Oregon State Board of Forestry

Testimony of Dr. Michael Newton, 7/23/15

My testimony:

1. The Forest Practices Act of 1972, assigns to ODF the oversight of streams and fish as well as forests. The proposal to adopt a stream rule not backed by fish research, and that removes significant forest land and fishery from management is surely counter to the purpose of this act.

2. Abundant literature shows the importance of light on streams to power photosynthesis and aquatic insects, hence fish food. I ask you to reject the PCW Standard and its attendant negative effect on the fishery without relevant data support. I am handing out copies of a manuscript Dr. Ice and I have prepared dealing with data need while designing rules.

3. I question requiring buffers wider than those in South-sided buffers. Our data from seven streams indicate that stream temperatures with 40-foot sun-sided buffers are equal to those of two-sided 50-foot ODF buffers. And also that harvested units have consistently more fish than unharvested; our complete clearcut had the most fish out of 18 study reaches, six buffered, nine uncut.

4. Please consult the research by Brett et al, This nails down what experiments are needed to determine temperature tolerance of salmon and duration of exposure without stress. This is real data showing salmonids acclimating to temperature far above 64° (17.°C). Acclimation to temperature is best when well fed. Also see our "Linkage" paper, real data.

   I led a substantial study for ODF in 1996 describing temperature in 16 streams in a $140,000 contract with ODF. It showed many sources of "noise" in streams, and high variance. Wasn't this ever made available to RipStream? Also, The RipStream study was apparently prohibited from dealing with fish. Please see the Newton and Ice manuscript on the paradoxes in regulations.

I find four major conceptual flaws in the logic of the proposed buffers and where applied:

1. If there is no difference between the 40-foot, one-sided buffer and ODF's two-sided rule, <u>please reject buffers of 90 feet as adding to cost, but not benefit, as per data.</u>
2. The 40-foot sun-sided buffer is as consistent as the ODF 2-sided buffer for cool water. Trees on the non-shading side <u>must be returned to owners as non-functional buffers.</u>
3. Reliance on PCWS to protect fish is contradicted by many scientific references. Without supporting data, it should be <u>rejected</u> as potentially harmful to forest and fish.
4. Buffers have been implemented to avoid excess warmth. <u>Cold streams must be defined and exempt, and management returned to owners.</u>

State of Oregon, Board of Forestry

Testimony of Dr. Michael Newton regarding Stream Regulations

July 23, 2015

I am Dr. Michael Newton, Professor Emeritus of Oregon State University College of Forestry, where I have been engaged nearly full time in forest and stream research since 1960. In the past 24 years, including 15 years of retirement, my focus has been on how solar radiation influences streams and their temperature, and effects of local warming of water on downstream environment of fish.

I have published 12 refereed publications on various aspects of stream management, mostly relating to stream temperature and its response to stream environments. I led a major research project for ODF on stream features and temperature management, 1994-6.

Stream temperature became an issue following the work by Krygier and Brown, in the early 1960s. In that study, now identified as the Alsea Watershed Study (AWS), three headwater streams in the Coast Range, tributaries of Drift Creek, were used as examples of consequences of harvesting on stream temperature. One of these was left untouched. One was clearcut with buffers, and one was clearcut without buffers. The last, Needle Branch, was completely de-forested, the stream was cleared out with bulldozers that skimmed down to bedrock, and the entire approach was dependent on maximum disturbance.

The uncut, and also the buffered stream, did not warm appreciably. The completely clearcut stream did warm a great deal, largely owing to very shallow fully exposed water flowing across flat bedrock. These two observations, without qualification, provided the basis for the stream rules as we see them today, requiring buffers. This research was grossly inadequate as a basis for today's stream rules. They launched a program of regulating stream temperature rather than net fish productivity.

The AWS derived temperature data based on practices prohibited today, and relied on data from only one abused stream totally non-representative of modern silvicultural practices. It led to practices that require two-sided buffers, half of which have no influence on shade or temperature. The shade over streams to prevent warming, and *which obscures the light that leads to stream productivity* was not factored into the use of those data. The modern regulatory focus for forest streams is temperature control. The focus is on shade with no reference to fish tolerance of either shade or temperature. Conversion of streams to maximum shade is the worst possible outcome for fish. It fails to accommodate the historically-wide variation in temperature with which fish have evolved in a fire-dominated forest region.

The shade over streams for temperature control is being provided by putting Forest Practices buffers on both sides of a fish bearing streams. Our research has made clear that trees that do not shade the stream, i.e. all those north of water and more than 40 feet from the water, have no effect on stream temperature. Our data from seven intensively monitored streams reveals that these sun-sided buffers allow some diffuse radiation for primary production, but exclude direct sun equal to two-sided buffers of any width. The way the South-sided buffers switch sides when streams change alignment with the compass ensures that the back-side of the south-sided buffer has no cooling function. It should be returned to owners for management.

The current riparian rules are based on one sea-level stream, yet are being enforced on all privately-owned fish bearing streams, at all elevations. There are many fish-bearing streams far colder than optimum, all being buffered. Their biological productivity is being kept low. The focus on riparian rules must be modified to emphasize fish nutrition as well as temperature, and need to be made to match the ranges of environments of Oregon streams. Some variation is obviously well within the natural environments of this fishery. It must be allowed.

Work by Bateman (OSU Watershed Research Coop) shows that fish respond markedly to reduction of shade, with gains increasing for several years. Strangely, a similar observations was made in Needle Branch (AWS) a few years after bulldozing the creek-bed. It takes several years for a hatch of fish to provide a big run of adults. We know that now, but the rules based on AWS have not changed appreciably since enactment.

The Protecting Cold Water Standard is flawed. Several observations from the various Watershed Research studies stand out as having been ignored:

1. Once warmed, streams lose the excess heat in a matter of hours downstream, meaning that within a half-mile to a mile downstream, that heat is no longer detectable unless there had been a huge infusion of energy, beyond normal harvests without buffers. Accumulation of heat is generally a non-problem except in the warmest climates.
2. Primary production of food for fish is provided by photosynthesis, and a food chain of phytoplankton and macro-invertebrates. Dark streams are not productive.
3. Fish can tolerate much higher temperatures, and prosper in so doing, as long as peak temperatures do not persist more than a few hours per day. Over a dozen scientific references attest to the abundance of fish in clearings. These reports include observations in our study streams. Fish also acclimate to warm temperatures as long as well fed. Newton has these references, mostly by Brett et al, (1982 and a dozen others.)
4. The interaction of temperature with food availability is a critical component of the mathematics needed to justify anything like the PCW. Models must include fish.

There are many references to abundant fish in open reaches of streams over a wide array of conditions:

1. Brett and his team (1982, and other publications) have observed that salmonids tolerate a wide array of temperatures. Whereas ideal temperature may be centered around 62-64°F, they have been observed, as in our work, to tolerate much higher temperatures for a few hours in large numbers, allowing them to feed in morning and

evening. In our work, a complete clearcut where water reached 71.7°F. supported the largest numbers of fish of any treatment in census of six test-buffer treatments on one of our study streams recorded by ODFW. Fish abundance was greatest in the complete clearcut, then Partial buffer, then harvest with ODF BMP buffers, then the three uncut units in that study stream had the lowest numbers. We had similar findings in two other streams of our study for which we were able to obtain census data on six treatments.

2. Brett et al, 1982, also showed that even though salmonid habitats appear ideal at about 60-62°F, as food availability increases, their tolerance of higher temperatures is remarkable:
    a. Mortality of salmonids in free-flowing mountain streams is rare, even when very warm as such streams go.
    b. Fish that slow their feeding rate at high temperatures can and do feed when temperature drops, leading to little if any loss of growth.
    c. Fish kept at elevated temperature develop a tolerance for the higher temperature even when held at a steady 70°F.
    d. Mortality of salmonids did not begin until continuous temperature exceeded 74°; temperatures in the low 80s were tolerated for a matter of hours.

2. The shade-intolerance of Doulas-fir attests to the need for complete clearing in order to survive and grow above the brush. The even-aged nature of forests, and prevalence of Douglas-fir west of the Cascades is persuasive evidence that these fish have evolved in river systems where the periodically burned land was cleared for decades, often repeatedly, between which maturing forests leading to prolonged dense shade were intervals of cool water. All of our anadromous fish have evolved with both extremes on a scale infinitely larger than that provided by scattered harvest units with cooling between.

4. The need for continuous closed-canopy forest cover over streams provides limited nutrition for fish. Open buffers or periodic clearings are justified in maintaining fish.

5. Numerous reports cite evidence of best fish populations occurring in clearings. To the best of my knowledge, the only incentive for maximum shade is regulatory convenience, at the expense of fish.

6. Research to define where buffers are or are not needed is a critical need.

In 1994-6, I led a relevant research contract funded by ODF to evaluate stream temperature patterns in Coast Range streams. It was roughly a $140,000 project, from which a detailed final report was submitted in July, 1996.

This report described the thermal behavior of 16 streams, grouped in various ways to see if there were patterns of warm vs. cold streams, temperature downstream from various silvicultural activities, and temperature patterns downstream of units where warming was observed. Streams always warmed from source on down. High-discharge/acre streams warmed at different rates. Cold streams warmed, and warm streams warmed, at different rates. Much of the water in these streams was transpired (lost) before it went very far. The important part of this contract was the determination that streams vary enough to question the wisdom of applying a single temperature standard. We also showed water warmed and cooled in reaches often less than 500 feet long. Our recent work corroborates this.

For unknown reason, my recent research on stream temperatures and buffers (Cole and Newton, (2013) was not used by the RipStream team. It would have defined some limits on interpretation of RipStream data.

Papers by Zwieniecki and Newton, 1999, and Cole and Newton, 2013, provided details of an approach to temperature management requiring less than half of the buffer cover now required in the FPA. These two papers provide all the necessary information needed to justify using the Partial Buffer (40 feet wide, mostly south) as the standard for control of solar heating. The Cole and Newton (2013) paper has some important details in evaluating shade.

At no point has there been evidence that buffers wider than a total of 40 feet, located on the sun-side of a stream, improve fish habitat. I am not aware of any study anywhere indicating that buffers wider than 40 feet, only on the South side of streams of any size, favor fish.

The colder streams at higher elevations now require buffers. This is absurd, and very costly*.

The State has recently made no attempt to determine effects of buffers on the fishery. These oversights need remedy. State funding of the RipStream study harnessed excellent scientific leadership, but failed to ask the critical questions about fish. Interesting, but pointless.

I strongly believe that the fishery will be enhanced once narrower buffers are maintained or not required, depending on cold status of streams. Where buffers are needed, consider 10% of reach lengths to be open to the sky to enhance primary productivity if requested by owners. On very warm streams e.g. Willamette Valley and southwest Oregon, buffers are reasonable. Partial (South side only) buffers would provide some improvement of primary production.

These actions are all in keeping with literature on where fish populations are reported to be high, and with my personal experience in studies of roles of shading on streams.

I urge ODF and ODFW to remedy the absence of fish and temperature data for cold streams and high-elevation streams and their relation to cover, and to revise buffer requirements to Partial Buffers as a maximum. I also urge ODF to convert management of all streamside habitat to focus on fish rather than buffer quantity.

*Categories of stream temperatures must be defined by data surveys for all of western Oregon.

Regulating Riparian Forests for Aquatic and Terrestrial Productivity: Conflicting Perspectives

By Michael Newton[1] and George Ice[2]

Abstract. Forested riparian buffers isolate streams from the influence of harvesting operations that can lead to water temperature increases. Only forest cover between the sun and stream limits stream warming, but that cover also reduces in-stream photosynthesis, aquatic insect production, and fish productivity. Water temperature increases that occur as streams flow through canopy openings decrease rapidly downstream, in as little as 150m. Limiting management options in riparian forests restricts maintenance and optimization of various buffer contributions to beneficial uses, including forest products, fish, and their food supply. Some riparian disturbance, especially along cold streams, appears to benefit fish productivity. Options for enhancing environmental investments in buffers should include flexibility in application of water quality standards to address the general biological needs of fish and temporary nature of clearing-induced warming. Local prescriptions for optimizing riparian buffers and practices that address long-term habitat needs deserve attention. Options and incentives are needed to entice landowners to actively manage for desirable riparian forest conditions.

Additional index words: Aquatic habitat, buffer management, conifer regeneration, disturbance, fish productivity, forest practice regulations, herbicides, riparian, rotation length, shade, transpiration, water quality, water temperature, woody debris.

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I. Introduction

Forested streams in northwestern states (USA) are hosts to several salmonid fisheries. Forests in this region are regulated by forest practice rules to protect or enhance these fisheries, in part by reducing the negative impacts of excessive stream temperatures. States regulate harvesting near streams to achieve this (Stednick, 2008). Riparian (streamside) forests interact with streams by providing shade to limit direct solar radiation which can heat water. Potential negative effects of forest harvesting operations are controlled by retaining strips of forest cover along stream banks (buffers).

Direct solar radiation warms streams and but it also increases the photosynthesis and primary production that feeds the aquatic food chain. Food availability rises with increased solar radiation. The ecological history of this region's forests has been dominated by periodic large fires, hence high variability in stream temperature as well as food supply. The current regulatory process is designed to minimize any human-caused temperature increases. Rigid interpretation of regulations designed to minimize fluctuations in water quality and the riparian forest environment represents a regulatory paradox that likely minimizes fish as well as forest values.

The State of Oregon has developed a set of rules and water quality criteria since the Forest Practices Act (1971) that constrains how private landowners can harvest trees near streams. This review compares riparian disturbances from natural events and human activities, focused primarily on lessons from the Pacific Northwest and the state of Oregon. We show that: (a) the region's fisheries are adapted to disturbance events, (b) current levels of disturbance from controlled logging can actually benefit fish populations, (c) site-specific conditions create opportunities to enhance fish populations through riparian forest management, and (d) long-term maintenance of favorable riparian forests requires active management. We propose that the present condition of streams, streamside forests and local climate guide riparian rules, hence management, be directed toward achievement of both fishery and riparian forest values.

II. Oregon's regulatory framework.

Forest management in Oregon is regulated by the Oregon Forest Practices Act. The State of Oregon's Departments of Forestry (ODF) and Environmental Quality (ODEQ) have a regulatory objective to "Evaluate the effectiveness of this Act and its rules in encouraging economically efficient forest practices while protecting forest productivity, water and air quality, and fish and wildlife at a variety of scales and over time…"(ODF, 2014a). Also in administrative rules (ODF, 2014b), desired future conditions for riparian management areas are defined in terms of mature forests with no provision for disturbances and regeneration of those buffers. This is despite the need for substantial disturbance where the dominant tree species is likely Douglas-fir (*Pseudotsuga menzieii*), a shade-intolerant species that needs near-full sunlight to propagate and grow.

Riparian rules for private forests in Oregon define buffers as riparian management areas of specified width (15-30m; 50-100 feet) along both sides of fish-bearing streams (on all private forest lands when timber harvesting is conducted). A major focus of buffer regulations is minimizing solar radiation on streams, thus avoiding adverse water temperature increases after timber harvests. This is an effective tool. But constant shade limits aquatic photosynthesis, the source of much stream productivity (Newton and Cole, 2005). Many mountain streams are naturally very cold; low valley streams are naturally warmer. Similar buffers are currently required on both. Not only are extensive buffers along very cold streams costly, heavily shaded streams may be counter-productive to fish as well as forest.

III. The Stream Environment and Challenges for Rule Makers

Stream regulations have greatly reduced short-term changes in water quality (Stednick, 2008; Kibler et al., 2013). The Alsea Watershed Study (AWS) (Brown, 1970; Stednick, 2008) demonstrated that stream protection is needed, especially from mechanical damage and severe burning in the riparian area. It showed that immediate large increases in water temperature could be avoided by maintaining shade. Despite design weaknesses, the AWS revealed the need for buffering rules. What it and similar studies throughout the Northwest and North America did not reveal was how diverse riparian conditions might benefit fish, how local riparian environments must define or adjust management strategies, and how maintenance is essential for long-term favorable riparian environments.

Riparian forests have many influences on streams. They vary widely in species composition and stand structure (Pabst and Spies, 1999; Villarin et al., 2009). They provide litter in streams, including nutritious detritus and decomposition products (Hawkins et al., 1982; Gregory et al., 1987; Kiffney et al., 2003; Wipfli and Musslewhite, 2004; and others) that partially support the aquatic food chain. They provide large wood that creates cover from predators and dams that reduce water velocity while creating pool habitat. One of the major functions of riparian forests is to minimize temperature fluctuations and increases in streams by providing shade (Zwieniecki and Newton, 1999; Cole and Newton, 2013; Cole and Newton, 2015, and many others). Solar radiation reaching water is inversely related to vegetative cover, of which trees are the most significant type in mature forests. Solar energy is inversely proportional only to tree cover on along the southerly sides of water (Zwieniecki and Newton, 1999; Cole and Newton, 2013).

Shading of streams has benefits and costs, depending on limitations of aquatic food supply and water temperature influences on fish metabolism (Newton and Cole, 2005). The value of sunlight for photosynthesis in water is decreased when temperature is excessive. Permanent, no-touch buffers, proposed by some, would limit management of the valuable forest and its requirement of sunlight to regenerate.

Natural history of the region and its forests must guide rules. The natural variation in forests, climate, and thermal environment of this large region is critical to the function of buffers. The widespread occurrence of Douglas-fir, a light-demanding species native in much of the Pacific Northwest, testifies to the near-universal fire history, i.e. extensive deforestation, where this species has grown. Anthropogenic disturbances, including fires set by natives and early large-scale regeneration harvests, have occurred in all sizes (Van Wagtendonk, 2007). Uncontrolled fires of Oregon alone in the last 200 years have led to very large areas with nearly complete deforestation, followed by even-aged forests after decade-requiring natural reforestation. Often these areas burned repeatedly. In western Oregon alone famous forest fires include the Biscuit, Tillamook (4X), Yaquina (2X) and Nestucca fires each denuding 20,000 to 240,000 ha (50,000 to 600,000 acres). These events also denuded many river and stream corridors, often for several decades, affecting generations of fish, but not eliminating them.

Even-aged natural stands of Douglas-fir reveal the near-universal roles of fires across most of the forested terrain of the Pacific Northwest, widely known as the "Douglas-fir Region". A much larger region sharing a similar history includes northern California, Washington, Idaho and western Montana wherever the shade-intolerant Douglas-fir, western larch (*Larix* *occidentalis*), ponderosa pine (*Pinus ponderosa*), and lodgepole pine (*P. contorta*) occur. The famous salmon fishery of this very large and varied region evolved in a setting dominated by extreme disturbance. Such variability in streams and environments requires rules compatible with local conditions.

Foresters have long recognized that inappropriate timber harvesting and site-preparation practices near streams can have negative impacts on aquatic habitats (See, for example, Lieberman and Hoover (1948), and Schenck (1955). The AWS data stimulated studies quantifying the interaction of shade from buffers in western Oregon on streamwater temperature (Brown, 1970). These data led to the first Oregon Forest Practices Act rules requiring stream buffers on fish-bearing streams.

Today, on-going research programs are increasing the precision with which we assess how forest buffers influence water temperature. The costs and complexity of research that includes both habitat and fish data for variable-buffer studies are high. But the costs of not adjusting for local conditions and restricting management options that could benefit stream productivity are high also.

.IV. Forest Streams, How Rules Must Adapt

a) Variable streams; fitting rule to local needs

Riparian forests in Oregon, by rule, are managed with a strong emphasis on maintaining favorable water temperature to the extent possible for cold-water fisheries, and growing mature riparian forests (for large wood recruitment and other functions). The Pacific Northwest states of USA experience extremely variable stream environments associated with high precipitation in winter and virtually none in summer. The temperature and precipitation interaction changes with elevation and precipitation zones. We consider this interaction as an essential component of effective rules.

At low elevations of the Pacific Northwest, extreme precipitation occurs in winter months; with negligible contributions to ground-water for 5-6 months of summer. Stream behavior ranges from cold torrents in winter to cool, low-velocity streams that become warmer as discharge declines in summer. Low elevation sites are warmer, on average, than high elevation sites, and may need protection from heating in summer. In some cases, fish habitat at higher-elevation source streams might benefit from exposure to sun in order to promote primary production and create water temperatures that elevate fish metabolism.

Oregon includes much well-watered terrain above 900m (3,000 feet) with persistent or transient snow packs and large water-holding capacity in deep volcanic soils. Ground water is very cold when it enters streams in mountainous terrain, and very cool even at lower-elevations in mountainous terrain. Where headwater streams are very cold, fish are small, but present in low numbers (Kaczynski, 1993); these streams represent a major fraction of regulated stream/kilometers (miles), and are major sources of water for impoundments and rivers. These cold-water streams have not had the research attention given the lower elevation sites. Buffers are still required at high cost and negative benefit in many instances. Appropriate research would reveal the appropriate level of buffer protection.

Most streams follow similar patterns; as they lose altitude, they gain heat as water passes through layer after layer of microclimatic temperature, leading to increasing need for attention to water temperature. There is no strict guide for determination of stream temperature change as microclimate warms in the downstream direction. Fish may be abundant in a range of temperatures. We consider that stratification of sites by elevation zones is an important area for research activity within the agencies regulating near-stream uses.

Oregon streams are highly variable in temperature despite widespread productive forests; buffers of commercial forests are costly. Avoiding confiscatory regulations is the responsibility of the regulators. Rules with no benefit to either landowners or fish are avoidable. In one small area of western Oregon, (Newton and Zwieniecki, 1996, fig. 4), mean temperatures of six streams with equal temperature at headwaters, but low discharge per unit of basin area, were 3°C (5°F) warmer four miles from their sources than six streams with high discharge per unit area. High- and low-discharge streams had significantly different thermal regimes, yet both require identical buffers, one stream never exceeding 15°C (63°F). All were in the same county. All were fish bearing streams. It is difficult to establish relevant rules for managing stream temperature when the streams vary this much, but these variations are not considered.

b) Protecting the Fishery from over-protection

The famous cold-water fishery of the Pacific Northwest, with high value primarily from migratory salmon, is regarded as sensitive to water temperature, and thus subject to political and societal pressure for temperature regulation. Tolerance to highly variable temperatures is under-appreciated. Before humans settled this area (1850 to 1880) all streams were in the wild state, a condition which had virtually all the hazards of modern times, sometimes with far greater intensity due to basin-size events. These fish have evolved in forest areas where the dominant tree species were regenerated primarily by huge fires. Many generations of fish would spawn before burned forests provided shade anywhere in the watershed. Yet, despite fires and decades without cover, among the early settlements on the coast, many were supported by large salmon canneries at the mouths of burned-over landscapes in varying stages of self-rehabilitation. It is easy for regulators, a century or more later, to miss the implications of this history. Variations in stream temperature are natural, and high extremes are part of that (Ice and Schoenholtz 2003). Danehy et al. (2005) and Arismendi et al. (2013) provide some useful observations of natural thermal regimes in this region. These patterns must not be ignored.

It is difficult to minimize water temperature increases without adversely affecting productivity of the stream from photosynthesis. The numerous reports of abundant fish associated with forest clearings reveals light as a critical component of aquatic habitat (Newton and Cole, (2005). Water temperature and food supply interact. Brett et al. (1982) have conducted encyclopedic experiments with several salmonid species over a period of 30 years. They have elaborated on the interaction between feeding satiety and response to water temperature. The importance of food supply qualified by temperature must guide plans for protective management within wide bounds. Their observations of the range of survivable temperatures, and the interaction of feeding level on tolerance to high temperatures, provide very useful guidance on conditions to be avoided. They also identified conditions to which fish can adapt, presumably explaining how they can respond positively to huge, vegetation-denuding fires. Such information allows thinking outside conventional boundaries. Among other discoveries was the observation that salmon juveniles actually grow reasonably well only a degree below lethal temperatures, i.e. 23°C (74.2°F). Growth under such conditions, while not optimal, offer important evidence of how fish survived huge events, exhibiting functional persistence and resiliency in widely varying environments. They also showed that different strains of the same salmon species vary in food conversion efficiency, and that the adaptability to elevated temperature depended heavily on food consumption.

Brett et al. (1982) showed that growth of fish increases with food availability and that food availability and stage of growth influences the optimum temperature for growth. As fish feeding satiety increased from 60 to 80 to100 percent, their maximum weight gain was 1.7, 2.5 and 3.2 g/day. Optimum temperatures increased as fingerlings grew. Maximum growth rates of fingerlings occurred at temperatures of 14.8°, 17.0° and 18.5°C, respectively, for the different feeding levels. At each level of satiety, growth was about 90 percent of maximum within a range of plus or minus about 2.5°C above and below these optimum levels. An increase in temperature tolerance coincides with the warming of streams as spring trends toward summer. When water temperature was elevated three degrees above optimum growth rate, growth dropped off rapidly. These data offer guides for establishing acceptable water temperature levels in accord with feeding opportunity, including insects provided by primary production associated with exposed water (Newton and Cole, 2005).

Exposure to some solar radiation is associated with more and larger fish even at elevated water temperatures (Greene, 1950; Murphy et al., 1981 Hetrick et al., 1998b; Leach et al., 2012). This may be factored within design of field experiments as well as temperature-based regulations. For forest streams with salmonid fish, before harvest, the most extreme water temperatures represent short periods during diurnal and seasonal fluctuations in water where solar radiation penetrates natural canopy gaps (Zwieniecki and Newton, 1999; Cole and Newton, 2013). Of greater importance, as long as lethal temperatures are avoided, is the mean and range of temperature encountered season-long; peaks are brief and seldom lethal. Rules should reflect the broader base. This would define expected fish growth trends during the majority of time. Reality for most forest streams is cold water, well within a desirable range. The range of temperatures in complete clearcuts that extend along streams for 300-400m (1000-1300 feet) typically shows an increase from uncut reaches of 1.2-2.5°C.(2-4° F) (Cole and Newon, 2013), often remaining well within a favorable range. In one stream they reported a maximum temperature of 69.4°F (21°C) but cutthroat fish biomass was twice that of uncut units in the same stream.

There is strong evidence that maintaining dense overstories of trees over every fish-bearing stream all the time is not necessary and may not be desirable. Newton and Zwieniecki (1996), Zwieniecki and Newton, (1999), Cole and Newton (2013), and Cole and Newton (2015) have shown that even fractional cover can maintain stream temperature with little change as long as that cover shades the stream from 9AM to 5PM. There are numerous reports of fish productivity that increases, or is naturally high, in streams in or immediately adjacent to openings in forest cover (Murphy et al., 1981; Hawkins et al., 1982; Sedell and Swanson, 1984; Wilzbach et al., 1986; Gregory et al., 1987; Hetrick et al., 1998a; Kiffney et al., 2003; Leach et al., 2012; and many others). McMahon et al. (2001) found that food ration had a larger effect on trout productivity than did large water temperature differences. These reports provide evidence that both fish health and growth are associated with increased phytoplankton-supported macroinvertebrates (food). As reported earlier, Brett et al. (1982) showed the interaction with food that allows well fed fish to tolerate increased temperatures. A recent meta-analysis of dozens of timber harvesting studies with clearcuts and without buffers found that "The majority of studies showed positive response for salmonid density and biomass with openings in forest cover" (Mellina and Hinch, 2009). Clearly, the role of food supply is an important co-variate when predicting over-all fish health in headwater streams. This includes both instream primary productivity and regeneration of streamside vegetation with associated increases in terrestrial invertebrate production falling into the streams. The focus on maximum temperatures during the warmest week of the summer masks the potential benefits of openings (Brett et al., 1982).

c) Scope of Research to Guide Rules

There is no single management prescription applicable to all streams. Rule-making that prescribes one management approach can be effective for some sites but not others. This becomes increasingly important when applied to small and cold headwater reaches, the majority of stream miles in Oregon, where few streams exceed tolerable temperatures (Kaczynski, 1993; Newton and Zwieniecki, 1996). High variation in streams being regulated demands data with which rules may segregate according to site-specific parameters. "Conditioning factors" are essential for adjusting Best Management Practices and forest practice rules to adapt to variable forest and stream conditions.

Newton and Zwieniecki (1996) and Cole and Newton (2013) have shown that temperature peaks reached under unbuffered conditions rapidly return to untreated levels within 150-1000m downstream. They also observed that water temperature varied naturally in reaches as short as 150m, sometimes warming and sometimes cooling more than the Protect Cold Water Standard (PCWS) for Oregon of a 0.3°C (0.5°F) change due to management. The environment where the water flows after leaving a clearing is important information about how any heat inputs will be dissipated, and where fish can find save havens. .

Shade on the water during hours of intense sun prevents most warming by solar radiation. Regulating non-shading trees will not result in achieving cooler water temperature goals. Shade in the Northern Hemisphere is provided only by trees in a southerly direction from exposed water, and most shade is generally from trees immediately adjacent to the stream. These are the trees projecting shadows on the water during hours of high-angle sunshine when shade is important, i.e. 9 AM to 5 PM (Newton and Zwieniecki, 1996).

The current interpretation of the PCWS (Groom et al., 2011) has little or no relevance in cool streams. Any elevated water temperatures from openings rapidly decline downstream as streams equilibrate with their environment, returning to their natural downstream warming trends. Small, infrequent, and brief water temperature exceedances do not define the overall quality of habitat for fish, especially when food supply is overlooked (Ice et al., 2007, Loehle et al., 2014). With relevant research, there are opportunities to optimize our investment in stream resources and stream protection by fitting forest practices to broad classes of site-specific conditions.

d) Obtaining Relevant Data for Stream Temperature and Fish

Research is needed to refine relevant site-specific prescriptions. This research must inform regulators about the consequences of management choices under differing environmental conditions, appropriate for the range of environments being regulated. The research must be objective and focus on the practical ecology of stream environments, their adjacent forests, and the food supply for fish. This research will determine where preventive actions, like buffers providing shade, will avoid harm and where management that increases exposure is beneficial. In major management zones or areas defined by regulators, fisheries biologists need to identify test streams where fish are present, and where fish can be observed for multiple years before and after treatment. These streams would be tested with potential riparian management options. The purpose of these tests is to: (a) provide test data capable of meeting safe and productive temperature environments appropriate to climate zones, (b) prescribe suitable forest management along streams, as defined by the growth and numerical responses of fish, and/or persistence of downstream temperature changes, and (c) inform regulators as to how forest practice rules might adapt to regional and elevational differences influencing the local climate of fish-bearing streams.

The proposed testing system provides guidance about where regulation is needed, and if so: (a) where stream reaches may need various amounts of functional shade, and (b) how these alternative prescriptions provide for acceptable levels of water temperatures, primary production, and sources of large woody debris. These would be installed within each of two or three elevation zones in large geographical regions, e.g. from the east side of the Cascade Mountains to the Pacific Coast. Perhaps three elevation zones would be sufficient to evaluate how climate affects season-long water temperature patterns for each region. The array of tests might include: (a) complete clearcuts, (b)<15M (<50-foot)-width South-side only buffers[i] (as described by Cole and Newton (2013)), c) current riparian rule application, (d) 50% greater buffer width than existing requirements, both sides, and (e) a repeat of (b) with a 70-foot buffer, South-sided only.

Each test stream would include two adjacent reaches 375m (1200 ft) long, selected according to presence of fish populations large enough to find representative samples. One of those reaches would not have any harvest, while the reach below would be harvested according to one of the prescriptions described above. Each reach would be examined for a three-year pretreatment period to characterize the fish communities, including population, size, and growth rates. The same fish sampling process would be repeated after logging with the time lag being suitable for populations to adapt to the changed environment, usually about three years. Methods, such as those used by Wilzbach et al. (1986), might be needed to isolate reaches to avoid fish movement confusing test results.

5) Discussion and Conclusion

The State of Oregon, is considering rule changes to the Oregon Forest Practices Act designed to meet the state's water quality standards, particularly the PCWS. The Oregon Board of Forestry must choose the least burdensome alternative (ORS-527.714(5)(e), and resource benefits achieved by the rule must be proportional to the harm caused by the forest practices ORS527.714(5)(f). Wilkerson et al. (2006) have described substantially narrower shade-buffers in Maine than are being considered for Oregon as adequate to maintain stream temperatures at desirable levels. Fish response data is meager but suggests that some stream openings could be beneficial to fish and that current practices are not negatively effecting fish populations (Mellina and Hinch 2009). Lack of fish data on a range of management alternatives creates a regulatory paradox that management practices designed to protect water quality and fish habitat could actually diminish fish productivity while costing landowners more.

A large number of reports reveal that fish food and fish biomass are greater where streams run through clearings than when flowing through unbroken forests (Murphy and Hall, 1981; Murphy et al., 1981; Hawkins et al., 1982, 1983; Sedell and Swanson, 1984; Wilzbach et al., 1986, 2005; Johnson et al., 1986; Gregory et al., 1987; Hetrick et al., 1998a; Hetrick et al., 1998b; Kiffney et al., 2003; Wipfli and Musslewhite, 2004; Newton and Cole, 2005; Leach et al., 2012), as long as abusive forest practices (such as equipment operating in the stream or in-stream wood removal) are avoided. An early study by Murphy et al. (1981) in the Oregon Cascades found that "*…streams traversing open clear-cuts had greater rates of microbial respiration, and greater densities or biomasses of aufwuchs, benthos, drift, salamanders, and trout than did the shaded, forested sites…*" This is powerful evidence that maintaining or removing cover can both be used as management tools to protecting stream from excessive water temperatures or enhance the fisheries productivity.

We see evidence of a positive fish response to timber harvesting in our own research and the research of others testing the effectiveness of the current Oregon Forest Practices Act (e.g. Newton and Zwieniecki, 1996; Newton and Cole, 2005; Cole and Newton, 2013; Kibler et al. 2013). This evidence suggests there is no emergency to fish created by the existing OFPA rules, but current rules do minimize management that could favor both forests and fish.

Increasing protection from a non-point source activity where changes are minor, and which diminish rapidly downstream (Newton and Zwieniecki 1999, Holaday 1992, Johnson 2000, etc.) and over time (Summers 1982) is costly, especially when it does not benefit fish. We postulate that to support an abundant fishery, rules must allow *positive* riparian management to: (1) maintain stream-banks and avoid in-stream wood removal, (2) provide for reasonable amounts of future wood recruitment for stream structure, cover, and allow for associated terrestrial invertebrate production, (3) *allow enough light* on the water to provide a reasonable level of primary productivity, and (4) provide a favorable range of water temperatures in which moderately well fed fish are likely to grow near their maximum potential (perhaps 80-90% of maximum) free of disease. This last element acknowledges the interaction of temperature tolerance and feed abundance outlined by Brett et al. (1982).

Fish are cold blooded. Body temperature and activity vary with water temperature; demand for food varies directly with stream temperature (Brett et al, 1982; Ice, et al, 2004); temperatures can be colder as well as warmer than optimum while still supporting an abundant fishery. The range of temperatures fish are exposed to is important. Greene (1950), Brett (1956) and Brett et al. (1982) long ago noted that the interaction of stream temperature and food supply is strong, and that there is a range of several degrees at which fish weight-gain varies very little around a healthy rate if fed to satiation; Brett et al. (1982) described how tolerance to rising temperature increases as the season progresses. Greene (1950) was among the first to observe that fish abundance was greater in meadow environments than in a shaded stream despite considerably warmer water. General application of this relationship would suggest that fish in very cold water need less extensive buffers than fish in warm water. There is strong evidence that short periods of temperatures above 70°F (19°C) are not harmful if foraging is adequate (Ice et al. 2007).

The 24 Oregon streams Newton and Zwieniecki (1996), Zwieniecki and Newton (1999), Newton and Cole (2005), Newton and Cole (2013), and Cole and Newton (2013, 2015) have examined include a range of diurnal changes of 1.2° to 3.1°C (2.0-5.6 °F). They also observed large temperature variations within 150-m reaches while flowing beneath forest cover, representing the influence of highly localized energy sources and sinks. Natural water temperature fluctuations due to streamflow levels, season and time-of-day, channel exposure, and even disturbance events are much greater than the 0.5°F (0.3°C) limit prescribed by the PCWS.

Most riparian forests dominated by Douglas-fir or red alder need full sunlight to reproduce, grow, and survive. The continuous occupation of existing riparian cover by shrubs or rapidly decaying hardwoods, such as red alder that will eventually give way to shrub dominance, fails to provide or maintain a source of durable wood for streams (Newton et al, 1968). Current silvicultural options for riparian areas, other than the seldom-used hardwood conversion option, seem to doom the mature conifers identified as a desired future condition. Only by active management will long-term forest management goals be met.

Retention of buffers on the north side may provide for other functions (e.g. favorable relative humidity regimes for amphibians) but not shade. Yet current rules have two equal buffers, one on each side. It may be useful to emphasize the shade-making south-side for the best return on the environmental investment if additional shade is needed. Removal of north-side cover may also allow escape of long-wave radiation from water, in so doing allowing modest cooling and maintenance of cool streams, as shown by Cole and Newton (2013; see supplement). Local sub-regions may have some storms from directions other than south, hence justify trees elsewhere for large woody debris recruitment.

Streams experience extreme changes in flow (floods to droughts). Daily and seasonal variations in solar radiation, wind-damage, wildfires, landslides, insect outbreaks, and other disturbances are normal. Clearing of cover and warming of water has had substantial attention, primarily toward negative effects. But fish have survived extreme damage to their environment. Aside from storms, Bisson et al. (2005) reported that following the 1980 eruption of Mt. St. Helens, fish populations thrived in what would otherwise be considered undesirable stream temperatures due to the presence of abundant food supplies. Bisson et al. (2005) observed that previous estimates of fish productivity in a river draining volcanic ash had such high populations of fish that estimation of fish growth was confounded by competition among these super-abundant populations. Heck (2004) found fish growth in a forest watershed after wildfire positively correlated with increased temperature, presumably owing to increased photosynthesis and aquatic biota. Positive response to wildfire disturbance has been reported elsewhere (Malison and Baxter, 2010).

It remains important that rules balance environmental and economic benefits. William Ruckleshaus (1989), first EPA administrator, noted that "environmental protection and economic development are complementary rather than antagonistic processes…" Forest landowners need to be confident that foregone economic benefits are buying a strong environmental return on investments.

The condition of streams or their riparian forests is not currently being considered as a factor in deciding management options; warm and cold, high and low elevation, all streams are treated alike. The PCWS seems to imply that any warming in a harvest unit will be harmful and that heat pulses are cumulative. This reasoning ignores natural cooling downstream by heat exchange mechanisms and cold water mixing (Newton and Zwieniecki, 1996; Zwieniecki and Newton, 1999; Cole and Newton, 2013), and the benefits of primary productivity resulting from solar radiation. This standard for change in water temperature is substantially smaller than year to year differences in peak temperatures in given locations (Cole and Newton, 2013). The PCWS does not adapt to changing forest conditions or the potential benefits from occasional disturbances events, including timber harvests. It is an anti-degradation standard that does not take a landscape view of a management activity (forestry) when applied across a region, with sites dependent on disturbance and subsequent productive stages of recovering over space and time. It was made into a requirement, while lacking supporting data.

Contemporary forest practices have greatly reduced the immediate negative impacts, including large water temperature increases, observed as a result of historic timber harvesting and management activities. We need to consider how to provide for both productive forests and fisheries. There is strong evidence that openings and disturbance in riparian areas can boost cold-water fish production in forest streams. Considering the site-specific conditions of forest reaches, some riparian management should be allowed to provide for increased fish-food production and to achieve the long-term silvicultural goals for riparian corridors.

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[i] Minimum of 50 feet width positioned to provide shade 9 AM to 5 PM; elsewhere a fringe of residual trees >12" diameter within 15 feet (4.5 m) would be left for recruitment of woody debris as described by Cole and Newton (2013).