Addendum to Water Quality Monitoring Technical Guide Book:

Chapter 14

Stream Shade and Canopy Cover Monitoring Methods

This document is designed as an additional chapter to the Water Quality Monitoring: Technical Guidebook (OWEB July 1999). Many of the broader monitoring concepts presented in the Water Quality Monitoring Technical Guidebook apply to shade and riparian cover monitoring. Please add this to your current version 2.0 as chapter 14.

Credits

This chapter was developed by a Stream Shade Monitoring Team formed in 2000 as a subcommittee to the Oregon Plan for Salmon and Watersheds Monitoring Team. The work group was comprised of representatives from Oregon Department of Environmental Quality (DEQ), Oregon Department of Forestry (ODF), Oregon Department of Fish and Wildlife (ODF&W), and Oregon State University Extension, Bioengineering, and Range Departments. Key contributors to these guidelines included: Liz Dent, Micheal Mulvey, Dennis Ades, Barry Thom, Jerry Clinton, Derek Godwin, Kathy Lowson, Tamzen Stringham, and Greg Pettit. The protocol relies heavily on protocols developed by the DEQ, ODF, EPA, ODF&W, and OSU. Valuable review comments on earlier drafts from Mack Barrington, Bob Beschta, Ken Bierly, Rick Hafele, Phil Kaufmann, Bruce McIntosh, Scott Peets, Steve Ralph, Paul Ringold, and John Runyon were greatly appreciated.

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Chapter 14

Stream Shade and Canopy Cover Monitoring Methods

Introduction

Riparian areas provide a number of important functions that benefit salmonids and salmonid habitat. For example, large conifer trees that fall into the stream from the riparian area provide critical fish habitat structure and complexity that benefit fish reproduction and refuge needs. Other riparian functions include, but are not limited to, bank stabilization, flood plain development, nutrient inputs for aquatic insects, and stream shade. This chapter *only addresses stream shade and cover measurement* and at this time *does not* address riparian composition and structure. The fact that stream shade is the only riparian component addressed is not meant to minimize the importance of the other riparian components. On the contrary, the composition and structure (e.g. species and size class distributions, understory components, distance from stream, etc.) of the riparian area can affect any or all of these functions and may be of equal or greater interest to the user. Various techniques for monitoring these other riparian components are being used by Oregon State University (Borman and Chamberlain), Oregon Department of Forestry (ODF 1996, 1999), Department of Environmental Quality (Mulvey et al 1992), Oregon Department of Fish and Wildlife(ODF&W 1998), EPA (Kaufman and Robison 1998, Bauer and Burton 1983), and US Forest Service (Platts et al 1987). Please contact these groups if more information is desired on this topic (See the mentors section at the end of this chapter).

Stream Shade Versus Canopy Cover

Shade is the amount of solar energy that is obscured or reflected by vegetation or topography above a stream. It is expressed in units of energy per unit area per unit time, or as a percent of total possible energy. Canopy cover is the percent of the sky covered by vegetation or topography. Shade producing features will cast a shadow on the water while canopy cover may not. Two trees of equal size and distance from the stream channel, one on the north bank and the other on the south bank of a stream with an east-west stream channel, would have exactly the same contribution to stream canopy cover while making very different contributions to stream shade. Unlike the tree on the south bank, the tree on the north bank would cast little, if any, shadow on the stream. Of the measurement devices described in this chapter, the densiometer and clinometer both measure canopy cover while solar pathfinder and hemispherical photography measure both shade and canopy cover. Stream aspect can be combined with clinometer measurements to calculate stream shade. Information is provided in this chapter to assist in making the choice on which device to use.

There are several reasons for monitoring stream shade or canopy cover, and monitoring designs will vary accordingly. The most common motive for monitoring shade or cover is in relation to stream temperature. There are many factors that affect stream temperature (incoming solar radiation, outgoing longwave radiation, evaporative and conductive heat transfers, channel morphology, heat capacity of water, volume of water) some of which are outside the control of management practices. Stream shade is one factor that both affects stream temperature and is also sensitive to management practices. Also, in the summer, it is direct solar radiation that plays the dominant role in warming streams. Therefore, providing shade to a stream is one of the most important mechanisms that mitigates potential negative effects of land management on stream temperature.

By monitoring shade in conjunction with stream temperature the land manager can begin to evaluate relationships between management practices and water quality.

Cover measures can be used as a surrogate or index of shade. Both cover and shade measurements are valuable for tracking changes in riparian characteristics which may occur as a result of management or restoration activities. The relationship between stream temperature and cover is variable, particularly if the canopy cover is neither exceptionally high nor low. Figures 14-1 and 14-2 compare shade to cover data collected at the same locations using different tools. Clearly shade increases as cover increases. However, the variability about the lines (r^2 = 0.62 and 0.72) indicate that the composition of the streamside vegetation ulitmately dictates the amount of shade that will be cast on the stream.

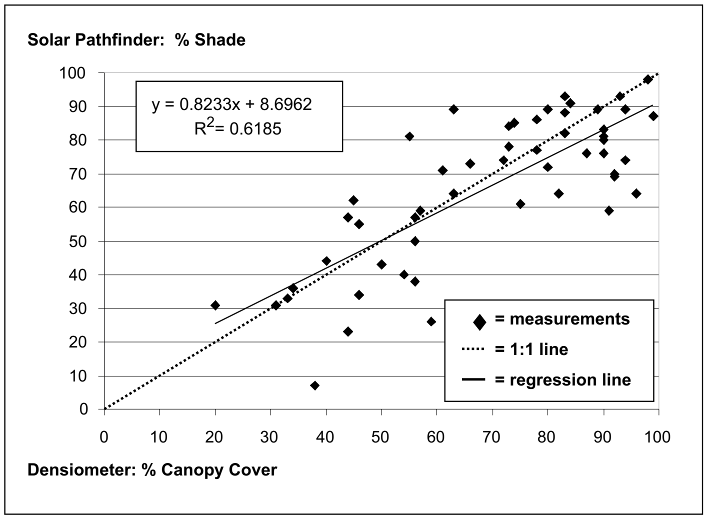


Figure 14-1. Shade (measured with a solar pathfinder) versus canopy cover (densiometer).

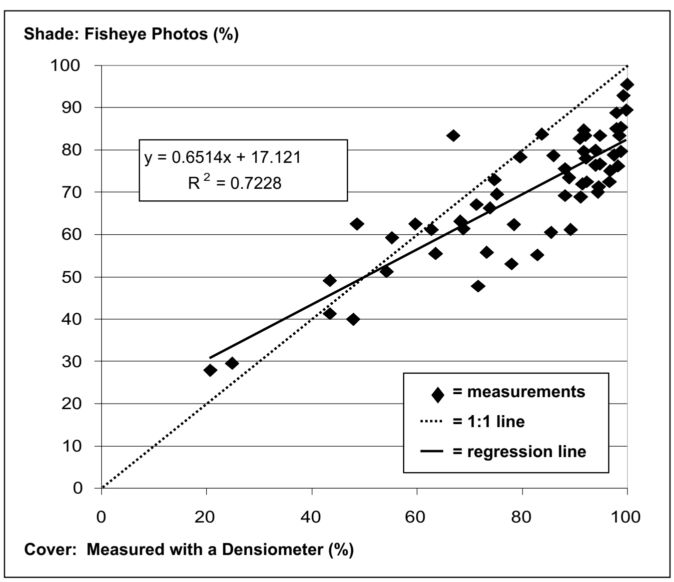


Figure 14-2. Shade (measured with a fisheye camera) versus cover (densiometer).

The data in figure 14.1 were collected from forested streams in the Nestucca River basin in north western Oregon, summer 1999. Each comparison is an average of three transects within a 200- to 500-foot long reach. (Provided by Larry Caton, Oregon DEQ.) The data for figure 14-2 were collected in Northeast Oregon and Northwest Oregon during the summer of 1999 and were contributed by the Oregon Department of Forestry (Liz Dent). Each comparison is a reach average. Reach length varied from 500 – 800 feet.

Chapters 2 and 3 of this guidebook provide background information on how to design a monitoring plan and select field sites. This chapter provides additional detail on study design as well as detailed field measurement procedures for measuring stream shade and cover. Six different tools for measuring stream shade are presented. The user of this chapter can decide which tool to use based on available resources and the particular monitoring question being asked.

Study Design

Riparian vegetation characteristics (stand density, height, species composition, proximity to stream) and channel characteristics (width and constraint) affect canopy cover and shade over the stream. The riparian vegetation in turn is influenced by disturbances such as wind, fire, flood and land management practices. Riparian vegetative trends are also dependent on local geomorphology and channel constraint. For example, terraces, meandering channels, abandoned channels, beaver complexes, floodplains, and wetland areas are common in unconstrained systems. These variable conditions favor some tree and shrub species over others and thus result in patchy vegetation types. Constrained reaches commonly have less geomorphic and vegetative variability than unconstrained reaches. The OWEB Watershed Assessment Manual (WPN 1999) describes classification methods that can be used to define vegetation type (riparian condition unit) and channel type (channel habitat type). Use of that classification system in the shade monitoring study design can be used to account for the variability in riparian and channel characteristics and disturbance regimes.

The study design presented in this chapter is closely aligned with the field protocols described in section 6 (physical habitat assessment) of the EPA Environmental Monitoring and Assessment Program (E-MAP) (Klemm and Lazorchak 1994). The E-MAP methodology was intended for evaluating physical habitat in wadeable streams during low flow. The design requires systematic intervals for measurements (i.e. every 100 feet) rather than habitat-based intervals (i.e every time the habitat type changes measurements are taken) and therefore results can be readily compared to other systematically collected data.

Chapter 2 (Monitoring Strategy and Plan) of this guidebook describes the basic components of a monitoring plan. The objectives or specific questions determine the appropriate scale, data analyses, and type of monitoring approach that will be used. The following discussion gives examples of shade-monitoring questions and how those questions influence the study design. The questions are organized under three scales: reach, watershed, and region. See Appendix B for a more detailed discussion of monitoring types (i.e. baseline, trend, implementation, and effectiveness).

Reach Scale Questions and Analyses

<u>Monitoring Changes in Shade that Result from Management or Restoration Activities</u>
The reach scale is commonly used to monitor effectiveness of specific management practices, water quality management plans, and restoration efforts. It is important to select a reach which is representative of the management or restoration activity. How to select a representative reach is discussed in greater detail below. Collection of pre-treatment data greatly enhances the ability to answer effectiveness questions. Measurements collected

upstream and downstream of the management practice can also be utilized to understand effectiveness of management practices and strategies. Reach scale monitoring efforts are point measurements that can be aggregated to larger scales depending on sample design, budget and time. Example questions include:

1. Have shade levels increase as a result of modifying riparian vegetation from grass and shrubs to trees?

2. How much have shade levels increased over the next 5, 10, 15, and 20 years?

The study design would consist of measuring shade levels before the treatment, then after the treatment at 5-year intervals. The data would be collected in one reach (Figure 14-3: sites B, C, or E).

Comparing Shade Under Different Management Strategies

The user may be interested in monitoring the effectiveness of different management activities along different stream reaches. Under this scenario the study reaches should have the same vegetation potential, valley and channel type. This assures the project is testing the effects of the management practices and not inherent differences that would have occurred with or without management. Example questions include:

1. How do the shade levels in an unmanaged or "reference" reach compare with treated agricultural reaches?
   The study design would establish sample reaches along reference and treated reaches. Average shade or cover along the reference reach E (Figure 14-3) are then compared with average shade from reaches B and C.

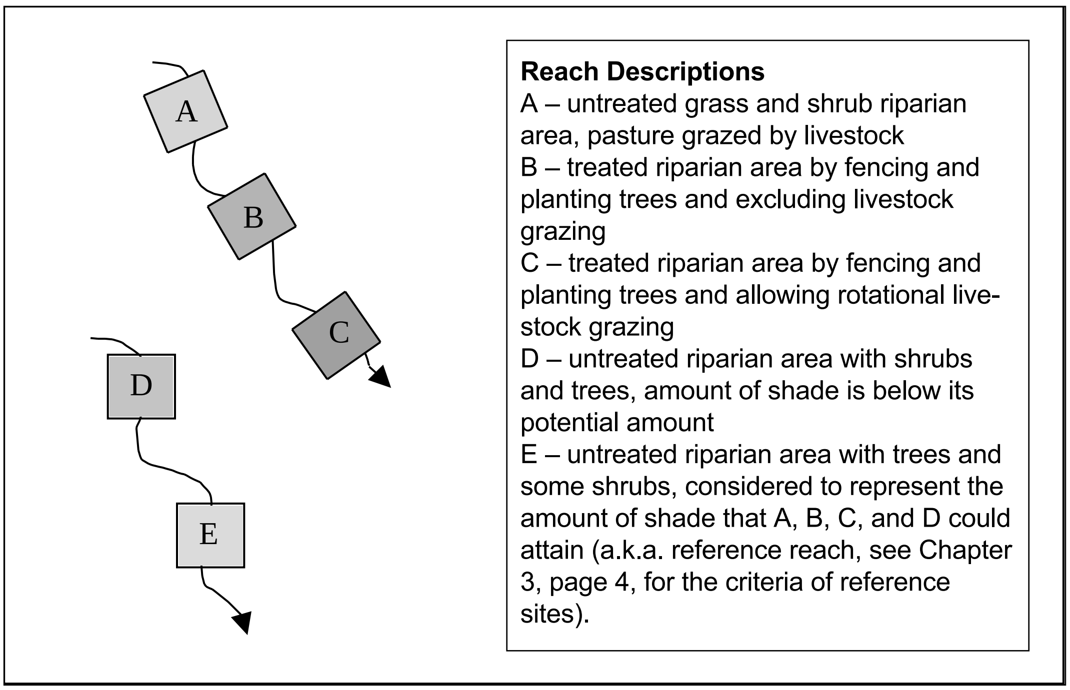


Figure 14-3. Schematic of theoretical monitoring reaches.

2. *How does the shade level of one treated agricultural site compare to the other?*

   The study design would establish sample reaches within two differently managed agricultural reaches. Effectiveness of treatments is evaluated by comparing shade or cover between reaches B and C (Figure 14-3).

Comparing Management Strategies on Streams with Different Channel, Valley, or Vegetation Types

Sometimes the channel, valley or vegetation type has a greater effect on shade levels than the management strategy. In this case, the same management strategy can be applied to different stream channel types to determine the influence of other environmental conditions. For example a channel with steep valley walls might have greater shade than a channel with a wide floodplain even if the management practices are the same. Likewise, similar treatment strategies on different vegetation types (i.e. fir versus pine, willow versus cottonwood) may result in different shade levels. In this case, the channel types must be the same, but the vegetation types are different. Example questions include:

1. *Will the riparian treatment make a greater difference for valley-bottom streams than it will for narrow-valley streams?*
2. *Do vegetation treatments in a white fir-dominated stand result in different shade levels than in a pine-dominated stand?*

   The study designs would establish sample reaches along streams with similar management activities but with different channel, valley or vegetation types. Average shade levels are then compared between reaches.

Watershed Scale Questions and Analyses

Multiple Reach Analyses for Watershed Trends

Monitoring efforts at the watershed scale can look at effectiveness of treatments within the context of the larger system (e.g. percent of stream miles shaded, downstream effects). It is also useful for understanding trends, condition, and disturbance regimes. The watershed scale is a particularly important scale for examining historic watershed processes and how the disturbance regime has shaped the current condition. Finally, the watershed scale is essential to examining cumulative effects of natural disturbances (flood, fire, etc.) and a variety of practices (urban growth, roads, vegetation changes, etc.).

Watershed level questions might seek to understand trends in shade levels throughout the basin, how those change over time, and how management affects those trends. Example questions include:

1. *What percentage of streams in the watershed have desired shade levels?*
2. *How do shade levels change over time?*
3. *Are there streams in the watershed with significant shade deficits relative to established reference conditions?*
4. *How do restoration and other management activities affect shade levels?*

   The study design would establish sample reaches distributed throughout different channel, valley, and vegetation types to account for the natural variability within the watershed. The samples have to be numerous enough to provide a reliable estimate of watershed condition. Average shade or cover can them be compared between multiple reaches. Results can also be reported in terms of what percent of the watershed is in a given shade condition for each of the channel, valley and vegetation types. For example, 20%

of the streams sampled are providing their maximum amount of shade possible, 60% are providing half of their potential, and 20% are providing 1/3 of their potential. Changes in shade over time can be tracked by repeating the measurements over time. Finally, the effectiveness of management activities can be evaluated by nesting pre-management and post-management sample reaches within the study design.

Regional Scale Analyses

Regional scale monitoring efforts are typically used to monitor trends in resource condition over large geographic areas (Pacific Northwest, State of Oregon) and long time periods (e.g. decades). This type of monitoring requires large sample sizes collected over long periods of time. While monitoring at the regional scale is beyond the scope of this document, an awareness of the approach is valuable since regional monitoring efforts might draw on local efforts.

To address questions posed at this scale, the site selection needs to be probability based. A spatially balanced probability design distributes sample sites across the landscape, so that each stream segment has an equal chance of being sampled within the area in question. As an example, The Oregon Department of Fish and Wildlife, Oregon Department of Environmental Quality and U.S. Environmental Protection Agency have randomly selected sites across the landscape to monitor stream health and fish populations. This is part of the statewide monitoring of the Oregon Plan for Salmon and Watersheds. The sample sites were selected using a Random Tessellation Stratified Design (Stevens, 1997). Sites were distributed such that inferences can be made for Gene Conservation Areas and the coast as a whole. However, because of the sampling design, data from these studies cannot be used to make inferences at smaller scales such as watersheds.

Selecting A "Representative" Reach

All sampling designs proposed in this chapter require multiple measures of shade or cover within a stream reach. A stream reach that represents the shade or cover conditions to be monitored is called a "representative" reach. This manual proposes three main characteristics to consider when choosing representative reaches. They include:

1. *Channel Type*: gradient, width, depth, constraint within the valley, substrate, sinuosity, etc.

2. *Vegetation Type and Size*: conifer, hardwood, mixed tree, shrub, grassland, size based on diameter and height,

3. *Treatment or Management Strategy*: examples include fencing and planting with livestock exclusion, fencing and planting with rotational grazing, increasing percentage of conifers and reducing hardwoods (and vise versa), reference (represents potential future condition), no activity, forestry BMP's

The OWEB Watershed Assessment Manual (WPN 1999) describes classification methods that can be used to define vegetation type and channel type. Some variability is likely, but no ***major*** changes in channel type, vegetation type, or management strategy should occur *within* the reach of stream that is going to be monitored. This helps to assure that the results are "representative" of the condition being monitored. The stream should be surveyed prior to monitoring to determine where the major changes occur. The survey results define the maximum extent of the reach. The sample reach can be placed anywhere within the "representative" reach and may be determined based on where the management strategy has been implemented.

Selecting A "Reference" Reach

Reference reaches can be established to document comparisons for "optimal" or ‘desired” conditions. Typically reference reaches represent the best available conditions and have minimal levels of anthropogenic disturbance. Reference reaches should be selected to represent variable disturbance regimes that can be tracked over time. Because of the great variability that exists in riparian characteristics throughout the state, it is important to recognize that each reference reach represents one possible condition that will change over time. Selecting a reference site is described in detail in *Reference site selection: A six step approach for selecting reference sites for biomonitoring and stream evaluation studies. Technical Report BIO99-03* (Mrazik 1999). It is also discussed in Chapter 3 of this guidebook.

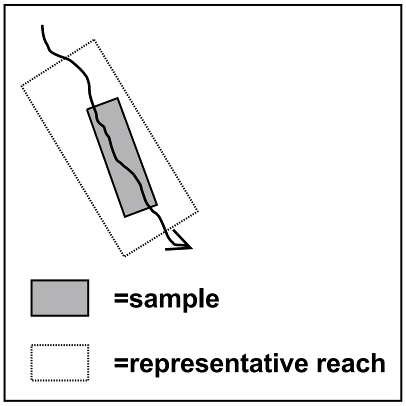
Sampling Designs

Sample designs vary somewhat depending on the scale of interest and the type of monitoring question that is being asked. This chapter proposes a design based on a reach with consistent vegetation and channel types. Once the representative reach has been identified, the next step is to delineate the “sample” reach within the representative reach to be measured and determine the number of samples that will be collected (Figure 14-4).

The length of the “sample” reach is calculated by multiplying the average wetted width by 40. Studies indicate that this length of stream is necessary to adequately describe stream habitat and biology (Kaufmann and Robison. 1998), although the number and configuration of measurements may be different depending on the needs of particular studies.

<u>Procedure for Establishing The Sample Reach</u>

1. Survey the reach of interest to determine where the major changes in vegetation, management, or channel morphology occur. Shifts in these characteristics define the upper and lower limits of the representative reach.
2. Estimate the average wetted channel width by taking a few measurements during step 1.
3. Multiply the average wetted width by 40. This is the length of your sample reach.
4. The sample reach can be randomly placed within the reference reach, or established at a location which satisfies the objectives of the study.
5. Divide the sample reach length by 10 to determine the distance between transects.
6. Transects are placed perpendicular to streamflow, numbered sequentially, and can be marked with labeled flagging (i.e. Deer Creek Station 1).
7. Beginning at one end of the sample reach, shade or cover measurements are taken at 11 evenly spaced transects. This sample scheme can be used for analyzing individual reaches, comparing one reach to another, and analyzing multiple reaches at a watershed scale.

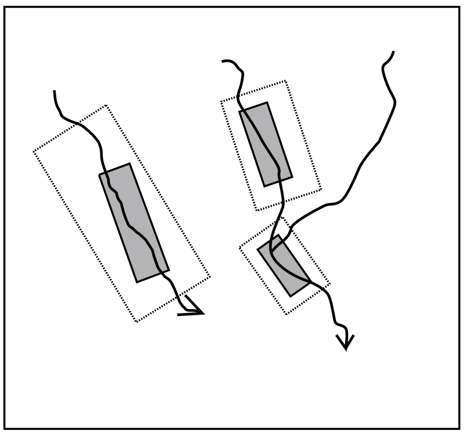


Scale
– Reach

Types of Monitoring
– Effectiveness of water quality management plans

Selecting a Reach
– Consistent channel, vegetation, and management

Sample Scheme
– Sample length= 40 x channel width
– 11 evenly spaces shade measures

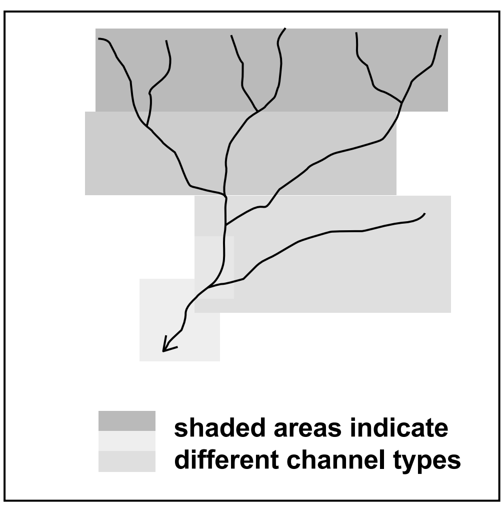


Scale
– Comparing multiple reaches

Types of Monitoring
– Effectiveness
– Comparisons under variable conditions

Selecting a Reach
– Different management strategies in streams with similar reach types

Sample Scheme
– Sample length= 40 x channel width
– 11 evenly spaces shade measures



Scale
– Watershed

Types of Monitoring
– Trend over time and space
– Baseline
– Statue

Selecting a Reach
– sample reaches within similar channel and vegetation types

Sample Scheme
– 30-50 sample reaches per channel, vegetation and management types

Figure 14-4. Study designs for different scales of interest and different types of monitoring.

Field Methods

This section describes how to measure shade and cover using six different tools or methods. The user will need to determine which tool best fits their needs. What follows is a comparison of the different methods and then a detailed description of how to apply each method. No matter which field method is decided upon, the physical setting of the stream needs to be described as well. A list and brief description of ancillary data collection is provided later in the chapter.

Method Comparison

All the tools presented in this manual basically do the same thing: measure the proportion of sky that is shaded by vegetation or topography. Which tool you choose depends on several factors including ease of use, cost, level of data precision desired, and the questions asked of the monitoring data. Table 14-1 is designed to help you make your choice. Each method is later described in detail in this chapter.

Densiometer

The procedure described in this section uses a densiometer to measure stream canopy cover. The device used in this procedure is a spherical convex densiometer Model A (Lemon 1957). The procedure is taken from the Environmental Monitoring and Assessment Program monitoring manual for streams (Kaufmann and Robison 1998), that is derived from Platts et al. (1987).

The densiometer is a small, convex, spherical mirror with an engraved grid that reflects the canopy over the stream. Canopy cover is measured by counting the grid intersections covered by vegetation. Measurements are taken by holding the densiometer level and 0.3 meters above the surface of the water. This standard height helps to minimize the potential to get different results from people of different heights and to include the contribution of low hanging vegetation to stream cover.

This method measures canopy cover at 11 evenly spaced transects over a length of stream 40 times the channel width with a 150-meter minimum reach length. Six canopy measurements are taken at each transect. Four measurements are taken facing in different directions from the center of the stream and one is taken at each stream bank.

It is important to consider the seasonal flow and riparian vegetation conditions when measuring cover using this method since stream widths and deciduous vegetation cover measurements will differ seasonally. Ideally, measurements would be taken during seasonal low flow periods each time to minimize the effects of varying wetted widths. Low flow conditions are usually a time of critical temperature stress to aquatic organisms and stream shade is important. Also, measurements should be taken during a time of year when deciduous plants have leaves. Usually canopy measurements will not vary during the low flow season unless the canopy is predominantly rapidly growing vegetation.

The densiometer reflects vegetation to the sides as well as overhead. Multiple measurements taken in different directions from the same point will overlap vegetation measurements on the sides. The method described here is a modification of the instructions that come with the densiometer that corrects for this bias by using only a portion of the mirror surface.

<u>Equipment</u>

1. Convex spherical densiometer (Model A)
2. Tape measure
3. Flagging
4. Forms for recording data

<u>Procedure</u>

1. Tape the densiometer mirror exactly as shown in Figure 14-5.

Table 14-1. Comparison of shade measurement methods.

NOTE: All costs are estimates based on 1999 and 2000 price lists. Refer to vendors list (page 44) for more specific sources.

Method	Description	Advantages	Disadvantages	Cost
Densiometer	Small spherical mirror with grid reflects sky. Grid intersections are counted to determine % canopy cover	Inexpensive, quick, easy, and indestructible. Small, light weight device. Procedure has been widely used.	Difficult to keep hand-held device level. Taking into consideration different vegetation qualities is difficult. Measures canopy cover, not shade directly.	$100
Clinometer	Measures angle from horizon to open sky. Gives percentage of 180-degree arc that is covered by vegetation or topography.	Inexpensive, quick, easy and fairly rugged. Small, light weight device. Procedure has been widely used.	Internal moisture can obscure reading and foul moving parts if dropped in stream. Taking into cons-ideration different vegetation qualities is difficult. Requires good vision in two eyes. Measures angles to open sky, not shade directly. Tends to lump a site into high or low with no gradation.	$100
Hemispherical photography	180 degree photograph of the sky is computer analyzed	Produces high-quality, permanent canopy cover records. Less prone to user error than other methods. Computer analysis enables more com-plex data mani-pulation, analysis, and storage. Directly measures shade.	Expensive, heavy, and delicate. Not simple and easy to use. Different lighting conditions can cause problems. Requires more data reduction than other methods. This is a fairly new technology that has had limited use.	$4000 to $8000
Solar Pathfinder	180 degree diagram of sky is hand drawn. Open area on diagram gives amount of solar energy reaching the stream.	Fairly easy, and quick to use (not as quick and easy as densio-meter). Inexpensive and light weight. Produces permanent canopy record. Mea-surements are not effected by lighting conditions. Directly measures shade.	Light weight plastic parts are not part-icularly rugged. Adjusting for different vegetation shade qualities is possible but not automatic. Prone to user error. Operating equipment in center of rapidly flowing stream can be challenging. Requires more data reduction than other methods.	$200
Photo Documentation	Photographs are repeatedly taken from established locations over time to document status and trends.	Easy and cheap. Produces permanent visual record of status and changes over time. Can be a very effective com-munication tool. Complements other monitoring data.	Does not measure shade or cover. Qualitative rather than quantitative. Quality varies with photo-graphy skills. Finding existing photo point landmarks can be difficult.	$450 fixed costs $3/photo film developm-ent

2. Following the procedures described in the study design section of this chapter (page 12) establish 11 evenly spaced transects along the sample reach (Figure 14- 6). Transects can be flagged ahead of time, if desired.

3. Stand on the transect at mid-channel facing upstream.

4. Hold the densiometer 0.3 meters above the water surface.

5. Hold the densiometer so that it is level using the level bubble indicator and the top of your head just touches the point of the "V" as in Figure 14-5.

6. Count the number of points covered by vegetation. Values will be between 0 for completely open and 17 for completely covered canopy.

7. Record the value on the canopy cover form under "Center-UP" (Figure 14-7).

8. Repeat steps 7 through 9 at the channel center facing towards the right bank, downstream and left bank. Record on the canopy cover form. (Left and right directions when facing downstream.)

9. Stand on the transect with the densiometer 0.3 m from the left bank. Repeat steps 7 through 9 and record on the canopy cover form.

10. Repeat for the right bank. At this point you should have six measurements for the transect: four from the center and one at each bank.

11. Repeat steps 7 through 14 for each transect and record on a separate line of the canopy cover form (Figure 14-7).

12. Canopy cover is usually represented as an average percent for either the center or margins separately or combined for a single canopy cover measurement for the stream reach.

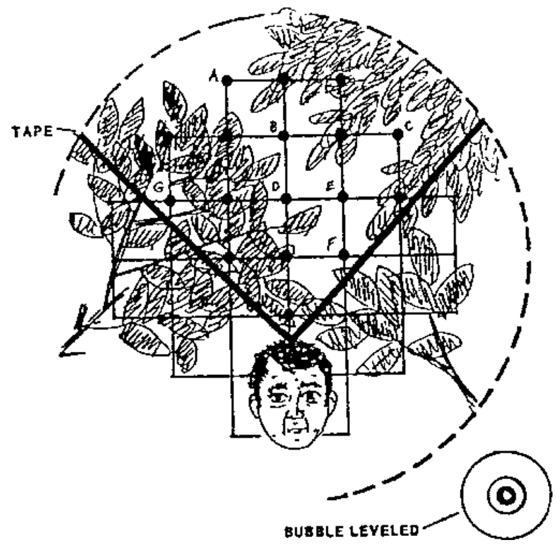


Figure 14-5. Schematic of modified convex spherical canopy densiometer. In this example, 10 of the 17 intersections show canopy cover, giving a densiometer reading of 10. Note proper positioning with the bubble leveled and the head reflected at the apex of the "V." (Mulvey et al. 1992).

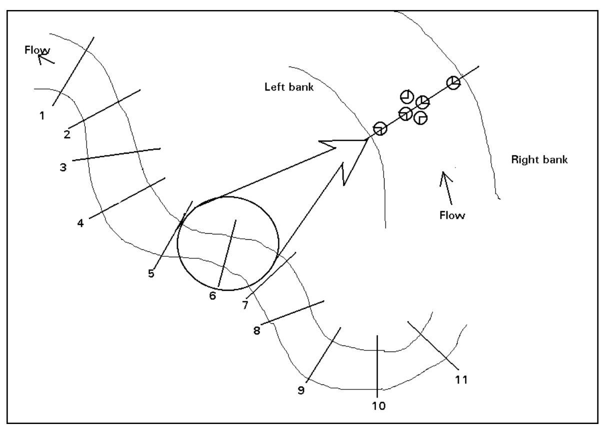


Figure 14-6. Study reach with 11 sample transects and example of 6 densiometer measurements taken at each transect.

Site Name:							Date:
Reach Length:				Transect Interval:			Initials:
Transect	Left Bank	Center-Up stream	Center - Right	Center - downstream	Center - Left	Right bank	Comments:
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							

Figure 14-7. Canopy Cover Form.

Complex Channels: Islands, Bars and Side Channels

Sections of streams with side channels, mid-channel bars or islands, or complex braided channels are treated differently. In part, it depends if a bar or an island forms the side channel. Bars are stream channel features below the bankfull flow height and may be dry during summer field surveys. Bars are wet during bankfull flows. Islands are channel features that are as high or higher than the bank full flow height. Islands are dry during bank full flows. Bars are considered part of the wetted channel and densiometer readings are taken over bars and boulders, just as if they were a part of the wetted channel.

Island-formed side channels are treated differently than those created by bars. Visually estimate the percent of flow in the smaller side channel. No canopy measurements are taken on the side channel if the side channel carries ≤ 15% of the total stream flow. If the side channel carries >16% of the steam flow, then six densiometer measurements are taken on the main channel and an additional six are taken on the side channel. Extra transects are designated as “X1”, “X2”, etc. on the canopy cover form (figure 14-5).

Data Analysis

The 66 densiometer measurements for the stream reach are typically analyzed separately for the stream center and margins. The 44 center channel measurements are averaged and reported as a percent of total possible stream cover. The center channel average is more independent of seasonal flow changes than the margin measurements and is a better overall indicator of stream cover. The average percent cover of the 22 stream margin measurements is a better indicator of riparian vegetation density and is independent of stream size.

Measurement Precision

Precision of densiometer measurements can be evaluated by repeating canopy closure measurements at the same site with a second field crew. Measurements can be repeated on or close to the same day as the first measurement, or can be repeated later in the study to evaluate seasonal changes within the survey period.

Figures 14-8 and 14-9 present 23 repeat densiometer measurements at 20 sites. These sites were a random sub-sample of a survey of approximately 200 first through third order streams in forested watersheds in western Oregon. Of the 23 repeat measurements 9 were conducted on the same day and 14 were conducted within the same July to September survey season. Seasonal repeat measurements were separated by at least one to two months. Repeat measurements were taken independently by different workers.

Figure 14-8 represents the reach average shade based on measurements taken along the stream margin and Figure 14-8 represents the reach average shade based on measurements taken along the center of the stream. The measurements were taken on 11 evenly spaced transects as described above. The diagonal solid 1:1 line represents repeat values that agree exactly.

The graphs indicate that measurement variability is partially a function of the amount of canopy closure. Replicates tend to be closer together when the stream is either very heavily or very sparsely canopied. Replicates tend to be further apart at more intermediate levels of canopy cover <80% and >20%.

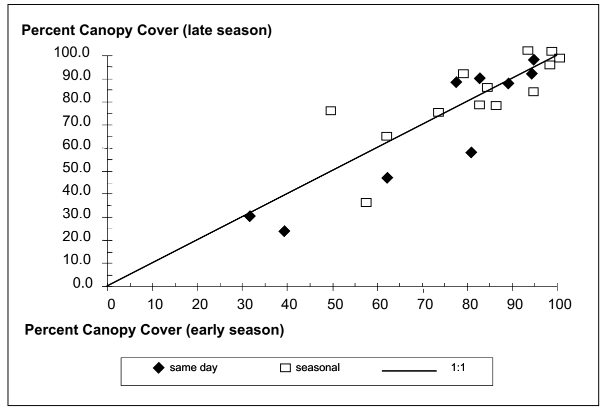


Figure 14-8. Comparison of repeat densiometer measurements taken in the center of the channel only. Points represent reach averages from western Oregon. (Provided by M.Mulvey, DEQ)

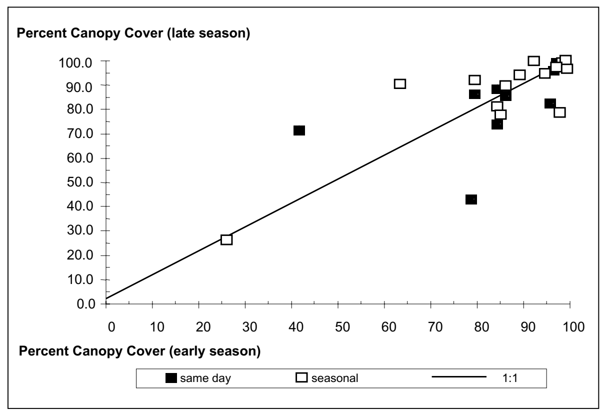


Figure 14-9. Comparison of repeat densiometer measurements taken along channel margins only. Late and early season designation on axis titles applies to seasonal duplicate measurements only and not same day duplicates. Points represent reach averages from western Oregon. (Provided by M. Mulvey, DEQ)

Table 14-2. Mean Difference in Repeat Canopy Closure Measurement

	Same Day	Different Days	Same/Different Days Combined
Channel Margins Only	11.5%	6.5%	8.5%
Channel Center Only	9.3%	7.6%	8.3%

Overall, replicate measurements differed by an average of less than 9% for forested western Oregon streams reported here (Table 14-2). Surprisingly, there appears to be little difference between precision of repeat measurements taken at different times in the season and repeat measurements taken on the same day.

Clinometer

This method describes the use of a clinometer to measure the angle between the stream channel and the vegetation or topography that is providing cover. This procedure is taken from the Oregon Department of Fish and Wildlife Methods for Stream Habitat Surveys (Moore et al. 1997).

The clinometer is a small handheld device used to measure the slope of a surface in degrees or percentage. Both scales are provided within a single view. Therefore, caution must be exercised to reference the desired scale. The clinometer method described in this section is used by ODF&W in conjunction with stream habitat surveys to determine percent cover angles. Cover angels measured in this way are also used in stream temperature models when the direction of measurement is known (i.e. azimuth). The clinometer can also be used to measure channel slope and define bankfull and flood prone areas of the stream during the habitat surveys.

The clinometer is used to measure the angle from the center of the stream to a point that provides cover to the stream on both the right and left banks. Stream cover is calculated as the percent of a 180-degree arc over the stream that is covered by either vegetation, and or blocked by topographic features such as hillslopes or high terraces.

Equipment

1. Clinometer (SUUNTO® self dampening clinometers are most commonly used)
2. Data sheets

Procedure

1. Following the procedures described in the study design section of this chapter (page 12) establish 11 evenly spaced transects along the sample reach.
2. Stand in the center of the channel and face to the left (relative to the downstream direction).

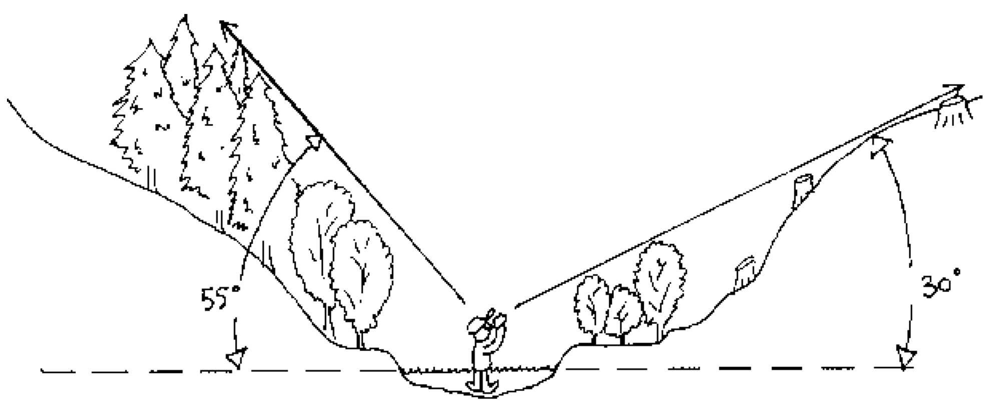


Figure 14-10. Use of the clinometer to estimate topographic (30°) and vegetative shade (55°) angles.

3. Identify the top of vegetation that is providing cover to the stream. This is the vegetative cover target. Identify the top of the topographic feature that is providing cover to the stream. This is the topographic cover target (Figure 14-10).

4. Hold the clinometer to your eye and with both eyes open look simultaneously through the lens and along side the housing. A horizontal sighting line will appear. Raise the sighting line to the vegetative cover target. Read and record the cover angle in degrees (the left side of the scale inside the clinometer) which is closest to the sighting line.

5. Repeat step 4 for topographic cover, and for the right, upstream and downstream directions.

6. Repeat steps 4 and 5 at each of the eleven transects.

Data Analysis

The data can either be used as a degree measurement or converted to percent cover. Conversion to percent shade is calculated as a percent of the 180-degree arc. Typically the data from the eleven transects are averaged for the reach.

Precision

Depending on site conditions, clinometer measurements can be highly variable within a sample site or reach. Stream cover measurement precision can be evaluated through repeat site measurements from a second field crew. Figure 14-11 presents repeat cover measurements for 52 randomly selected sample reaches monitored in 1998 and 1999 between June 15 and September 15. Each plotted point represents an average for the sample reach where 20 or more clinometer measurements were taken. Overall stream cover measurements differed by an average of 6.5%. Repeat measurements were not taken on the same day, but were conducted within the same June 15 - September 15 sampling period.

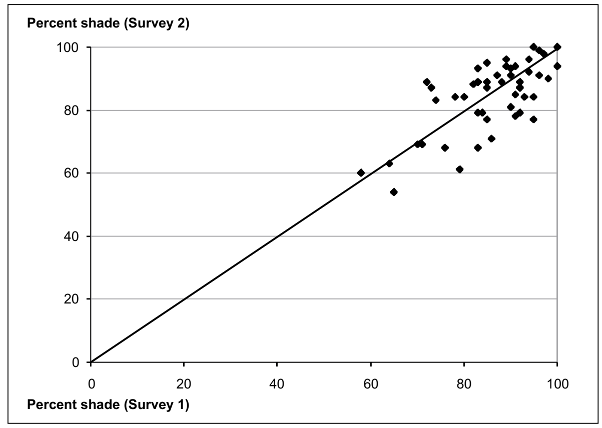


Figure 14-11. Comparison of repeat cover measurements using a clinometer. (Provided by Barrry Thomm, ODF&W)

Hemispherical Photography

Hemispherical canopy photography is a data collection technique for recording tree canopies and understory vegetation from beneath a canopy looking skyward. The method provides a means to record a precise and permanent record of tree canopy cover in relation to the sun’s path. The photographs are analyzed using a computer software package to determine percent shade. Fisheye photography has been used for many years. Although it hasn’t been until relatively recent advances in image digitization and integrated computer image analysis systems that it has become a viable monitoring and research tool.

Photographs are taken with a standard 35mm or digital format camera fitted with a hemispherical (fisheye) lens, and secured in a “self-leveling” camera mount that is supported by a tripod or monopod. Such hemispherical photographs provide an extreme wide-angle view, with up to 180° (horizon to horizon) and 360° (horizontal) field of view.

Figure 14-12. Examples of hemispherical (fish-eye) photographs taken at a site in the Coast Range (left) and at a site in Eastern Oregon (right) (ODF unpublished shade study).

These photographs (examples in Figure 14-12) can then be analyzed to determine the geometry of canopy openings, and, in turn, to estimate light levels beneath the canopy. Therefore, canopy photographs can be used to assess shade. These photos can be put into digital format and analyzed by a computer software program. The program overlays the sun's path on the photograph and calculates percent of the total solar radiation that is reaching the stream's surface. Canopy photography can be used to monitor management activities and as a ground-truth technique for studies of plant canopies using remote sensing from aircraft and satellites.

Although this method is more expensive because of initial equipment and software costs, it does afford a proportionately higher degree of accuracy and repeatability. This method allows the data collector to gather data at varying heights for studying relations between understory and tree canopy influence on light penetration.

Equipment

The basic array of equipment required for capturing tree canopy images suitable for analysis with software programs such as *HemiView©* is not a great deal different than is used for standard, high quality photography, with the exception of the last two items in the following list.

1. A single lens reflex camera such as a Nikon FM2 or suitable digital format camera
2. Handheld light meter
3. Mono-pod(s) or tripod (dictated by particular application)
4. Remote shutter release
5. Hard case—for protection of camera/ mount assembly
6. 100-400 asa film
7. Lens cleaner
8. 180° fisheye lens such as the Sigma 8mm, F4, fisheye
9. Self-leveling camera mount with affixed compass

Procedure

1. Create a checklist to use prior to going in the field to confirm that you have all of the necessary equipment and supplies, that it is all in good condition, and that it is assembled properly.

2. Put a new role of film in the camera for each new sample reach even if only half of the roll is used. (If an exposed roll is destroyed, no more than one set of photos is lost.). If a digital camera is employed, download and "save" often.

3. When you arrive at the site take the first photo of a sheet of paper containing pertinent site information, i.e. site name, ID number, date etc. This reference photo is a precaution which will help identify the photo series should other identifications (some cameras provide a databack feature which will identify the photo) be switched or lost. If using a digital camera this step can be omitted since each image has an associated date and time that can matched up tot he field notes.

4. Establish eleven evenly spaced transects along the sample reach as described in the study design section of this chapter (page 12).

5. At the first transect set the shutter speed and f-stop based on the use of a handheld light meter. The internal light meter built in to most cameras is nearly impossible to use for tree canopy photography! Use the same shutter speed throughout all stations and use f-stop setting of one "stop" lower than light meter indicates. This will produce a slightly under-exposed image for more contrast between open sky and other "features".

6. Mount the camera on the monopod and self-leveling mount or tripod, with the camera pointed skyward.

7. Position the camera at the sampling point with the top of the camera oriented to Magnetic North such that the camera is 3 feet above the water surface. Make sure the camera is steady and the self-leveling framework has stopped moving then trigger the shutter.

8. Step 7 can be repeated at different heights to determine influence of shrubs versus overstory canopy. Be sure camera shutter is "set" before setting up for photos being taken at a height which places the equipment out of reach.

9. Record photo series data on a field data sheet (Figure 14-13, example) which contains fields for all information pertinent to your database design.

10. Repeat steps 7 – 9 at each of the eleven transects.

Photo Processing and Analysis

When it comes time for film processing, choose a reliable film processor and make sure they understand, and agree, to accommodate all photo quality and identification requirements. Attention to photo series documentation/identification cannot be over emphasized.

Photo prints must be scanned to produce digital images for analysis with pc software packages while images from digital cameras need no further processing. Either digital image is adequate provided the highest resolution practicable is used—consideration should be given to image-file size and file storage capabilities when choosing image resolution.

Photo analysis procedures, as well as computer system requirements, are unique to each photo analysis software package. Consult each publisher's software documentation for details. In general, the software package overlays the sun's path for a particular latitude and longitude, and day of the year. Percent shade is calculated as the proportion of available radiation to the amount that reached the stream's surface. Outputs are available for diffuse, direct, and total radiation as well as canopy cover. Table 14-3 shows examples of some output values from *HemiView*©.

ID#

HEMISPHERICAL PHOTO DATA

Date_____Roll#_____
Page____ of ____
Surveyors______________________
____
Typical Shutter Speed: 125

Wind: Constant motion (CM), Still (S)
Light: Overcast (O, even light), Partly cloudy (PC, uneven light with periods of high glare), Raining (R, even light), Sunny (S, high glare)

Distance (ft)	Photo #	Time	Photo Height (ft.)	Understory Height (L,M,H)	Shutter speed	F-Stop	Wind (CM or S)	Light (O,PC,R,S)	Light meter	Wetted edge to veg. (ft)	
										R	L

Figure14-13. Sample field data form for recording hemispherical photography field data.

Table 14-3. Sample of some of the output values with *HemiView*© analysis software.

Software Output	Definition	Relationship to other outputs
VisSky	The proportion of visible sky (open) to closed. The values range from 1 to 0 with 1 representing total open sky, and 0 representing total blockage of sky—no open sky visible. 0.36 = 36% visible sky. Site factors are indices of the proportion of radiation reaching a given location. Values range from 0 to 1, with 0 being no radiation and 1 being radiation for an open location.	
ISF	(Indirect site factor) is the proportion of diffuse solar radiation reaching a given location.	ISF = DifBe/DifAb
DSF	(Direct site factor) is the proportion of direct solar radiation reaching a given location.	DSF = DirBe/DirAb
GSF	(Global site factor) is the proportion of global radiation (direct to diffuse) reaching a given location.	GSF = TotBe/TotAb
DifAb	Diffused solar radiation above canopy.	
DifBe	Diffused solar radiation below canopy.	
DirAb	Direct solar radiation above canopy.	
DirBe	Direct solar radiation below canopy.	
TotAb	Total solar radiation (direct and diffuse) above canopy.	TotAb = DifAb + DirAb
TotBe	Total solar radiation (direct and diffuse) below canopy.	TotBe = DifBe + DirBe

Shade measurement using the Solar Pathfinder©

A Solar Pathfinder is used to measure shade in a manner that considers characteristics of solar radiation such as latitude, solar azimuth, time of day and season while integrating local features including channel aspect, topography and streamside vegetation. Solar Pathfinder is a field instrument that consists of a tripod, base, and reflector dome (Figure 14-14). The reflector dome is transparent plastic and reflects the image of nearby topography and vegetation (Figure 14-15). A paper sun path diagram for horizontal surfaces is placed on the Solar Pathfinder base under the transparent dome. This allows an observer to estimate the percent of total daily radiation that is shaded at a given location. When placed in a stream channel, the Solar Pathfinder becomes a convenient tool for estimating the amount of solar radiation blocked or attenuated by local topography and streamside vegetation.

The sun path diagram has 12 parallel sun path arcs, one for each month of the year (Figure 14-16). Vertical lines that represent solar time intervals of 30 minutes intersect these arcs. These segments of each monthly solar arc are assigned values that represent the percentage of solar radiation available during each 30-minute interval. The total value of all segments for a solar path arc is 100. The values vary by month as day length and solar azimuth change. For example, tracing the August solar arc in the sun path diagram, it can be determined that six- percent of total daily solar radiation is available during the 30-minute period of 11:30 to 12:00. Following the December solar arc it is apparent that 10 percent of the daily solar radiation is available during that same time period. Shade is simply a tally of those sun path arc segments that are partially or completely shaded. The actual energy reaching the stream can also be calculated.

The distribution of solar energy throughout the day should not be confused with the amount of solar energy that is available. The amount of solar energy for an Oregon location is actually much greater and more evenly distributed throughout the day in August than December. Solar energy information is available in many cities where the National Weather Service maintains monitoring sites.

This method measures shade at 11 evenly spaced transects over a reach length of 40 times the wetted width with a 150-meter minimum reach length. One midchannel measurement is taken on each transect. Solar pathfinder measurements for all 11 transects are averaged to determine shade on the stream reach.
Detailed instruction on Solar Pathfinder use is available in the instruction manual that accompanies the device, and in Platts et al., 1987. This document is not a substitute for the Solar Pathfinder manual, but provides additional guidance for shade data collection and stream assessment purposes.

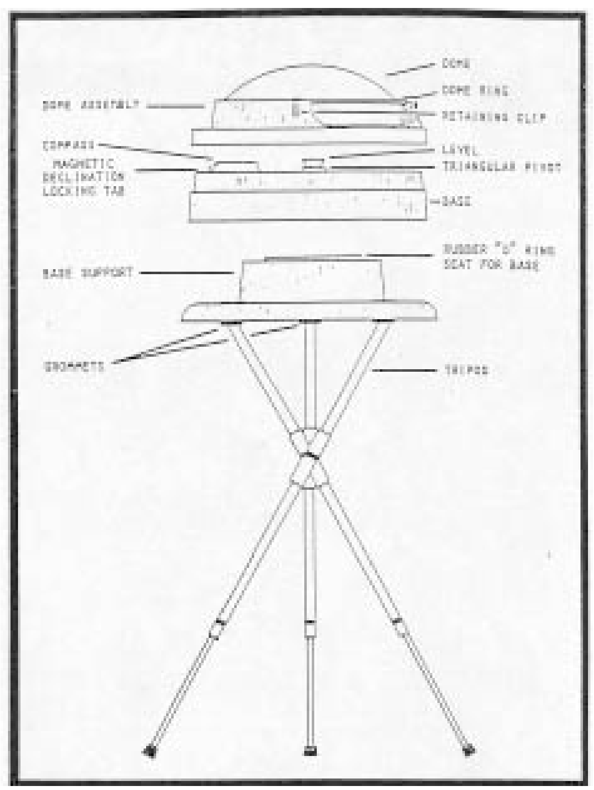


Figure 14-14. Solar Pathfinder Apparatus

Figure 14-15. Trees and other shade producing features are reflected on the Solar Pathfinder dome. The transparent dome allows the user to see the sunpath diagram placed on the base of the instrument.

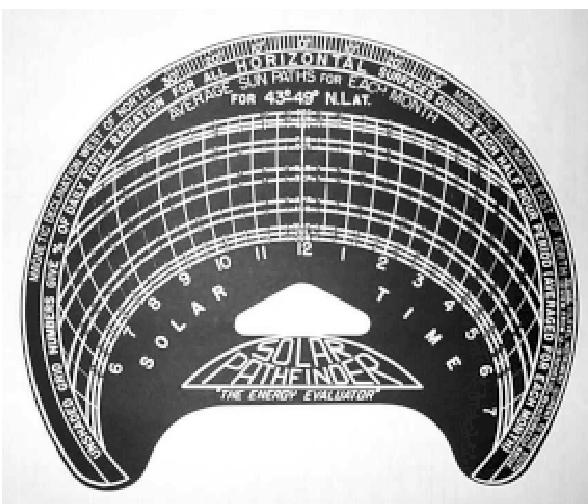


Figure 14-16. Solar Pathfinder sunpath diagram for latitudes 43^{o} to 49^{o} N.

Equipment

1. Solar Pathfinder
2. Tape measure
3. Wax pencil
4. Field form
5. Field notebook for recording general observations

Procedure

1. Select the appropriate solar path chart for your location, 37^{o} to 43^{o}N in Southern Oregon or 43^{o} to 49^{o}N in other Oregon locations (these are purchased from Solar Pathfinder).

2. Ensure the sun path diagram is corrected for compass declination for your location. Declination correction for Oregon ranges from 17^{o} to 19^{o} east as shown on page 12 of the Solar Pathfinder Manual. Release and rotate the center pivot counter-clockwise to set the declination if neces-sary.

3. Establish 11 evenly spaced transected along the sample reach as described in the study design section of this chapter (pg. 12).

4. Record the date, time, site name, transect number, stream wetted width, and names or initials of field personnel on the back of a sun path diagram.

5. Place the labeled sun path diagram on the base of the Solar Pathfinder.

6. Place the Solar Pathfinder in the center of the stream.

7. Orient the Solar Pathfinder to south using the compass attached to its base.

8. Level the Solar Pathfinder using the level attached to its base.

9. Trace the silhouette of the shade produc-ing features on a sun path diagram using

the white pencil as described in pages 6 and 7 of the Solar Pathfinder Manual. This provides a permanent record of shade and results can be tabulated in the office.

10. Repeat steps 5 through 10 at each transect.

<u>Data Analysis</u>
Determine the percent shade for the month of interest by totaling the values for each shaded segment on the solar path arc for that month. An estimate of shade is made for a 30-minute segment when it is partially shaded by topography or vegetation. For example, if two-thirds of the 30-minute segment on the August solar path is shaded, multiply the total value for the segment (printed on the sun-path diagram) by 0.66 to determine shade for that period. Thus, the August sun path arc indicates that 6% of the daily solar energy occurs during the 30-minute period of 1:30 to 2:00. Shade for the half-hour interval is determined by multiplying 6 by 0.66. The value is rounded to 4 and added to the shade tally. The final shade value is recorded on the back of the sun path diagram and on appropriate field data sheets. Average the 11 shade measurements to determine percent shade for the stream reach.

<u>Precision</u>
Measurements should be repeated at 10% of sites to document reproducibility within and among field teams. Experienced field staff can produce duplicate shade measurements within 5% of one another. Figure 14-17 illustrates duplicate shade measurements made by different observers. The average difference in Solar Pathfinder shade values at seven sites was less than 3% shade. When shade measurements were repeated at nine sites after two months, the average difference in shade was 7% (Figure 14-18).

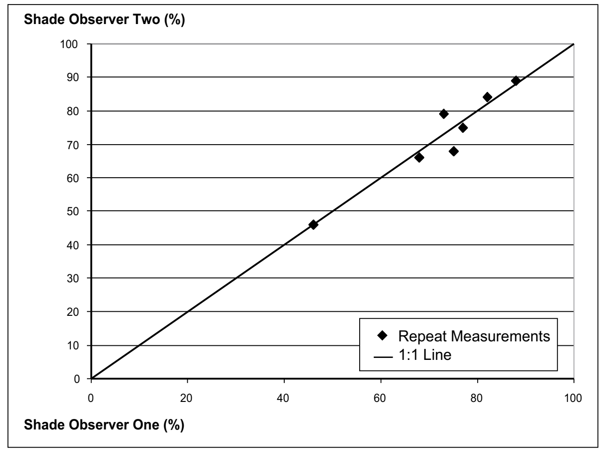


Figure 14-17. Duplicate solar pathfinder shade measurements at seven sites. (Provided by Dennis Ades, DEQ)

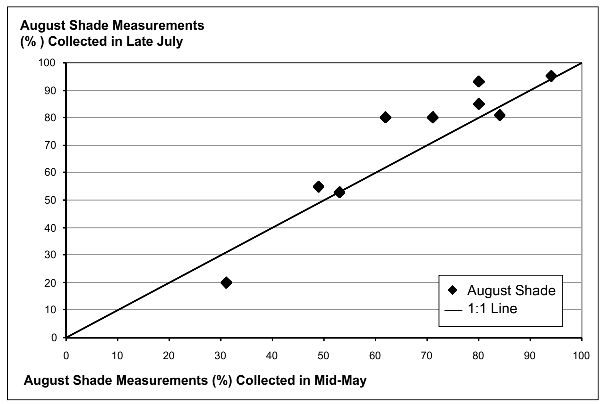


Figure 14-18. Comparison of Solar Pathfinder "August" shade measurements taken at the same locations in May and July. (Provided by Dennis Ades, DEQ)

Photo Documentation

Photographs are an important element in any monitoring program, as they can illustrate changes that other methods of sampling might not describe. A detailed photo record can help landowners and managers alike to document change, observe trends, and evaluate the effectiveness of a management plan.

Equipment

While photo monitoring is relatively easy, there is a specific list of equipment that you will need for it to be effective:

1. Permanent Markers*
2. Metal Tags*
3. Hammer*
4. Spray Paint
5. Camera
6. Film
7. Tripod (optional)
8. Profile Board
9. Photo Identification Board
10. Compass
11. Measuring Tape
12. Maps
13. Field Notes
14. Filing System

**These items will be needed only for the initial setup of your monitoring sites.*

Procedure

1. *Establish Camera Points and Photo Points*. The camera point refers to the location of your camera, and the photo point is the center of focus of the picture, as illustrated in Figure 14-19. Establishing the site for photo documentation might differ from the other field methods described in this chapter depending on what is being monitored. You will need to choose a monitoring site that is representative of the area you want to monitor. Also be aware of the variability of the streams and stream channels when locating your points. Flood damage and erosion may result in the loss of points located too close to the stream bank.

2. *Permanently Mark the camera and photo point.* Because you will be returning to the same site to repeat photographs, it is important to permanently mark your camera and photo points. Metal fence posts are recommended because they are cost-effective, visible and relatively theft-resistant. Rebar or metal stakes can be used, but must be driven flush with the ground to prevent damage to hooves/feet and tires. A metal detector will be required to relocate them. Spray paint will improve the visibility of the fence posts, and metal tags can be used to record the site name and camera point number.

3. *Set up your camera and tripod.* A 35mm camera is recommended for photo monitoring. Use a consistent camera format, which is the combination of the body image size and the focal length of the lens. You have three choices when deciding the type of film you want to use: color slide film, which is good for presentations, color prints, and black and white film, which is good for reports when photocopies will be made. A tripod will help you to take clear, consistent photographs, although it is not necessary.

4. *Take a compass bearing between the camera and photo points and record*. This bearing will be used when subsequent photos are taken to assure that the photographs are taken in the same direction and enable comparisons between photographs.

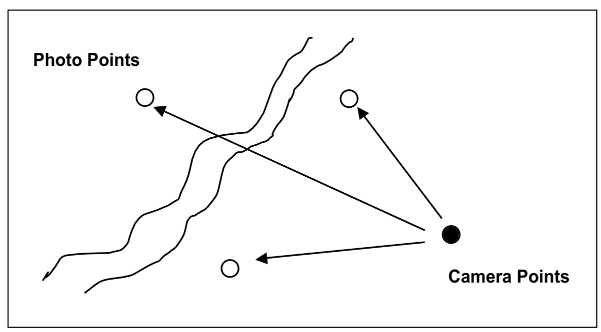


Figure 14-19. The above diagram illustrates the relationship between the camera point, where the camera is located and the photo points, which are the center of focus for the picture. The arrows indicate the distance and direction between the camera and photo points; be sure to record this information in your field notes.

5. *Measure and record the distance between the camera and photo points*. When subsequent photos are taken make sure the same distance is used.

6. *Measure the height of the tripod*. When subsequent photos are taken make sure the same tripod height is used.

7. *Take a picture of the photopoint with a profile board and photo identification board included in each picture*. A profile board like the ones shown in Figures 14-20 is a plywood board, marked with a scale, generally one or two meters in height, that is used to provide a reference of vegetation changes over time. A photo identification board like the one shown in Figure 14-21, should be used to display basic information such as the date, site and photo point number. Although bright blue paper is ideal, a small chalkboard is suitable. Avoid white paper as it does not photograph well.

8. *When to take pictures*. When you take your photographs depends on what you want to monitor. You may want to consider a fixed date or dates, which would allow you to compare both seasonal and annual differences in plant development. A fixed date would also give you the opportunity to compare the changes in the vegetation over several years, as your collection of information grows. Pictures taken upstream, downstream and across the channel are helpful and provide a good view of the channel, bank and riparian vegetation.

9. *Maps and Field Notes*. You should have two sets of maps, a general overview to locate your monitoring sites, and a site map with your camera and photo point locations. The information on your data form should include the photopoint number or name, the name of the photographer, and the date and time the picture was taken. Describe the use of the camera, lens, film type, and height of tripod (if used). Provide a description of the location (as detailed as possible), and notes on vegetation, weather, and other conditions. Leave room on your form to sketch a diagram of the area, showing direction of stream flow, and prominent features, like boulders and stumps. Figures 14-22and 14-23 are sample Photographic Site Description and Location and Camera and Photo Point Locations forms that can be copied for use in the field.

Study Reach, June 15, 1975.

Study Reach, June 15, 1981. (*Photographs courtesy of Fred Hall.)*

Figure 14-20. These photographs taken at the study reach in 1975 and 1981 capture the increased shrub growth, but they also illustrate the importance of considering future vegetation growth when choosing your meter board position to avoid losing your reference site.

Figure 14-21. Including an identification board (hand held) within the picture provides a permanent record on your negatives of the site location and description, and will help to eliminate any confusion about the site in the future

10. *Filing System*. It is a good idea to have a container or file folder that will hold all the information from a site; maps, notes, negatives, extra set of prints, slides, etc. A pocketed three-ring binder will hold field notes and pictures nicely. A helpful hint is to label all of your prints and negatives immediately after processing, while your memory is still fresh.

Data Analysis

Photo monitoring does not provide a direct measurement of shade or cover, but it is a powerful, qualitative method for monitoring the establishment, growth and maintenance of riparian vegetation. When combined with other monitoring systems, photo monitoring can be a very effective communication tool.

Precision

The most important thing to remember in photo point monitoring is to be consistent. Use the same camera (if possible), be sure the focal length is consistent, and use the same film. Take pictures from permanent camera point locations, and make sure the distance and direction between the camera and the photo point stays the same. Be sure to take pictures at the same time each year for good comparison. Furthermore, detailed notes and a filing system that will keep all of your information in one place will be very beneficial when comparing change over time.

Site Description and Location

Date:__________________________ **Observer:**__________________________________
Project: ____
Location Description (key features): ____
____

Weather: ____
Number of Camera Points: _________ **Number of Photo Points:**___________

Notes/Discussion:____
____

MAP

Use back of sheet for additional information.

Figure 14-22. Site Description and Location form (Hall, 1999).

Camera and Photo Point Locations

Date: ______________________ **Observer:** ____
Project: ____
Camera Location: ___________ **Number of Photo Points:** ___________________________

Photo Point A:
Compass Bearing: ___________________
Distance: ___________________________
Notes: _____________________________
____
____
____
____
____

Photo Point B:
Compass Bearing: ___________________
Distance: ___________________________
Notes: _____________________________
____
____
____
____
____

Photo Point C:
Compass Bearing: ___________________
Distance: ___________________________
Notes: _____________________________
____
____
____
____
____

Figure 14-23. Camera and photo point locations form (Hall, 1999).

Ancillary Data

Stream shade and cover monitoring efforts are usually coupled with stream temperature, channel morphology and/or riparian stand monitoring activities. Chapter 6 of this guidebook explains in great detail how to go about stream temperature monitoring. What follows is a brief description of some of the other stream and riparian characteristics that can be measured at the same stations where instream shade or cover is being measured. A Salmon Plan Monitoring Team workgroup has been formed to produce a guidebook for monitoring riparian characteristics.

- Hourly water temperature: Use continuously recording temperature probes at the downstream end of the reach monitored for stream shade.
- Hourly air temperature: Use continuously recording air temperature probes at locations effected by the treatment being monitored.
- Stream Flow can be measured using a velocity meter and cross-sectional area. Good to measure if also measuring stream temperature.
- GPS locations: Can be measured at a landmark or permanent plot marker.
- Buffer width: Distance from stream's edge to the outer edge of riparian vegetation.
- Buffer Height: Estimate average height of riparian stand each side of the stream.
- Topographic shade angle: Using a clinometer measure the angle to the highest topographic source of shade (ridge top, terrace) orienting yourself in four directions (upstream, left, right and downstream). This was discussed in this chapter.
- Wetted Width: Using a surveyors rod or tape measure the width of the wetted surface, subtracting mid-channel point bars and islands that are above the bankfull depth.
- Bankfull Width: Using a surveyors rod or tape measure the width of the channel at the average annual high water mark.
- Thalweg depth: Measure the deepest part of the channel with surveyors rod or tape.
- Gradient: Measure the slope of the channel with a clinometer, survey rod and two people. The downstream person finds eye level on the rod. The upstream person stands at the top of a riffle or pool holding the rod level. The downstream person stands approximately 100 feet downstream, at the top of a similar habitat unit as the upstream person. Both are at the water's edge. The downstream person looks upstream through the clinometer aiming at the predetermined eye level on the rod.
- Azimuth: Measured with a compass by orienting yourself downstream and with the direction of the valley (not a meander).
- Substrate: Estimate the percent of channel bed composed of each size class of material (Bedrock, bolder, cobble, gravel, sand or fines).
- Valley width and constraint ratio: Use a method (i.e. Rosgen) to categorize the valley width and constraint ratio (channel width/valley width).
- Dominant overstory species: Document the species of tree which dominates (tallest, and/or greatest in number) the stand.
- Dominant shrub species: Document the most common and shade-influencing shrub.

- Diameter distributions: Measure diameter at 4.5 feet above the ground on trees within a given survey plot).

- Basal Area: Use the diameters to calculate basal area.

- Stand health: Estimate the percent of stand composed of dead, diseased, or dying trees. Or when measuring diameter document tree health.

- Activities within the riparian area: Use a method to document, measure, or rate the level of grazing, harvesting, development, restoration or recreational activities taking place in the riparian area.

Equipment Vendors

Table 14-4 lists for the equipment described in this chapter. The vendors table may not be exhaustive, but rather lists vendors known to the authors and is intended as a starting point for the user. This list should not be interpreted as an endorsement. Prices are approximate as of May 2000. Please contact the vendor for current and accurate costs.

Table 14-4. Equipment Vendors

Tool	Contact, Address, Phone Number, Web address	Approximate Costs * If known, as of May 2000
Densiometer	Robert E. Lemon Forest Densiometers 5733 SE Cornell Drive Bartlesville, OK 74006 (918) 333-2830	$100
Densiometer and Clinometer	Ben Meadows Company 3589 Broad Street Atlanta, GA 30341 1-800-628-2068 web: www.benmeadows.com	Densiometer: $100 Clinometer: $100
Densiometer and Clinometer	Forestry Suppliers, Inc. PO Box 8397 Jacksonville, MS 39284-8397 1-800-647-5368 web: www.forestry-suppliers.com	Densiometer: $100 Clinometer: $100
Solar Pathfinder	Solar Pathfinder 196 Moore Road Iron City, TN 38463 (931) 724-6528	$200
Scanopy© - Hemispherical photograph analysis software and related photo acquisition and processing equipment.	Regent Instruments Inc. 4040 rue Blain Quebec, Qc. G2B 5C3 Canada web: www.regent.qc.ca	• Software: $500 - $2,000 • Cameras: $2,000 (digital) • Self-leveling mount: $1,300 (Complete starter packages available)
*** HemiView© - Hemispherical photograph analysis software and related photo acquisition and processing equipment.**	DELTA-T DEVICES LTD. 128 Low Road, Burwell, Cambridge, CB5 0EJ England web: www.delta-t.co.uk	• Software/hardware: $5,200-$6,150 • HemiView software and manual: $1,600

*By purchasing some of the equipment (i.e. camera, lense, tripod rather than a monopod) from vendors other than Hemiview the costs can come down.

Contacts

Contacts for more information on riparian monitoring are provided below.

Oregon Department of:

Agriculture
OPSW Monitoring Representative
(503) 986-4778

Environmental Quality
Volunteer Monitoring Coordinator
(503) 229-5983

Fish and Wildlife
Habitat Monitoring Coordinator
(541) 757-4263

Forestry
Forest Practices Monitoring Coordinator
(541) 929-3266

Oregon State University:

Department of Bio-resource Engineering
(541) 737-6299

Department of Rangeland Resources
(541)737-0923

Extension Program
(503) 566-2909

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Chapter 15

E. coli protocols

Background

<u>Escherichia coli</u> (*E. coli*) bacteria are indicator organisms; that is they are monitored in surface waters because their presence indicates fecal contamination is present. Because it is not practical or feasible to test for all the disease-causing organisms that can be present in surface water, we use *E. coli* as an indicator because it is commonly found in human and animal wastes and is easy to quantify in the laboratory. If *E. coli* is present above certain levels, then other disease-causing organisms may be present and a potential threat to human health exists.

Over the years the choice of indicator organism used in water quality standards has changed as new studies are performed to determine which indicator correlates best with human illness. The 1992-1994 Triennial Water Quality Standards Review recommended that *E. coli* replace enterococci as the indicator for freshwater and estuarine/non-shellfish producing waters and that fecal coliform be retained as the indicator for marine/shellfish producing waters.

This protocol explains the methods for sample collection and use of the Quanti-Tray® and Quanti-Tray 2000® MPN (most probable number) Enumeration Test Procedure and Colilert® reagent, both patented by IDEXX Laboratories, Inc. The U.S. Environmental Protection Agency (EPA) approved the Colilert® procedure in 1990 and the Quanti-Tray® addition in 1996. The substrate used in the test contains two indicator compounds (ONPG and MUG) that either produce a color or fluoresce when metabolized by total coliform or *E. coli*, respectively. This method is easy to use, provides results in 24 hours, and compares favorably with other methods for quantifying *E. coli*. The IDEXX Quanti-Tray 2000® MPN Method has a maximum counting range of 2,419 E.coli per 100 ml on undiluted samples. The maximum counting range of the Quanti-Tray® MPN Method is 200 MPN/100 mL on undiluted samples. As with other bacterial enumeration methods, the counting range can be extended by serial sample dilution. The Quanti-Tray 2000® method is recommended for environmental water samples because the 200 MPN/100 mL maximum quantification of the Quanti-Tray® method is less than the state *E. coli* standard of 406 MPN/100 mL.

Colilert®-18 reagent produces results after 18, rather than 24, hours of incubation, and should be used with marine samples. Marine samples must be diluted at least ten-fold before analysis with Colilert®-18.

In brief, a water sample is mixed with the Colilert® reagent and divided up into a series of wells. After incubation at the optimal temperature the number of positive wells are recorded (the number which turn yellow and the number which fluoresce under 365 nanometer (nm) ultraviolet (UV) light). The number of positive wells depends on the bacterial concentration in the original sample. The actual bacterial concentration is read from an MPN table based on the principle that each well has a certain probability of being positive.

Equipment and Supplies

All of the equipment and supplies can be ordered directly from IDEXX Laboratories, Inc. at the phone number 1-800-321-0207.

Item	Catalog Number
Colilert® reagent packs for 100 ml samples	WP020 (20-Pack)
Colilert® reagent packs for 100 ml samples	WP200 (200-Pack)
Colilert®-18 reagent packs for 100 ml samples	WP020-18 (20-Pack)
Colilert®-18 reagent packs for 100 ml samples	WP200-18 (200-Pack)
Quanti-Tray Sealer	WQTS-110 (110 Volt) WQTS-220 (220 Volt)
Quanti-Tray/2000®	WQT2K-100 (100 trays)
Quanti-Tray®	WQT-100 (100 trays)
97-Well Rubber Insert	WQT RBR-2K (use with Sealer)
Colilert® Comparator with Vessel	WP104
Collection Bottles with thiosulfate 120 ml	WV120SBST-20 (20 per case) WV120SBST-20 (200 per case)
Quanti-Cult® QC Kit Quality Control Bacteria (3 sets)	WKIT-1001
UV Viewing Cabinet	WCM10
Incubator, 35°C	WI300 (110 Volt/60Hz) WI3001 (220 Volt/50Hz)
Fluorescent UV Lamp, 365nm Or other 365 nm long wave UV lamp	WL160 (110V AC cord) WEA160F (220V European cord)
UV Absorbing Safety Goggles Or	WLG
UV Absorbing Safety Spectacles	WLS

Calibration and Standardization

1. This equipment need not be calibrated, although the incubator temperature must be maintained within 0.5°C of 35C° during incubation. Dry incubators may need to be turned on at least 12 hours before use to ensure that the temperature is stable. The incubator temperature should be checked and recorded daily during periods of use.

2. For each batch of Colilert® reagent (check Lot Number on package), follow the quality control procedure provided with the Quanti-Cult® QC Kit. This involves inoculating three separate bottles containing 100 ml of sterile water with three different bacteria cultures and following the test procedure explained in the Methods section. The following results should be obtained:

   E. coli—yellow, fluorescent;

   Klebsiella pneumoniae—yellow, not fluorescent;

   Pseudomonas aeruginosa—clear, not fluorescent.

Methods

Refer to the instructions that accompany the reagents and equipment.

1. Remove the lid from a 120 ml clean, sterile bottle without touching the bottle neck or cap threads. The bottle should have a 100 ml fill line like the IDEXX Collection Bottles listed in the equipment and supply list, and adequate volume to allow for vigorous mixing of the sample. For chlorinated water, use sample containers containing sodium thiosulfate so that chlorine will be neutralized.

2. After collecting sample, pour out excess sample so that the final volume is approximately 100 ml. Tightly cap the bottle and shake to dissolve the sodium thiosulfate, if present. If the sample was collected in a Whirl-Pak bag or a larger sterile container, transfer 100 ml into a clean, sterile bottle. Sample transfer should be done in the laboratory with a pipette for sterile transfer.

3. If the sample *E. coli* concentration is likely to exceed an MPN of 2,419 per 100 mL (200 MPN/100 mL for Quanti-Tray®) **or if the sample is saline**, the sample should be diluted with sterile distilled water. Use an aseptic pipette to transfer a portion of sample into a prepared sterile dilution water blank. For example, a ten-fold dilution is accomplished by transferring with a pipette 10 mL of sample into 90 mL of water. The diluted sample is then capped, shaken vigorously, and treated like a regular sample.

4. Carefully separate one Snap Pack of Colilert® or Colilert®-18 (for saline water) reagent from the strip. Tap it so that all of the powder is on the bottom of the pack.

5. Open the Snap Pack by snapping back the top at the line. Do not touch the opening.

6. Add the reagent to the 100 mL water sample (Figure 1).

Figure 1

7. Cap the sample jar tightly without touching the bottle neck or cap threads.

8. Shake the sample vigorously until the reagent powder is dissolved.

9. Allow sample to sit undisturbed for a few minutes to reduce foaming.

10. Open the Quanti-Tray or Quanti-Tray/2000® and hold it in one hand in a U-shape as you pour the entire sample into it, touching only the foil tab (Figure 2). Tap the small wells two to three times to eliminate air bubbles.

Figure 2

11. Follow the manufacturer instructions to send the sample tray in the insert through the sealing machine.

Figure 3

12. Incubate the tray filled with sample for 24 hours (with Colilert®) or 18 hours (with Colilert®-18) at 35+/-0.5°C. Do not overload incubators or water baths with sample trays because samples will not achieve proper incubation temperature. The IDEXX incubator holds a maximum of 12 trays, six on the bottom and six on the shelf.

13. Prepare the comparator sample by aseptically transferring the comparator from the glass bottle to a sterile Quanti-Tray® or Quanti-Tray/2000® and sending it through the sealing machine. Record the lot number and expiration date of the comparator on the tray. Store the comparator sample in the dark between 4 and 30°C when not in use.

14. After 18 (for Colilert®-18) or 24 (for Colilert®) hours of incubation, read and record the results of the test.

- If the wells in the Quanti-Tray® or Quanti-Tray/2000® do not have a yellow color, the test is negative.
- If the wells are yellow but a lighter yellow than the comparator, the tray may be incubated an additional four hours (no longer than 22 or 28 hours total, respectively, for Colilert®-18 and Colilert®) and reexamined. If they are still lighter yellow than the comparator after an additional four hours of incubation, the test is negative.
- Wells that have turned as yellow as the comparator indicate the presence of total coliform bacteria (Figure 4).

Figure 4

15. If the wells are at least as yellow as the comparator, check each well for fluorescence (Figure 5) by placing a 6 watt 365 nm UV light within five inches of the sample in a dark place. For convenience and safety, use the IDEXX viewing cabinet. If a cabinet is not available, use UV protective eyewear.

Figure 5

16. If using the Quanti-Tray/2000® read and record the number of small wells that fluoresce and separately record the number of large wells that fluoresce, including the large well at the top of the tray.

17. If using the Quanti-Tray® read and record the number of wells that fluoresce, including the large well at the top of the tray.

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photos courtesy of: www.idexx.com

LABORATORY CHEMICAL SAFETY

Ultraviolet (UV) light damages the human eye. Wear UV eye protection if viewing the sample with the light outside of a dark, enclosed box.

If comparator comes in contact with eyes or skin, flush thoroughly with water.

QUANTI-CULT contains live microorganisms and should be used only by individuals with bacteriological training. Properly disinfect any spills and sterilize all used containers according to appropriate regulations before disposal.

Calculations and Data Reporting

Refer to the MPN table provided with the Quanti-Tray® or Quanti-Tray/2000® to obtain the Most Probable Number (MPN) of *E. coli* in the sample.

If the sample was diluted, multiply the result by the appropriate dilution factor.

If all the wells in the tray are positive, the results must be reported as >2,419 MPN/100 mL (Quanti-Tray/2000®) or >200 MPN/100 mL (Quanti-Tray®). Remaining sample, if it exists and has been stored at 4°C, may be diluted, prepared, and placed in the incubator within 30 hours of collection. If incubation begins more than 30 hours after sample collection, any results must be reported as estimates.

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