these times of year. Adequate documentation is necessary to ensure that data are of known quality. Documentation should include a detailed monitoring plan and an explicit quality assurance/quality control document whenever water temperature data are submitted to MDE.

Decision Diagram Step 2: Assessment of Temperature Regime

Use III(-P)

The Department will review all valid temperature data taken outside of any permitted thermal mixing zones and recorded between the period from June 1 to August 31. (Measurements should be taken at a minimum frequency of every 30 minutes.) If the 90th percentile of these values is equal to or less than 20°C and the maximum temperature recorded during that time period is less than 23.8°C, that stream reach will be placed in Category 2 (not impaired) of the Integrated Report. If either of these statistics is exceeded for a particular stream, that stream will be further evaluated in step 3.

It is important to note that deviations (up to 10%) above 20°C apply only to the summer months. Temperature measurements recorded between September 1 and May 31 of any year are not permitted to exceed 20°C.[4] However, to be considered valid, any data collected between September 1 and May 31 must also be collected according to the aforementioned protocols which include taking measurements in 30 minute or shorter intervals. Although data providers can conduct use support determinations, MDE reserves the right to analyze the raw data provided by individuals or groups to determine if the numeric temperature criteria are met for Use III(-P) waters.

Decision Diagram Step 3: Assessment of Cold Water Obligates

Step 3 is initiated when the temperature data for a Use Class III(-P) stream exceeds either the 90th percentile and/or the thermal maximum threshold. In either case, State assessors will assemble all data, historical and current, that describe the presence of cold water obligate species. Currently, Maryland recognizes three fish species and two benthic macroinvertebrate taxa as cold water obligates (species that generally require water colder than 68°F/20°C). Those species are listed below:

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[4] In rare cases where a few exceedances occur in early September due to weather-related events, State Biologists may determine that an impairment does not exist if summer data meets the listing threshold.

Fish

- Brook trout, Latin Name: *Salvelinus fontinalis*
- Brown trout, Latin Name: *Salmo trutta*
- Rainbow trout, Latin Name: *Oncorhynchus mykiss*

Benthic Macroinvertebrates (Both Stoneflies – Order: Plecoptera)

- Latin Name: *Tallaperla*
- Latin Name: *Sweltsa*

Step 3a: Assessment of Coldwater Fish

When fish data are available for the site, State assessors will use this data to determine if two conditions are met:

1. Do young-of-year (YOY) trout inhabit the stream as evidenced by trout less than 100 millimeters in size? **And**
2. Are there multiple year-classes of that same trout species?

If both of these conditions are met, it may suggest that the temperature data and analysis for this site needs further refinement in terms of temporal or spatial sampling resolution. In such cases, MDE will place these waters in Category 3 (insufficient information) and prioritize them for follow-up monitoring. If fish data does not exist or does not meet the aforementioned conditions, the water segment will be considered in Step 3b for the presence of coldwater benthic macroinvertebrates.

To conduct this analysis, State assessors typically use the Maryland Biological Stream Survey (MBSS) data[5]. By setting up a histogram of the lengths for each species of trout caught in the stream, the assessor can determine if YOY and multiple year classes are present. Young-of-year trout are generally less than 100 millimeters in length during the time of MBSS sampling (June 1 – August 31) so individuals smaller than this are counted as YOY (Charles Gougeon, MD DNR, personal communication). To assess for multiple year classes, the assessor will look for breakpoints in the histogram that suggest divisions between year-classes of trout. Since most trout of a single species are hatched at the same time of year, the size difference between consecutive year classes usually has a discrete boundary.

Figure 2 below shows an example histogram displaying the number of brook trout of varying lengths caught at MBSS sampling station SAVA-117-R-2002. In this case, bin sizes for the histogram were set to 5 millimeters.

[5] The MBSS data provides the lengths (in millimeters) and abundance of all gamefish caught during electrofishing. (In Maryland, all trout species are considered gamefish.)

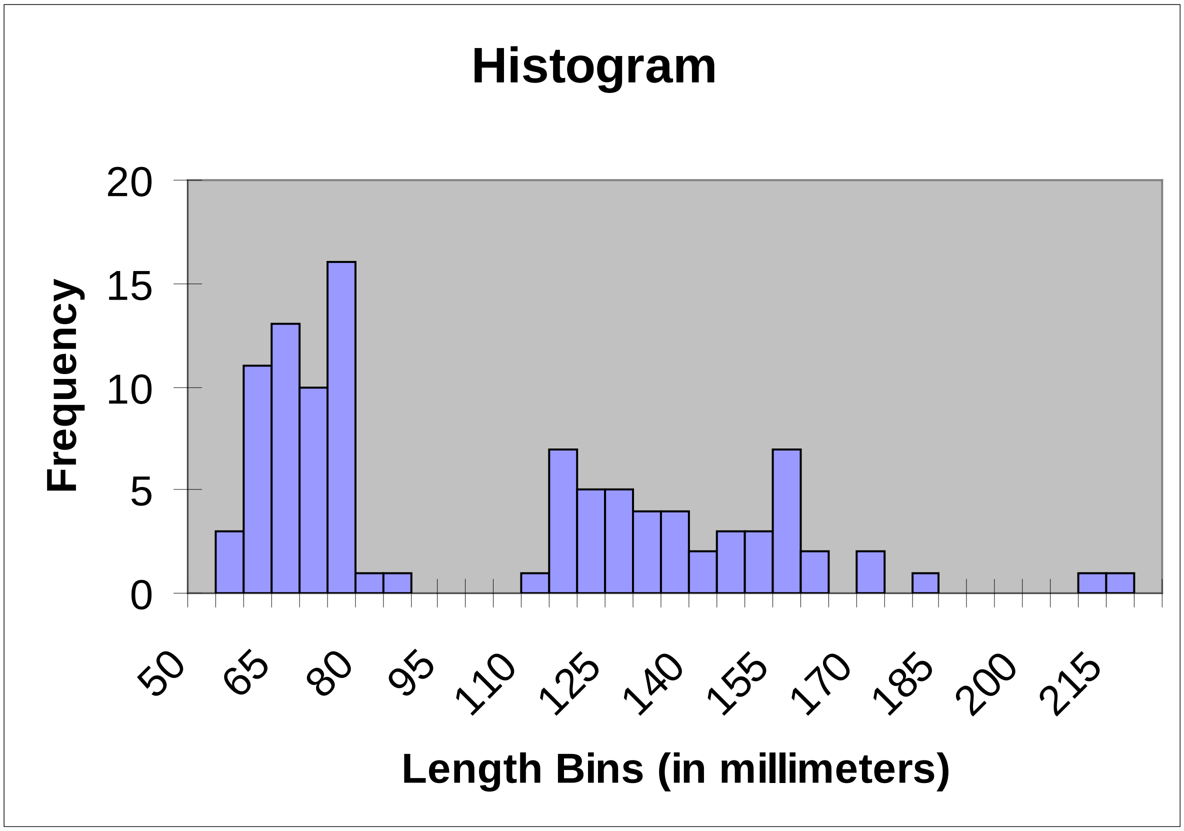

Figure 2: Histogram showing the distribution of brook trout sizes (SAVA-117-R-2002).

This particular example reveals at least three distinct year-classes as indicated by the trimodal distribution of trout lengths. In addition, the histogram shows the presence of young-of-year brook trout, illustrated by those individuals that are less than 100 millimeters in length. Such a scenario provides some evidence that stream temperatures were sufficiently cold enough to support the Use III coldwater use. If this particular stream (SAVA-117-R-2002) exceeded the thermal thresholds, MDE would place this water segment in Category 3 (insufficient information) of the Integrated Report due to conflicting information from the temperature and biological data.

For waters that have been sampled more than once, such as MBSS sentinel sites, State assessors will evaluate historical cold water fish data. For these waters, assessors will compare abundance and year-class structure over time in addition to looking at the most recent year. In this case, decreasing abundances or year classes may indicate an impacted thermal regime and could be used to support a Category 5 impairment listing. Alternatively, increasing abundances and year classes may be used to support a Category 3 (insufficient information). Many scenarios can potentially occur given the variability in stream temperature and biological data so State assessors must retain flexibility in making categorical determinations for such sites.

Step 3b: Assessment of Coldwater Benthic Macroinvertebrates

Cold water benthic macroinvertebrate information can also be useful for assessing current stream temperature conditions. Since both of the taxa that Maryland uses for cold water determinations

(*Tallaperla* and *Sweltsa*) have long aquatic nymph stages, and are relatively immobile (as compared to fish) during this life phase, they serve as appropriate indicators of cold water use support.

For water segments that have exceeded the thermal thresholds and which do not meet the conditions under Step 3a, cold water benthic macroinvertebrate data will be considered (Step 3b). In these cases, when multiple (more than one) Tallaperla or Sweltsa are found at a sampling site that water segment will be placed in Category 3 (insufficient information). Conversely, if benthic macroinvertebrate data fails to demonstrate the presence of either taxa, the water segment will be placed in Category 5 (impaired) of the Integrated Report.

In summary, for streams that exceed the thermal thresholds described in Step 2, data demonstrating the recent persistence of any one cold water obligate species will be used to support a Category 3 (insufficient information) assessment. The five taxa discussed in this step (Step 3) represent some of the most sensitive aquatic taxa in the state. Therefore, the demonstration of persistence by any one of these cold water obligates provides significant justification for requiring additional data prior to making an impairment listing. Likewise, when data on cold water obligates shows a declining trend or an absence of cold water obligates, the stream will be assessed as impaired and placed in Category 5. The Department acknowledges that scenarios are likely to arise in which data on cold water obligates may be incomplete, inconclusive, or unavailable. In any of these scenarios, the assessor will place such streams in Category 5 (impaired) if they exceed the thermal thresholds discussed in Step 2. This document cannot anticipate all such data scenarios. For this reason, State assessors may need to exercise best professional judgment to ensure that streams are accurately characterized (i.e., placed in the appropriate listing Category) for the Integrated Report.

Table 3: Generalized matrix describing hypothetical data scenarios and likely assessment outcomes.

		Step 3: Coldwater Obligate Assessment		
		Persistent Coldwater Obligate Population	**Incomplete, Inconclusive, or Unavailable Data**	**Coldwater Obligates Absent or Diminished**
Step 2: Temperature Assessment	**Temperature Thresholds Met**	Category 2 (not impaired for temperature)	Category 2 (not impaired for temperature)	Category 2 (not impaired for temperature)
	Thresholds Exceeded	Category 3 (insufficient information)	Category 5 (impaired for temperature)	Category 5 (impaired for temperature)

Decision Diagram Step 4: Integrated Reporting (IR) of Assessment Results

For the Integrated Report, temperature assessments will generally fall into Categories 2, 3 or 5. Temperature and cold water obligate data used to put waters in Category 2 (unimpaired) or 5 (impaired) must be of sufficient quality and collected according to proper protocols (Maryland's Temperature Measurement Protocols for Wadeable Streams). Data that do not meet these quality assurance protocols can be used to place a water body in Category 3 (insufficient information).

Use Class III(-P) streams with temperature data that meets both impairment thresholds (90^{th} percentile≤20°C and maximum≤23.8°C) will be placed in Category 2 as unimpaired by temperature (regardless of the presence/absence of cold water obligates). Streams with temperature data that exceeds one or more of the applicable thresholds (90^{th} percentile or thermal maxima) will be reviewed in greater detail in step 3. In cases where data for step 3 is nonexistent or inconclusive, a Category 5 assessment will be made. For streams where coldwater obligate information suggests use attainment, a Category 3 assessment will result. Then, as resources permit, the Department will prioritize these streams for additional temperature sampling.

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