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CALIFORNIA FOREST MANAGEMENT PRACTICES AND THE CONSERVATION OF ANADROMOUS SALMONIDS

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NOTE TO READERS

This document was produced in relation to the collaboration of the California Department of Fish & Game with the California Department of Forestry & Fire Protection, and other state and federal agencies, in work to revise the California Forest Practice Rules to benefit the conservation of anadromous salmonids in the rivers of California. This Administration Report reflects the Department's official recommendations for changes to the Forest Practice Rules that were adopted in October, 2009.

As with all of its products, Fisheries Branch is very interested in ascertaining the utility of this document, particularly regarding to its application to the monitoring and management decision process. Therefore, we encourage you to provide us with your comments. Please be assured that they will help us direct future efforts. Comments should be directed to Dr. Stephen Swales, Fisheries Branch, Coho Salmon Recovery Program, 830 S Street, Sacramento, CA 95811, Tel. 916 324-6903, e-mail: sswales@dfg.ca.gov.

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SUMMARY

In California and the Pacific Northwest, widespread declines in the abundance of anadromous salmonids over the last several decades have been attributed largely to the loss and degradation of suitable habitat conditions in river systems for the rearing of juveniles and spawning of adults. Numerous studies have shown that forest management practices may have significant adverse effects on the habitat conditions of anadromous salmonids through, for example, loss of riparian vegetation and increased input of fine sediments.

This publication discusses fish/forestry interactions and riparian management practices carried out by various state and federal agencies in California in relation to the conservation of anadromous salmonids. In addition, the importance of three key habitat areas for the conservation of threatened anadromous salmonids is discussed; i) riparian (bankside) habitats, ii) headwater streams, and iii) off-channel floodplain habitats. Scientific justifications are also presented for proposed changes to the Threatened and Impaired (T&I) rulings of the California Forest Practice Rules (FPR).

The Aquatic Conservation Strategy (ACS) of the Northwest Forest Plan has components that have been implemented in federal forested areas. The ACS consists of four main components; i) Riparian Reserves, ii) Key Watersheds, iii) Watershed Analysis, iv) Watershed Restoration. A ten-year review of the effectiveness of the ACS found that it had met its main expectation in that watershed conditions had begun to improve.

The *Recovery Strategy for Coho Salmon*, published in 2004 by the California Department of Fish and Game (DFG) discussed forestry activities in California in relation to salmonid and coho habitat. The *Recovery Strategy* states that in California historical forestry practices, and some current forestry practices, have been shown to impact habitat components important to anadromous salmonids in general, and coho salmon (*Oncorhynchus kisutch*) particularly. The *Recovery Strategy* includes many range-wide recommendations concerning timber management to address the threats and issues facing coho salmon conservation, as well as specific watershed recommendations.

Forest Practice Rules (FPRs) proposed by various state and federal agencies are discussed and compared. FPRs in California and the Pacific Northwest continue to evolve with time as further scientific information becomes available. The Board of Forestry and Fire Protection's (BOF) recent *Scientific Literature Review of Forest Management Effects on Riparian Functions for Anadromous Salmonids* discussed literature related to changes in water temperature, large woody debris (LWD), and nutrients and sediment input to streams. DFG finds that many subjects important to the conservation of anadromous salmonids, such as inner gorge protection and slope specific buffer widths were not addressed in the literature review.

ED466-000010596 EPA-6822_035518

DFG proposes several changes to the Threatened and Impaired Watersheds (T&I) FPRs to benefit the conservation of coho salmon and other anadromous salmonids. These include, increased protection to headwater streams and off-channel floodplain habitats, increased riparian buffer widths and increased canopy retention. Recommendations for changes to the FPR are proposed which would benefit salmonid habitat and ecology. The likely consequences and benefits of the proposed changes to the FPRs to salmonid ecology and conservation are discussed.

In conclusion, changes to the T&I rulings of the FPRs are warranted to protect and restore habitat conditions for coho salmon and other anadromous salmonids in California river systems, increase fish population abundance and so improve the conservation status of threatened salmonid species.

[NOTE: In October 2009, BOF formally adopted a joint submission from California Department of Forestry and Fire Protection (CalFire) and DFG to revise the "Threatened & Impaired' rulings of the California FPRs. The revised T&I rulings will henceforth be known as the *'Anadromous Salmonid Protection Rules'* and will afford permanent increased protection to anadromous salmonid habitat in the state of California.**]**

TABLE OF CONTENTS

Summary.....3

Introduction.....8

Impacts of Forestry Practices on Salmonid Habitat.....11

Importance of Riparian Habitats.....12

Importance of Off-channel Habitats.....16

Importance of Headwater Streams.....17

Fish/forestry Interactions and Riparian Management Practices.....19

Northwest Forest Plan – Aquatic Conservation Strategy (ACS).....20

Riparian reserve descriptions.....22

California Forestry Activities, Coho Salmon Recovery and Forest Practice Rules.....25

Review of Forest Practice Rules by Other Agencies.....29

- National Marine Fisheries Service 29
- Watershed Protection and Restoration Council 29
- California Department of Fish & Game/Board of Forestry and Fire Protection.....30
- California Regional Water Quality Control Board 30
- California Board of Forestry and Fire Protection 32

Comparison of Guidelines for Establishing Riparian Zones and Canopy Retentions by Different Agencies.....33

Justifications for changes in T/I rulings on riparian widths to benefit anadromous salmonids.....37

Summary of Findings and Recommendations.....41

References Cited.....44

ED466-000010596 EPA-6822_035520

LIST OF TABLES

Table 1.1 Recommended Changes to Forest Practices proposed by DFG and likely effects on salmonid habitat and ecology

Table 2.1. Forestry activities and potential effects to stream environment, salmonid habitat, and salmonid biology. Source: Recovery Strategy for California Coho Salmon - adapted from Hicks et al. 1991

Table 2.2. Estimated widths of unmanaged near-stream vegetation in forested watersheds needed to maintain various functions of riparian ecosystems. Source: Everest & Reeves, 2007.

Table 3.1 Interim Riparian Reserve widths from the Northwest Forest Plan (slope distance each side) by site tree height and distance for riparian types. Widths are the larger of the two measures. See text for other geomorphic and vegetative considerations. Source: FEMAT 1993

Table 3.2 Riparian Reserve "Buffer" Widths from the Northwest Forest Plan. Source: FEMAT 1993

Table 4.1 Comparison of Watercourse Protection Standards (Source; *2004 Coho Salmon Recovery Strategy*)

Table 5.1. Riparian width and canopy retention guidelines recommended by the Northwest Forest Plan, Current California Forest Practice Rules, California Department of Fish and Game 2112 Rules for coho salmon, other agencies

ED466-000010596 EPA-6822_035521

LIST OF ACRONYMS AND ABBREVIATIONS

ACS	Aquatic Conservation Strategy
BOF	California Board of Forestry and Fire Protection
CCC	Central California Coast
CESA	California Endangered Species Act
Commission	California Fish and Game Commission
CRWQB	California Regional Water Quality Control Board
DFG	California Department of Fish & Game
ELZ	Equipment Limitation Zone
ESU	Evolutionarily Significant Unit
FGC	California Fish and Game Code
FPR	Forest Practice Rules
FEMAT	Forest Ecosystem Management Assessment
LWD	Large woody debris
MOA	Memorandum of Agreement
NOAA	National Oceanic and Atmospheric Administration
NMFS	National Marine Fisheries Service
SONCC	Southern Oregon-Northern California Coasts
SPTH	Site-specific tree height
SRP	Scientific Review Panel
T&I	Threatened and Impaired Watersheds
WLPZ	Watercourse and Lake Protection Zone

ED466-000010596 EPA-6822_035522

INTRODUCTION

The continued survival and growth of threatened and endangered salmonid species, such as coho salmon (*Oncoryhnchus kisutch*) in the river systems of California and the Pacific Northwest are largely dependent on the continued presence of high quality habitat conditions for adult spawning and juvenile rearing and growth (Moyle 2002; Moyle et al., 2008; Quinn 2005). Widespread declines in salmonid populations in numerous coastal rivers over recent decades have been attributed largely to the loss and degradation of suitable habitat conditions in river systems (Bisson et al. 1992; Gregory & Bisson 1996; Moyle 2002; Moyle et al. 2008).

In July 2000, a citizen's group, namely the *Salmon and Steelhead Recovery Coalition*, petitioned the Fish and Game Commission (Commission) to list coho salmon north of San Francisco as an endangered species under the California Endangered Species Act (CESA) (FGC §2050 *et seq.*). In response to the petition, DFG issued a report to the Commission describing the status of coho salmon north of San Francisco (April 2002), recommending that coho salmon from San Francisco north to Punta Gorda be listed as endangered and that coho salmon from Punta Gorda north to the Oregon border be listed as threatened pursuant to the provisions of CESA. The division of coho salmon in California at Punta Gorda follows the Federal designation of Evolutionarily Significant Units (ESU): the California Central Coast (CCC) Coho ESU and the Southern Oregon-Northern California Coasts (SONCC) Coho ESU.

On August 30, 2002, the Commission found that coho salmon warranted listing per DFG's recommendations. DFG's recommendations and the Commission's decision were based on the best available information, which indicates coho salmon from San Francisco to the Oregon border have experienced a significant decline in the past 40 to 50 years. Coho salmon in California, including hatchery stocks, are currently estimated to be just a fraction of their former abundance during the 1940s (Moyle et al. , 2008). Coho salmon commercial harvest decreased considerably in the late 1970s, despite a fairly stable rate of hatchery production. Recent abundance-trend information for several stream systems along the central and north coasts indicates an overall declining trend throughout California (Moyle et al., 2008).

Habitat loss and degradation in coastal rivers has been associated with landscape and water disturbances such as channel impoundment, urbanization and forestry management activities, which have severely impacted many coastal river catchments in California and the Pacific Northwest. Habitat degradation has been associated with > 90% of the documented extinctions or declines of salmon stocks in the Pacific Northwest (Gregory & Bisson 1996). There is considerable evidence that widespread deforestation has had significant adverse effects on habitat conditions for coho salmon and other anadromous salmonids in the Pacific Northwest. In an extensive review of the riparian and aquatic habitats of the Pacific Northwest and Alaska in relation to forest management practices, Everest & Reeves (2007) reported that they found little evidence or studies in the peer-reviewed literature of fish populations or habitat responding positively to or remaining unchanged as a result of intensive timber management activities.

The habitat requirements of threatened and endangered salmonids, such as coho salmon, are relatively well established and described (e.g., Sandercock 1991; Moyle 2002; Quinn 2005). Habitat needs are known to vary according to life-stage and also vary seasonally (Hicks 1991). The 2004 *Recovery Strategy* identifies rearing areas used by juvenile coho salmon as being low-gradient coastal streams, lakes, sloughs, side channels, estuaries, low-gradient tributaries to large rivers, beaver ponds, and large slackwaters. The most productive juvenile habitats are found in smaller streams with low-gradient alluvial channels containing abundant pools formed by LWD. Adequate winter rearing habitat is important to successful completion of coho salmon life history.

This document summarizes the available scientific information concerning the important role which several key habitat components - riparian habitats, headwater streams and off-channel habitats - play in the ecology and conservation of anadromous salmonids in California and the Pacific Northwest, and compares and contrasts how different federal and state agencies incorporate these requirements into their FPRs .

The likely consequences to salmonid habitat and ecology from the general changes in the FPRs recommended and proposed by DFG are summarized generally below in Table 1.1 and are listed by stream classification.

The consequences of changes in FPRs on salmonid habitat and ecology are discussed in greater detail later in this publication, along with a review of the available scientific literature to provide scientific justification for the rule change recommendations.

Table 1.1 Recommended changes to Forest Practice Rules and the effects on salmonid habitat and ecology

Stream Classification	**DFG forest practice rule change proposal**	**Effects on salmonids**	
		Habitat	Ecology
Class I	Increase WLPZ width	Maintain adequate shading, bankside cover etc.	Maintain optimum survival and production of juveniles and adults
	Increase forest canopy area	Reduce stream temperature, light levels and primary production	Maintain growth efficiency, food production and growth rate
	Retain largest conifers in WLPZ	Increase LWD retention and input of organic matter to stream	Increase juvenile production and carrying capacity
	Increase protection to off-channel floodplain habitats	Protect existing side-channels, back-channels, ponds, sloughs etc.	Increase carrying capacity for juveniles and winter survival, enhance smolt production
Class II	Increase WLPZ width	Maintain adequate shading, bankside cover etc.	Maintain optimum survival and production of juveniles and adults
	Increase canopy area - % cover depends on slope	Reduce stream temperature, light levels and primary production	Maintain growth efficiency, food production and growth rate
	Retain largest conifers in WLPZ	Increase LWD retention and input of organic matter to stream	Increase juvenile production and carrying capacity
	Protect inner gorge and headwater swales	Reduce potential for erosion and sediment input	Increased food production, egg to fry survival and smolt production
	Increase protection to off-channel floodplain habitats	Protect existing side-channels, back-channels, ponds, sloughs etc.	Increase carrying capacity for juveniles and winter survival, enhance smolt production
Class III	Create Equipment Limitation Zone (ELZ)	Reduce potential for erosion and sediment input	Increased food production, egg to fry survival and smolt production
	Increase WLPZ width	Maintain adequate shading, bankside cover etc.	Maintain optimum survival and production of juveniles and adults
	Retain snags, LWD, trees	Increase LWD retention and input of organic matter to stream	Increase juvenile production and carrying capacity
	Retain largest conifers in WLPZ	Reduce stream temperature, light levels and primary production	Maintain growth efficiency, food production and growth rate
	Protect inner gorge and headwater swales	Reduce potential for erosion and sediment input	Increased food production, egg to fry survival and smolt production

ED466-000010596 EPA-6822_035525

IMPACTS OF FORESTRY PRACTICES ON SALMONID HABITAT

The effects of forest management practices on salmonid habitat and watershed processes in the Pacific Northwest are numerous and relatively well documented (see Table 1.1 and reviews by Chamberlin et al., 1991; Hicks et al. 1991; Hartman 2004; Melina & Hinch, 2009). Fish-forestry interactions in Oregon, Washington, Alaska and British Columbia have been well documented in the scientific literature (Hall et al. 1991, 2004; Murphy 1995; Everest and Reeves 2007). However, there have been fewer documented scientific studies of fish/forestry interactions in California river systems (Burns 1972; Ziemer 1998; Valentine et al. 2007). It has been suggested that the lack of aquatic ecosystem studies in coastal Redwood forest regions in northern California may be explained by the enormous complexity of aquatic ecosystems, reluctance to carry out inter-disciplinary studies, lack of funding and the private ownership of most of the region (Welsh et al. 2000).

Logging activities may result in increased instream sedimentation, changes in light and water temperature regimes, loss of organic debris and invertebrate food, changes in channel morphology etc. (Hicks et al. 1991). Since logging began in the Pacific Northwest in the 19th century there has been extensive damage to salmonid habitats in the region through poor forest management practices (Burns 1972; Everest and Reeves 2007). However, due to the complexities of diverse environmental factors affecting salmonid populations, including climate and ocean factors, it can sometimes be difficult to clearly discern the legacy effects of logging operations on salmonid populations (e.g. Caspar Creek, see Valentine et al. 2007).

Forest management practices in California and the Pacific Northwest have subsequently been revised to reduce management impacts, but there is still considerable scope for improvement and for the restoration of salmonid habitats affected by the legacy of previous forestry activities (Welsh et al. 2000).

A recent review of the current status of salmon, steelhead and trout in California found that a high proportion of species face extinction in the foreseeable future, with habitat degradation caused by logging activities being cited as a major factor causing the degradation of salmonid habitat in the region (Moyle et al. 2008). The authors of this report state; "*existing regulatory mechanisms, such as forest practice rules, water agreements, and stream alteration agreements, have been inadequate to protect coho. Our relationships with the landscapes containing coho salmon clearly needs to be changed on a large scale if only to prevent extirpation, much less recover some semblance of their historical populations* ". The report predicts that without serious intervention to restore suitable habitat conditions, most or all coho salmon populations in coastal streams in both the CCC and SONCC ESUs will be extinct within 25-50 years.

The 2004 *Coho Salmon Recovery Strategy* lists several historical and some current forestry practices which may adversely affect salmonid habitat and the survival of coho salmon and other salmonids. Although revised forest management practices in "Threatened and Impaired" watersheds have been in effect since the year 2000, there has been insufficient time to determine if there have been benefits to coho salmon. DFG's conclusion was that

historical forestry practices impacted and continue to impact watersheds inhabited by northern California coho salmon, and that current activities (e.g. road construction, use and maintenance; activity near streams and on unstable slopes; removal of sources of large woody debris) depending on how they are managed, can still affect important habitat elements essential to coho salmon.

Several significant habitat elements, including riparian zones, headwaters streams and off-channel habitats, are considered to be worthy of further protection to assist with the recovery of coho salmon and other threatened and endangered salmonid species. This publication will review the scientific literature to justify the need for further protection of these habitats.

IMPORTANCE OF RIPARIAN HABITATS

Riparian (bankside) habitats serve a wide variety of important functions for stream ecosystems and anadromous salmonids, including providing shade and cover, bank stability, input of allochthonous organic matter, invertebrate food, sediment control etc. (see Table 2.1 and extensive reviews in Everest and Reeves 2007; Pusey & Arthington 2003; Naiman & Decamps, 1997; Naiman et al. 2000; SWC 2008).

In a recent paper, Richardson et al. (2010) asked whether riparian zones qualify as critical habitat for endangered freshwater fishes. The authors stated in their report; *In response to decades of stream-riparian research, widespread implementation of regulations to protect riparian zones in most developed countries represent a de facto consensus that riparian buffers are essential for aquatic ecosystem health and the maintenance of populations of fish and other species. Consistent with widespread riparian regulations deemed necessary to protect not-at-risk species, riparian habitat adjacent to a body of water containing a listed freshwater species should be considered biologically critical unless the habitat requirements of individual taxa are demonstrated to be insensitive to the ecological functions associated with riparian habitat.*

The condition of aquatic ecosystems at the watershed scale is strongly tied to the condition of riparian vegetation within a watershed (Welsch, 1991). The structure and productivity of habitats for fish and other aquatic organisms are controlled to a large extent by adjacent and upstream vegetation. Additional critical functions of riparian vegetation for development and maintenance of habitat for fish and other aquatic species include;

- Contribution of large woody debris that provides habitat structure for salmonids and a variety of other organisms (Bisson et al.1987; Sullivan et al. 1987).
- Contribution of leaves and particulate organic matter, the primary energy source for aquatic food-webs in most small and mid-size streams (Minshall et al. 1985; Wipfli and Gregovich 2002)

The widths of riparian corridors needed to maintain these essential functions have been widely debated and researched. Everest and Reeves (2007) summarized the available

literature on estimated widths of unmanaged near-stream vegetation in forested watersheds needed to maintain various functions of riparian ecosystems in the Pacific Northwest and southeast Alaska (Table 3.2). Spence et al. (1996) considered that there are three important considerations in establishing riparian buffer zones; 1) the width of the buffer zone, 2) the level of activity allowed within the riparian zone, 3) whether riparian buffers are needed for tributary streams that do not contain salmonids. Specific recommendations for riparian buffers can also only be made with a clear definition of riparian management goals.

TABLE 2.1 Forestry activities and potential effects to stream environment, salmonid habitat, and salmonid biology. Source: Recovery Strategy for California Coho Salmon - adapted from Hicks et al. 1991

FORESTRY PRACTICE	POTENTIAL EFFECTS TO:		
	STREAM ENVIRONMENT	SALMONID HABITAT	SALMONID BIOLOGY
Timber harvest in the riparian zone	increased incident solar radiation	increased stream temperature, light levels, and primary production	decreased growth efficiency; increased susceptibility to disease; increased food productivity; changes in growth rate and age at smolting
	decreased supply of LWD	decreased cover, storage of gravel and organic debris, and protection from high flows; loss of pool habitat and hydraulic and overall habitat complexity	decreased carrying capacity, spawning gravel, food production, and winter survival; increased susceptibility to predation; loss of species diversity
	increased, short-term input of LWD	increase in number of pools and habitat complexity; creation of debris jams	increased carrying capacity for juveniles and winter survival; barrier to migration and spawning and rearing habitat
	increased influx of slash	increased oxygen demand, organic matter, food, and cover	decreased spawning success; short-term increase in growth
	stream-bank erosion	reduced cover and stream depth	increased carrying capacity for fry; decreased carrying capacity for older juveniles; increased predation
		increased instream fine sediment; reduced food supply	reduced spawning success; slower growth rates for juveniles
Timber harvest on upslope areas	altered stream flow	temporary increase in summer stream flow	temporary increase in survival of juveniles
		increased severity of peak flows during storm season; bedload shifting	increased egg mortality

FORESTRY PRACTICE	POTENTIAL EFFECTS TO:		
	STREAM ENVIRONMENT	SALMONID HABITAT	SALMONID BIOLOGY
Timber harvest on upslope areas and road construction and use	increased erosion and mass wasting	increased instream fine sediment; reduced food supply	reduced spawning success, growth and carrying capacity; increased mortality of eggs and alevins; decreased winter hiding space and side-stream habitat
		increased instream coarse sediment	increased or decreased carrying capacity
		increased debris torrents; decreased cover in torrent tracks; increased debris jams	blockage to migration of juveniles and spawning adults; decreased survival in torrent tracks
	increased nutrient runoff	increased primary and secondary production	increased growth rate and summer carrying capacity
	stream crossings	barrier in stream channel; increased sediment input	blockage or restriction to migration; reduced spawning success, carrying capacity and growth; increased winter mortality
Scarification and slash burning	increased nutrient runoff	increased primary and secondary production	increased growth rate and summer carrying capacity
	increased input of fine organic and inorganic sediment	increased sedimentation in spawning gravels and production areas; temporary increase in oxygen demand	decreased spawning success; increased mortality of eggs and alevins

Most studies on the functions of riparian ecosystems have addressed single functions at site scales with the intent of determining the width of riparian zone needed to maintain the individual function under study (Everest and Reeves 2007). However, the multiple functions of riparian ecosystems operate in concert, with differing widths of unmanaged nearstream vegetation needed to maintain different functions. Relatively few studies have investigated the empirical relationship between riparian buffer width and salmonid populations (Murphy 1995; Hall et al. 2004). Barton et al. (1985) studied the dimension of riparian buffer strips required to maintain trout habitat in southern Ontario streams.

Table 2.2 Estimated widths of unmanaged near-stream vegetation in forested watersheds needed to maintain various functions of riparian ecosystems. Source: Everest & Reeves, 2007.

Riparian function	Width unmanaged vegetation required	References
Maintain water temperature	~50 m	Brazier and Brown 1973, FEMAT 1993, Steinblums et al. 1984
Maintain microclimate	~125 m*	Chen 1991, FEMAT 1993
Control sediment	~50 m	For example, U.S. Army Corps of Engineers 1991
Control nutrients/contaminants	~100 m±*	Desbonnet et al. 1994, Nriagu and Lakshminarayana 1989, Wenger 1999
Maintain streambed/banks	~30 m*	Erman et al. 1977
Maintain wildlife habitats	~150 m±*	Schoen 1977, USDA Forest Service 1997
Maintain fish habitats	>70 m*	Bisson et al. 1987, FEMAT 1993
Note: Widths were derived from site-scale studies but correctly apply to riparian networks at watershed scales.		
* = Requires late-successional or old-growth forest vegetation.		

FPRs have been developed in California and the Pacific Northwest to protect riparian ecosystems from the effects of forest harvest practices. Those practices have evolved over a period of more than 30 years to accommodate new scientific information and provide increased riparian protection. The culmination of forest practice rules resulted in development of the *Northwest Forest Plan* for protection of riparian zones on federal lands. Current state-of-the art- forest practices provide extensive protection to riparian ecosystems, but they have not been fully evaluated, so their efficacy remains unknown (Everest and Reeves 2007).

Everest and Reeves (2007) discuss in detail the establishment and evolution of forest practice rules in the Pacific Northwest, including Oregon, Washington, Alaska, but not California. In their report the authors stated;

> *"current rules, with all of their commonalities and differences, protect more of the ecological processes that form and maintain riparian and aquatic ecosystems than any of their predecessors. However, monitoring and evaluation at the appropriate temporal and spatial scales are needed to evaluate the effectiveness of current strategies. Therefore, each of the current rule sets only represents another step in the evolutionary process of forest practices development, and all could be changed again in the future to more, or perhaps less, restrictive rules depending on results of evaluations and changing legal, social, and science issues. Even after more than two decades of development, Murphy (1995) reported that all state forest practice rules in the Northwest and Alaska were judged to be ineffective in meeting goals for riparian*

management. Also, the Independent Multidisciplinary Science Team (IMST 1999) concluded that the most current Oregon forest practice rules would not recover habitat of listed stocks of salmonids. The nature and timing of future changes in forest practice rules is of vital interest to all parties concerned with management of forest resources in the West."

IMPORTANCE OF OFF-CHANNEL FLOODPLAIN HABITATS

In addition to utilizing main channel habitats such as pools or undercut banks juvenile salmonids, particularly coho salmon, are also known to inhabit side-channels and off-channel habitats such as ponds, shallow lakes and other areas of standing water (Tshapalinski and Hartman 1983; Swales and Levings 1989; Solazzi et al. 2000; Bramblett et al. 2002; Giannico and Hinch 2003; Pollock et al. 2004; Henning et al. 2006; Roni et al. 2006; Henning et al. 2007; Rosenfeld et al. 2008).

In British Columbia, juvenile coho salmon were found to overwinter in side-channels, beaver ponds and shallow lakes and migrate out as smolts the following spring. These off-channel habitats provided a sanctuary from adverse winter habitat conditions and habitat where fish can feed and overwinter (Bustard and Narver 1975; Tshapalinski and Hartman 1983; Swales and Levings 1989; Giannico and Hinch 2003; Rosenfeld et al. 2008). Similar findings have been observed in coho populations examined in Alaska, Oregon and Washington (Solazzi et al. 2000; Bramblett et al. 2002; Pollock et al. 2004; Ebersole et al. 2006; Henning et al. 2006).

Although winter conditions are not as severe in California as in more northern regions of the Pacific Northwest, there is also some evidence that in fall juvenile coho in northern coastal streams also migrate into side-channels and off-channel areas to overwinter and avoid high mainstem winter flows (Bell et al., 2001; Ransom, 2007; Brakensiek & Hankin, 2007; D. Gale, pers. comm. 2008). For example, juvenile coho salmon in Prairie Creek, a third-order tributary to Redwood Creek in north-western California, showed a fall migration to habitats such as backwaters and alcoves to avoid high winter mainstem flows (Bell et al. 2001). Macedo (1992) investigated the utilization by juvenile salmonids of two side-channels in the upper Trinity River near Lewiston, California. Coho salmon preferred side-channels during all seasons, while steelhead preferred side-channels during winter. Chinook salmon (*Oncorhynchus tshawytscha*) preferred side-channels in all seasons except winter. Brown trout (*Salmo trutta*) preferred side-channels during winter.

In addition to providing a refuge from high flows in the mainstem, off-channel habitats also often provide a less variable temperature regime and a more constant invertebrate food supply. A number of studies have reported that juvenile coho salmon remaining in off-channel habitats to overwinter exhibit higher growth rates and survival relative to coho salmon occupying mainstem habitats (Bustard & Narver 1975; Tschapalinski and Hartman 1983; Swales and Levings 1989).

Other salmonid species, including juvenile Chinook salmon, Atlantic salmon and steelhead, are also known to utilize off-channel and floodplain habitats; for example, the

winter utilization of coastal shallow lakes in British Columbia, Canada and Washington (Swales et al. 1988; Cunjak 1996). As with coho salmon, these salmonids also appear to utilize these off-channel habitats as a refuge from adverse winter conditions in mainstem areas.

Floodplain wetlands are also known to be utilized for juvenile salmonid rearing in inland river systems, such as the Sacramento River system, in northern California. Sommer et al. (2005) found evidence for rearing of juvenile Chinook salmon in the Yolo Bypass, a 24,000-ha floodplain of the Sacramento River, California. The results of the study indicated that floodplains appear to be a viable rearing habitat for Chinook salmon, making floodplain restoration an important tool for enhancing salmon production. Studies also showed evidence for enhanced growth and survival of juvenile Chinook salmon on the floodplain (Sommer et al. 2001).

IMPORTANCE OF HEADWATER STREAMS

Headwaters streams are known to constitute >80% of stream networks and watershed land areas in the United States (Leopold et al. 1964; Naiman et al. 2000; Gomi et al. 2002). There is growing scientific recognition of the importance of headwater streams and their riparian zones as unique habitats and as sources (and controllers) of energy, water sediment, nutrients and organic matter to downstream reaches (Gomi et al. 2002; Wipfli and Gregovich 2002; Meyer et al. 2007). Richardson and Daneby (2007) provided a synthesis of the ecology of headwater streams and their riparian zones in temperate forests.

Currently, the California FPRs afford most protection to Class I (fish bearing) and Class II (aquatic life other than fish) streams, with Class III streams (not supporting aquatic life) having least protection. However, this is in direct contrast with current scientific understanding of the functioning of stream ecosystems, which places considerable emphasis on the important role in river ecosystem functioning played by headwater streams, which are classified as Class II or III, fishless, watercourses under the California Forest Practice Rules stream classification system. Other stream classification systems, such as the "stream order" system developed by Strahler (1957) are more commonly used in scientific studies.

The ecological functioning of river ecosystems is currently described by various models such as the River Continuum Concept (Vannote et al. 1980). In this model, there is a gradation of functioning along the riverine network, with shallow streams in headwater regions contributing organic matter in the form of wood and leaves etc. which are processed and consumed by invertebrate organisms in downstream reaches. LWD is an important component from riparian areas in headwater reaches which provides habitats, food and shelter for invertebrates and fish in downstream reaches. Almost half of the volume of wood found in fish-bearing streams in a pristine coastal Oregon watershed originated from small, steep tributary streams (Reeves et al. 2003).

Headwater streams are known to exert major influences on hydrogeomorphic process in

river systems, including the input of sediment, wood and organic matter (Naiman et al. 2000). Significant advances in our understanding of the dynamics of riparian systems in the last few decades have clarified how these processes affect riparian vegetation and how vegetation may modify stream channels through the delivery and routing of woody debris and sediment (Naiman et al. 2000; Wipfli 2005). Sediment is stored in small streams and is metered out to fish-bearing streams over time. The absence of wood results in these channels having bedrock exposed for extended periods because sediments move rapidly down the channel rather than being stored. The result is alteration of the sediment delivery regime and a reduction in the complexity of habitat in fish-bearing streams (Everest & Reeves 2007).

Intact riparian vegetation provides numerous benefits to instream fish habitat, including shading, bank stabilization, and inputs of organic matter and woody debris (Naiman et al. 2000;; Pusey and Arthington, 2003; Broadmeadow & Nisbet, 2004). Because of the widespread losses of riparian vegetation and the multiple benefits it provides, riparian restoration has been promoted as a key strategy for restoring the critical processes that create and maintain fish habitat (Kauffman et al. 1997; Beechie and Bolton 1999; Opperman and Merenlender 2004).

Although headwater streams, due to their high gradient and unsuitable habitat conditions, often do not support fish populations (Bliesner and Robinson 2007), they may provide important trophic linkages between headwater forests and downstream fish habitats (Chamberlin et al., 1991). Wipfli (2005) estimated that, based on the frequency of headwater streams in the watersheds studied, and the average amount of food delivered to downstream habitats by these streams, every kilometer of salmonid-bearing stream could receive enough energy from fishless headwaters to support 100-2,000 young-of-the-year salmonids.

Although headwater streams are frequently "fishless", they nonetheless appear to play a significant role in the ecology of river systems and hence the conservation of endangered salmonids. Naiman and Latterrell (2005) suggested that "fishless headwater streams are inseparable from fish-bearing rivers downstream" and that "fishless" streams are fish habitat in much the same way as is the riparian zone, and should hence be afforded protection.

From a fisheries perspective, headwaters may be crucial habitats for producing invertebrate food for fish, particularly since there is evidence that salmonid populations along the West Coast are often food limited (Everest and Reeves 2007). Consequently, headwater streams may provide an essential food supply for fish in downstream reaches (Wipfli 1996, 2005; Wipfli & Baxter, 2010). Stream reaches that are themselves inhospitable to salmonids may contribute to the maintenance of downstream salmonid populations (Everest and Reeves 2007). Headwater streams may also provide important habitats for amphibians and other wildlife (Richardson and Danehy 2007).

The ACS of the NFW Plan stated that "*headwater riparian areas need to be protected, so that when debris slides and flows occur, they contain coarse woody debris and boulders necessary for creating habitat farther downstream*". In an assessment of the success of the ACS after 10 years, Reeves (2006) stated that since the ACS was implemented new

scientific information has become available which underlines the importance of protecting headwater streams from disturbances. The concept of the riparian reserve was one of the cornerstones of the ACS, and the riparian reserve network included fish-bearing streams as well as small, fishless headwater streams. Before the ACS, these streams were not widely recognized as part of the aquatic ecosystem, but knowledge about and recognition of the ecological importance of headwater streams has increased since then (Reeves 2006).

Cummins and Wilzbach (2006) discussed the inadequacy of the fish-bearing criterion for stream management and forest management practices and suggest that the importance of intermittent, ephemeral, and very small first order channels as suppliers of invertebrates and detritus to permanently flowing, receiving streams that support juvenile salmonids warrant their protection during timber harvest. It was concluded that criteria other than the presence or absence of juvenile salmonids need to be considered in managing forested watersheds.

Recently, studies of coho salmon populations in an Oregon watershed showed that intermittent streams were an important source of coho salmon smolts (Ebersole et al. 2006; Wigington et al. 2006). Residual pools in intermittent streams provided a means by which juvenile coho survive during dry periods; smolts that over wintered in intermittent streams were larger than those from perennial streams. Movement of juvenile coho into intermittent streams from the mainstem was another way in which the fish exploited the habitat and illustrates the importance of maintaining entire stream networks. The authors concluded that loss of intermittent stream habitat would have a negative effect on coho salmon populations in coastal drainages.

Similarly, in a coastal Oregon watershed, a stream that was nearly dry in midsummer supported high densities of spawning coho salmon in the fall, and juveniles rearing there exhibited relatively high growth rates and emigrated as larger smolts (Ebersole et al. 2006). Improved winter growth and survival of juvenile coho salmon utilizing tributary habitats underscore the importance of maintaining connectivity between seasonal habitats and providing a diversity of sheltering and foraging opportunities, particularly where main-stem habitats have been simplified by human land uses (Ebersole et al., op.cit.).

FISH/FORESTRY INTERACTIONS AND RIPARIAN MANAGEMENT PRACTICES

Fish - forestry interactions in Oregon, Washington and Alaska are described by Hall et al. (2004), while in a recent report, Everest & Reeves (2007) described the riparian and aquatic habitats of the Pacific Northwest and southeast Alaska and their ecology, management history and potential management strategies. Lee and others (2004) provided a quantitative review of riparian buffer width guidelines from Canada and the United States. Mean buffer widths varied from 15.1 to 29 meters for different waterbody types when both countries were combined. Also, Young (2000) discusses and compares riparian zone management in the different states of the Pacific Northwest and also in Canada, and concludes that "the governments of the PNW have taken a "manage until degraded, then protect" approach to riparian forest management that is unlikely to maintain or restore the

full suite of riparian-stream linkages necessary for lotic ecosystems to function naturally at the stream, watershed, basin or regional scale."

NORTHWEST FOREST PLAN – AQUATIC CONSERVATION STRATEGY (ACS)

The ACS was developed to restore and maintain the ecological health of watersheds and aquatic ecosystems contained within them on public lands. The strategy aims to protect salmon and steelhead habitat on federal lands managed by the United States Forest Service and Bureau of Land Management within the range of Pacific Ocean anadromy. This conservation strategy uses several methods to further the goal of maintaining a "natural" disturbance regime.

Components of the ACS

Everest & Reeves (2007) state that as identified in the Northwest Forest Plan (NWF) Plan; the ACS consists of four main elements:

1. *Riparian Reserves:* Lands along streams and unstable and potentially unstable areas where special standards and guidelines direct land use.
2. *Key Watersheds:* A system of large refugia comprising watersheds that are crucial to at-risk fish species and stocks and provide high quality water.
3. *Watershed Analysis:* Procedures for conducting analysis that evaluate geomorphic and ecologic processes operating in specific watersheds. This analysis should enable watershed planning that achieves ACS objectives. Watershed analysis provides the basis for monitoring and restoration programs and the foundation from which Riparian Reserves can be delineated.
4. *Watershed Restoration:* A comprehensive, long-term program of watershed restoration to restore watershed health and aquatic ecosystems, including the habitats supporting fish and other aquatic and riparian-dependent organisms.

These components are designed to operate together to maintain and restore the productivity and resiliency of riparian and aquatic ecosystems. Late-Successional Reserves are also an important component of the ACS.

Summary of ACS for Riparian Reserves:

- Involves portions of the landscape where riparian-dependent and stream resources receive primary emphasis.
- Riparian Reserves are designated for all permanently-flowing streams, lakes, wetlands, and intermittent streams.
- Riparian Reserves include the body of water, inner gorges, all riparian vegetation, 100-year flood plain, landslides and landslide prone areas.
- Reserve widths are based on some multiple of a site-potential tree or a prescribed slope distance, whichever is greater. Reserve widths may be adjusted based on watershed analysis to meet ACS objectives.

- Standards and guidelines prohibit programmed timber harvest, and manage roads, grazing, mining and recreation to achieve objectives of the ACS.

Riparian Reserves are portions of watersheds where riparian-dependent resources receive primary emphasis and where special standards and guidelines apply. Standards and guidelines prohibit and regulate activities in Riparian Reserves that retard or prevent attainment of the ACS objectives. Riparian Reserves include those portions of a watershed directly coupled to streams and rivers. Riparian Reserves are required for maintaining hydrologic, geomorphic, and ecological processes that directly affect standing and flowing water such as lakes and ponds, wetlands, streams, stream processes, and fish habitats.

Riparian Reserves include primary source areas for wood and sediment such as unstable and potentially unstable areas in headwater areas and along streams. Riparian Reserves occur at the margins of standing and flowing water, intermittent stream channels, ephemeral ponds and wetlands. Riparian Reserves generally parallel the stream network but also include other areas necessary for maintaining hydrologic, geomorphic, and ecological processes.

Under the ACS, Riparian Reserves are used to maintain and restore riparian structures and functions of intermittent streams, confer benefits to riparian-dependent and associated species other than fish, enhance habitat conservation for organisms that are dependent on the transition zone between upslope and riparian areas, improve travel and dispersal corridors for many terrestrial animals and plants, and provide for greater connectivity of the watershed. The Riparian Reserves will also serve as connectivity corridors among the Late-Successional Reserves.

Interim widths for Riparian Reserves necessary to meet ACS objectives for different water bodies are established based on ecologic and geomorphic factors. These widths are designed to provide a high level of fish habitat and riparian protection until watershed and site analysis can be completed. Watershed analysis will identify critical hillslope, riparian, and channel processes that must be evaluated in order to delineate Riparian Reserves that assure protection of riparian and aquatic functions.

Riparian Reserves are delineated during implementation of site-specific projects based on analysis of the critical hillslope, riparian, and channel processes and features. Although Riparian Reserve boundaries may be adjusted on permanently flowing streams, the prescribed widths are considered to approximate those necessary for attaining ACS objectives. Post-watershed analysis Riparian Reserve boundaries for permanently-flowing streams should approximate the boundaries prescribed in these standards and guidelines. Post watershed analysis Riparian Reserve boundaries for intermittent streams, however, may be different from the existing boundaries. The reason for the difference is the high variability of hydrologic, geomorphic and ecologic processes in a watershed affecting intermittent streams. At the same time, any analysis of Riparian Reserve widths must also consider the contribution of these reserves to other, including terrestrial, species.

Watershed analysis should take into account all species that were intended to be benefited by the prescribed Riparian Reserve widths. Those species include fish, mollusks,

amphibians, lichens, fungi, bryophytes, vascular plants, American marten (*Martes americana*), red tree voles (*Arborimus pomo*), bats, marbled murrelets (*Brachyramphus marmoratus*), and northern spotted owls (*Strix occidentalis occidentalis*). The specific issue for spotted owls is retention of adequate habitat conditions for dispersal.

The prescribed widths of Riparian Reserves apply to all watersheds until watershed analysis is completed, a site-specific analysis is conducted and described, and the rationale for final Riparian Reserve boundaries is presented through the appropriate National Environmental Policy Act decision-making process.

RIPARIAN RESERVE DESCRIPTIONS (AFTER EVEREST & REEVES, 2007)

Riparian Reserve Widths
In the ACS, Riparian Reserves are specified for five categories of streams or water bodies as follows:

1. *Fish-bearing streams* - Riparian Reserves consist of the stream and the area on each side of the stream extending from the edges of the active stream channel to the top of the inner gorge, or to the outer edges of the 100-year flood plain, or to the outer edges of riparian vegetation, or to a slope distance equal to the height of two site-potential trees, or 300 feet slope distance (600 feet total, including both sides of the stream channel), whichever is greatest. (See Table 3-1 and Table 3-2.)

2. *Permanently flowing nonfish-bearing streams* - Riparian Reserves consist of the stream and the area on each side of the stream extending from the edges of the active stream channel to the top of the inner gorge, or to the outer edges of the 100-year flood plain, or to the outer edges of riparian vegetation, or to a slope distance equal to the height of one site-potential tree, or 150 feet slope distance (300 feet total, including both sides of the stream channel), whichever is greatest.

3. *Constructed ponds and reservoirs, and wetlands greater than one acre* – Riparian Reserves consist of the body of water or wetland and: the area to the outer edges of the riparian vegetation, or to the extent of seasonally saturated soil, or the extent of unstable and potentially unstable areas, or to a slope distance equal to the height of one site-potential tree, or 150 feet slope distance from the edge of the wetland greater than one acre or the maximum pool elevation of constructed ponds and reservoirs, whichever is greatest.

4. *Lakes and natural ponds* - Riparian Reserves consist of the body of water and: the area to the outer edges of the riparian vegetation, or to the extent of seasonally saturated soil, or to the extent of unstable and potentially unstable areas, or to a slope distance equal to the height of two site-potential trees, or 300 feet slope distance, whichever is greatest.

5. *Seasonally flowing or intermittent streams, wetlands less than one acre, and unstable and potentially unstable areas* - This category applies to features with high variability in size and site-specific characteristics. At a minimum, the Riparian Reserves must include::
   -- The extent of unstable and potentially unstable areas (including earth flows),

-- The stream channel and extend to the top of the inner gorge,
-- The stream channel or wetland and the area from the edges of the stream channel or wetland to the outer edges of the riparian vegetation, and
-- Extension from the edges of the stream channel to a distance equal to the height of one site-potential tree, or 100 feet slope distance, whichever is greatest.

6. *Wetlands and meadows less than 1 acre in size*. On slopes 20 percent and less, marshes, wet meadows (ecoclasses MS, MT, MW), moist meadows (MM), wet shrub lands (SW, SS) and forblands (F) are withdrawn from scheduled timber harvest. An influence area, typically up to 300 feet beyond the extent of riparian vegetation, shall be managed consistent with a prescription developed by an interdisciplinary team including a hydrologist and biologist or such that 85 percent of timber stands are in pole size or larger and 50 percent of the entire influence area is in mature and older age classes to provide hiding cover.

Table 3.1 Interim Riparian Reserve widths from the Northwest Forest Plan (slope distance each side) by site tree height and distance for riparian types. Widths are the larger of the two measures. See text for other geomorphic and vegetative considerations. Source: FEMAT 1993.

Riparian Type	Site Tree Slope Widths (Tree Heights)	Slope Widths (feet)
Fish-bearing streams	2	300
Lakes and natural ponds	2	300
Perennial, nonfish-bearing streams	1	150
Constructed ponds, reservoirs and wetlands greater than 1 acre in size*	1	150
Wetlands less than 1 acre in size	N/A	See Text
Intermittent streams	1	100

Table 3.2 Riparian Reserve "Buffer" Widths from the Northwest Forest Plan. Source: FEMAT 1993

Site Class	Site Index	Riparian Reserve
	Dominant Douglas-fir	"Buffer" Width
I	190' to 210'	244' to 257'
II	160' to 180'	208' to 232'
III	130' to 150'	170' to 195'
IV	100' to 120'	150' to 158'
V	80' to 90'	150' minimum for perennial streams; 100' for intermittent streams
VI	60' to 70'	150' minimum for perennial streams; 100' for intermittent streams

A series of reports were prepared to summarize the effectiveness of the NWF Plan over the first ten years of operation (1994-2003). Reeves (2006) provided an assessment of the success of the ACS and concluded that the ACS met its expectation that watershed condition would begin to improve in the first decade of the Plan. The conditions of watersheds in the NWF Plan appear to have improved slightly since the NWF Plan was implemented. The proportion of watersheds whose condition improved was significantly greater than those that declined. The primary reason for this was an increase in the number of large trees in riparian areas and a decrease in the extent of clearcut harvesting in riparian zones. This general trend of improvement is expected to continue, and may accelerate if the ACS is implemented in its current form. It is highly likely that these trends would have been reversed under many of the forest plans that were in place before the ACS (Reeves 2006).

In his 10 year review of the ACS Reeves (2006) stated the following; *"the riparian reserve network established by the ACS encompasses an estimated 2.6 million acres (Baker and others, in press) and was one of the major changes from previous forest plans. Before the ACS, the riparian ecosystem was generally defined as 100 feet on either side of fishbearing streams and some areas with high landslide risk. The riparian reserve network of the ACS was based on an "ecological functional" approach that identified zones of influence rather than set distances and included the entire stream network, not just fish-bearing streams. Consequently, the riparian zone along streams was expanded to the height of two site-potential trees (or 300 feet) along fish-bearing streams and one tree height (or 150 feet) along permanently flowing and intermittent non-fish-bearing streams (USDA and USDI 1994). The latter undoubtedly contributed the greatest to the increased amount of area considered as the riparian reserve. More than 800 of the more than 1,100 organisms*

considered in FEMAT (1993) were found to be associated with the riparian reserve network. It was also suggested in FEMAT (1993) that the width of the riparian reserve on each side of headwater streams be equal to one half the height of a site-potential tree, but it was changed to a full tree height in the ROD (USDA and USDI 1994) to increase the likelihood of persistence of habitat for aquatic and riparian-dependent organisms."

… "the initial riparian reserve network was expected to be interim, and activities within them were very restricted until a watershed analysis was completed. It appears, however, that the interim boundaries of the riparian reserves remained intact in the vast majority of watersheds. The primary reasons offered for the relatively low harvest in the riparian reserve were that it was difficult to justify changing the interim boundaries or that there was no compelling justification for changing the interim boundaries. (It should be noted that harvest from the riparian reserve was not part of the estimates of potential timber harvest.) Baker and others (in press) found that agency personnel thought that "burden of proof [for changing interim boundaries] was too high." No explicit criteria for changing the boundaries were offered by the Forest Ecosystem Management Assessment Team (FEMAT 1993) or the ROD (USDA and USDI 1994), but tools are available now that can help identify the more ecologically important parts of the riparian and stream network from an aquatic perspective (such as Benda and others, n.d.). Because watershed analysis is an interdisciplinary endeavor, however, changes in the riparian reserve boundaries need to consider nonaquatic factors such as terrestrial and social concerns. Only a few watershed analyses considered these factors (such as Cissel and others 1998). The effect of the extent of the riparian reserves is probably most likely in the steeper more highly dissected landscapes, where the riparian reserves network is most extensive (FEMAT 1993)."

CALIFORNIA FORESTRY ACTIVITIES, COHO SALMON RECOVERY & FOREST PRACTICE RULES

The 2004 *Coho Salmon Recovery Strategy* stated that historical forestry practices and some current forestry practices have been shown to impact several freshwater habitat components important to anadromous salmonids in general, and coho salmon specifically. These impacts include increased maximum and average summer water temperatures, decreased winter water temperature, and increased daily temperature fluctuations; increased sedimentation; loss of LWD; decreased dissolved oxygen concentrations; increased instream organic matter; and decreased stream-bank stability (Salo and Cundy 1987; Meehan 1991; Moring et al. 1994; Murphy 1995; Monschke 1996). Table 4.1 lists forestry practices and describes changes to the landscape and the potential effects on salmonid habitat conditions.

Even when some habitat conditions return to pre-timber-harvest levels, fish populations do not always recover, which may be due to other habitat conditions remaining sub-standard or having been permanently altered (Moring et al. 1994). Logged areas are further affected and aggravated by natural incidents (e.g., blow-downs, landslides) and by human activity subsequent to logging, all of which may result in negative cumulative impacts.

Identifying the relationships between forestry practices and habitat impacts is complicated for several reasons. First, there is a long history of timber harvesting, and some effects, such as sedimentation and slope instability, continue long after harvesting has occurred. These alterations are referred to as "legacy" effects, and recovery may take many decades (Murphy 1995). Legacy effects are a factor along the north coast of California (Monschke 1996). Second, there have been many technological and management changes in timber harvest, and it is difficult to differentiate legacy effects from recent or current effects. Third, the salmonid habitat elements affected by timber harvest are themselves intimately inter-related. The amount and size frequency distribution of LWD, water temperature, near-stream vegetation, sediment transport and deposition, land sliding, stream flow and supply, and turbidity are all linked to one another.

During the approximate 150-year history of timber harvest in coastal northern California, harvest practices have changed dramatically, primarily due to changes in technology and decreasing availability of larger or higher quality logs. Historical harvest and milling were often close to waterways; whereas modern trucks and tractors have enabled more recent harvesting to occur in a wider variety of areas within a watershed. Logs were once primarily transported by river and are now transported by trucks along specially constructed roads. Logs used to be removed from the forest by mules and railroad, and these mechanisms have been replaced by tractors and cabling networks (Mount, 1995).

Current forestry activities, including forest nonpoint source control programs, have made strides in improving pollution and sediment discharge into streams over historical forestry practices. California FPRs adopted, in part, for the benefit of anadromous fishes (e.g., FPR 916.9, 936.9, 956.9. Watershed Protection Extension, a.k.a Threatened and Impaired Watersheds) have been in effect since 2000. Table 4.1 compares the different watercourse protection standards, under pre-2000 FPRs, current California FPRs, and Federal protection (Forest Ecosystem Management Assessment; FEMAT). Although the new rules reduce some site-specific impacts, there has not been sufficient time to determine if there have been benefits to coho salmon.

The Department's conclusion is that historical forestry practices impacted and continue to impact watersheds inhabited by northern California coho salmon, and that current activities (e.g., road construction, use, and maintenance; activity near streams and on unstable slopes; removal of sources of future LWD), depending on how they are managed, can still affect important habitat elements essential to coho salmon.

The 2004 Recovery Strategy includes many range-wide recommendations concerning timber management to address the threats and issues facing coho salmon conservation (see Chapter 7), as well as specific watershed recommendations (see Chapter 8). DFG further subdivided and refined some recommendations to facilitate successful implementation, subject to the availability of funds (see Chapter 9). In addition, three alternative sets of recommendations were developed for timberland management in areas with coho salmon. Section I 13 of the Recovery Strategy measures the cost to forest landowners or companies from implementing these various alternatives.

Table 4.1 Comparison of Watercourse Protection Standards (Source: *DFG Coho Salmon Recovery Strategy, 2004*)

MANAGEMENT APPLICATION	CALIFORNIA FOREST PRACTICE RULES (FPR) PRIOR TO JULY 1, 2000	FPRS; PROTECTION IN WATERSHEDS WITH THREATENED OR IMPAIRED VALUES	FOREST ECOSYSTEM MANAGEMENT ASSESSMENT TEAM (FEMAT) JULY 1993
CLASS I WATERCOURSE			
Watercourse and Lake Protection Zone (from the hillslope edge of channel zone)	1. to 75' for <30% slopes 2. to 100' for 30-50% 3. to 150' for >50% Widths may be reduced if cable or helicopter system is used	1. 150' minimum 2. No Emergency Notice or Exemption operations allowed within the WLPZ	To top of inner gorge, outer edges of 100-year flood plain, outer edge of riparian vegetation, or to distance equal to height of two site potential trees, or 300 feet, whichever is greatest
WLPZ retention	1. 50% overstory canopy 2. 50% understory canopy 3. Retained overstory canopy must be at least 25% existing overstory conifer 4. Retention of at least 75% surface cover	1. Inner band (0-75'): 85% overstory canopy 2. Outer band (75-150'): 65% overstory canopy 3. Retained overstory canopy must be at least 25% overstory conifer 4. Retention of at least 75% surface cover	Removed from timber base; no timber harvest
Large wood debris retention	Two living conifers/acre, and 50' tall, within 50' of Class I and II watercourses.	The 10 largest trees (dead or alive) per 330' of stream, within 50' of the watercourse transition line.	No harvest zones in Riparian Reserves. Salvage allowed only if required to attain Aquatic Conservation Strategy (ACS) objectives
Inner gorge special treatment (special zone established where the slope >55%)	None	1. Extends to the first major break-in-slope a distance of 100' or 300' from the watercourse transition line, whichever is less 2. Requires use of selection harvesting 3. Even-age management above zone on slope >65% to be reviewed by geologist 4. All slopes exceeding 65% in the zone reviewed by Certified Engineering Geologist	Included in Riparian Reserve: no harvest.
CLASS II WATERCOURSE			
WLPZ	1. to 50' for <30% slopes 2. to 75' for slopes 30-50% 3. to 100' for >50% slopes	1. to 50' for <30% slopes 2. to 75' for slopes 30-50% 3. to 100' for >50% slopes 4. No Emergency Notice or Exemption	Permanently flowing non-fish bearing streams)- the edge of active stream channel" • top of inner gorge, outer edge of 100-year

Management Application	California Forest Practice Rules (FPR) Prior To July 1, 2000	FPRS; Protection In Watersheds With Threatened Or Impaired Values	Forest Ecosystem Management Assessment Team (FEMAT) July 1993
		operations allowed within the WLPZ	floodplain, outer edges of riparian vegetation, distance of one site potential tree, or 150 feet, whichever is greatest
WLPZ retention	1. 50% total canopy 2. Overstory canopy must be at least 25% existing overstory conifer 3. At least 75% surface cover	1. 50% total canopy 2. Overstory canopy must be at least 25% existing overstory conifer 3. At least 75% surface cover	Removed from timber base, no timber harvest
Large woody debris retention	None	None	No harvest zones in Riparian Reserves. Salvage allowed only if required to attain ACS objectives.
Inner gorge special treatment	None	None	Included in Riparian Reserve: no harvest.
Class III watercourse			
WLPZ	Established at the discretion of the Registered Professional Forester or California Department of Forestry and Fire Protection	Established at the discretion of the Registered Professional Forester or CDF	Definable channel and evidence of annual scour or deposition. Includes extent of unstable , potentially unstable areas, top of inner gorge, distance equal to ½ site potential tree height or 50‘, whichever is greatest
WLPZ retention	1. No canopy retention required. 2. 0-30% slope: 25’ equipment limitation zone (ELZ) 3. >30% slope: 50’ ELZ 4. 50% understory vegetation 5. Trees in channel zone	1. No canopy retention required 2. 0-30% slope: 25’ ELZ 3. >30% slope: 50’ ELZ 4. 50% understory vegetation 5. Trees in channel zone	No harvest
LWD retention	None	None	No harvest zones in Riparian Reserves. Salvage allowed only if required to attain ACS objectives.
Inner gorge special treatment	None	None	Included in Riparian Reserve: no harvest.

REVIEWS OF FOREST PRACTICE RULES BY OTHER AGENCIES

National Marine Fisheries Service (NMFS)

Further unpublished guidelines for forestry practices to protect salmonids have been prepared by other agencies, such as NMFS of the National Oceanographic and Atmospheric Administration (2000). The goal of the guidelines was to "protect and conserve federally listed salmonids in California by providing guidance to the State's timber management program that will allow for the attainment of healthy, functioning aquatic and riparian ecosystems. These guidelines are intended to assist the State of California in modification of the California FPR's, such that the forestry practices on non-federal lands will provide the ecosystem functions necessary for the conservation of salmonids."

NMFS report states that a strategy to address the adverse effects of forestry practices on the riparian environment must consider and adequately address the impacts of management on riparian functions important to salmonid habitat. Riparian zone width, management stand composition and stocking objectives may vary regionally upon variation in stand composition, site tree height, geology, slope, and baseline conditions. Studies indicate that air temperature and relative humidity are not significantly altered if buffer strips exceed 45 m (150 feet) in width. Buffer strips wider than this distance are likely necessary to maintain ambient conditions in managed second-growth stands and in relatively dry, inland low elevation forest types (NMFS 2000). The report considers the importance of floodplain and riparian connectivity, shade and microclimate, litter fall and nutrients, large woody debris, surface erosion, stream bank stability, roads and sediment, restoration, watershed analysis and cumulative watershed effects, and monitoring and adaptive management. However, the report lacks specific recommendations for riparian zone widths to protect salmonids. So far, these recommended guidelines appear not to have been adopted.

Watershed Protection and Restoration Council (WPRC)

In June 1999 a scientific review panel produced a report on California Forest Practice Rules and Salmonid Habitat (Ligon et al, 1999). The Scientific Review Panel (SRP) was created under the auspices of the Watershed Protection and Restoration Council, as required by the March 1998 Memorandum of Agreement (MOA) between NMFS and The Resources Agency of California. Under this agreement the state agreed to organize an independent panel of scientists to undertake a comprehensive review of the California FPRs, with regard to their adequacy for the protection of salmonid species.

The SRP concluded that "the FPRs, including their implementation (the "THP process") do not ensure protection of anadromous salmonid populations." The primary deficiency of the FPRs is the lack of a watershed analysis approach capable of assessing cumulative effects attributable to timber harvesting and other non-forestry activities on a watershed scale. As currently applied, Technical Rule Addendum No. 2 does not provide the necessary cumulative effects assessment at the appropriate temporal and spatial scales. Therefore,

with regard to the SRP's mandate, the state will need to sponsor and conduct watershed analyses in all watersheds within both steelhead ESUs. Also, specific rules governing onsite operations and road maintenance need stronger enforcement and/or modification to further minimize sediment production, improve stream habitat, and guarantee unrestricted passage by migrating juvenile and adult salmonids. The SRP focused on the following rule sections: watercourse protection measures, road construction and maintenance, and winter operations limitations.

Specific rule recommendations made by the SRP relevant to riparian zone protection include increased protection to the riparian zone and increased canopy cover, including:

- Increase Class I WLPZs to 150 ft and encourage thinning and selection harvesting to grow bigger trees faster; increase shade requirements to 85% for the first 75 ft and 65% for the remainder; permanently retain the 10 largest conifers trees for every 100 meters of stream channel; restrict salvage logging of downed trees within 75 ft of the watercourse; provide special harvesting zone on steep slopes and adjacent to evenage management.
- Class II: increase WLPZ to 100 ft and require 85% overstory canopy within 30 ft and 65% overstory canopy for the remainder; restrict salvage logging within first 30 ft; require retention of a minimum of 25% post-harvest overstory of conifers; assign a special operating zone adjacent to evenage management units.
- Class III: 30-50 ft ELZ; limit burning within zones; minimize and pre-designate all tractor crossings.

Some, but not all, of these recommendations were subsequently incorporated into the T/I rules.

DFG Commission/Board of Forestry and Fire Protection

In 2008, BOF adopted and implemented DFG 2112 Incidental Take Permit Guidelines for Timber operations. DFG also worked with CalFire to produce guidelines for implementing and using the new regulations. These regulations are for the protection of coho salmon with respect to timber operations. BOF's regulations, entitled *Coho Salmon Incidental Take Assistance, 2007*, specify forest practice requirements in planning watersheds containing coho salmon. DFG regulations, entitled *Incidental Take Permit Guidelines for Timber Operations, 2007,* specify conditions and circumstances when take of coho salmon is prohibited, when an incidental take permit is required, and when an incidental take permit is not required. These regulations are for the protection of coho salmon with respect to timber operations.

California Regional Water Quality Control Board (CRWQCB)

CRWQCB has also issued guidelines for riparian habitat protection in their draft report on Stream and Wetland Systems (CRWQCB, 2007).

This report listed several goals relevant to salmonids and their habitat, including:

- Achieve water quality standards and protect beneficial uses of waters of the state
- Restore habitat and protect aquatic species and wildlife
- To enhance flood protection through natural functions of stream and wetlands systems
- To encourage local watershed planning and support local oversight of water resources

The Stream and Wetland System Protection Policy recognizes that it is necessary to protect and restore the physical characteristics of stream and wetlands systems—stream channels, wetlands, riparian areas, and floodplains—including their connectivity and natural hydrologic regimes, to achieve water quality standards and protect beneficial uses, including for aquatic species. In a recent draft report on riparian buffers, their uses and maintenance, the Water Board stated that a riparian corridor that is wide enough to protect against all changes from associated clearcuts would have to be 600 to 900 feet wide and this zone would have to be protected against windthrow with a stand of trees equal to two potential tree heights of 300 to 600 feet. (CRWQCB *in-draft*).

Key components deemed necessary for considering appropriate buffer widths for the ecological recovery of coho salmon include:

1. Site-specific management prescriptions, watershed plans and regional recovery efforts. These goals should maintain and restore natural watershed processes that create habitat characteristics favorable to salmonids.

2. Maintain all habitat elements required by salmonids during every life stage from embryos through adults.

3. Maintain functional corridors linking the life stage habitats.

4. Maintain a well-dispersed network of high-quality stream habitats as refugia to serve as centers of population expansion.

5. Maintain centers of populations that can connect between high-quality habitats to allow for reinvasion and population expansion as degraded systems recover.

6. Maintain genetic diversity and integrity within and among salmonid stocks and species.

Establishment of riparian buffers must take into consideration:

1. What is the width and composition of the original historical buffer?

2. What is the composition and relationship between the adjoining forest and vegetative community adjoining the existing or historical riparian zone?

3. What riparian width is necessary to keep the existing beneficial uses intact considering the changes proposed?

California Board of Forestry and Fire Protection (BOF)

The recent *Scientific Literature Review of Forest Management Effects on Riparian Functions for Anadromous Salmonids* produced for BOF by Sound Watershed Consulting (SWC 2008) discusses the role of the riparian environment in stream ecosystem functioning and also considers how forest management practices may affect ecological functions. The report states that "*riparian management strategies require considerations of both science and policy. The reviewed literature offers many opinions, but little hard data to evaluate the scientific effectiveness of any approach. Ultimately, the choice of the best approach must be guided by forest policy*". The development of riparian reserves, selective management and proactive enhancement are discussed as options.

The report describes four key findings throughout the review of the literature that extend across all the exchange functions. These include:

1. Spatial context is important, as it influences functional response patterns.
2. Longitudinal controls (along the channel length) on exchange functions in addition to lateral controls (buffer width) are important in maintaining the watershed-scale ecosystem structure that maintains aquatic habitats.
3. There are dynamic interactions among and between riparian exchange functions that alter the importance of exchange functions for any particular setting.
4. While riparian zones can buffer a stream from direct management impacts, they do not protect streams from disturbances, but in fact alter the disturbance regimes in ways that can affect the functional response expressed by both short term and long-term evolution of riparian areas.

The report also states that there has been little agreement in the scientific community in defining the *minimum* buffer width necessary to provide sufficient wood recruitment to sustain salmonid habitat (Young 2001; Lisle 2002). One of the reasons that these issues remain unresolved is that there is no recognized ecological endpoint for which individual streams should be managed (Young 2001) and no consensus about how much wood is "enough" to support ecological functions (Lisle 2002). For example, the reviewed literature reports that the maximum width needed to contribute almost all of the woody debris recruitment *from treefall* is 1 tree-height (McDade et al.1990; Robison and Beschta 1990). Some of the reviewed literature has argued for wider buffers to protect the riparian community from direct and indirect disturbances associated with timber harvest (Reid and Hilton 1998; FEMAT 1993; Spence et al. 1996).

The report also states that …."*management of forests and fishes are both dependent on the restoration of natural processes that create diverse and productive ecosystems (Nakumura and Swanson 2003; Rieman et al. 2003). Recovery will generally require better integration of a common ecologically-based conceptual foundation, as well as improved attention to the landscape and ecological context".* A shift in thinking from a "protection" mindset (e.g. buffering the stream) to an ecosystem processes mindset is consistent with several general themes in the literature in recent years. These papers suggest that it may be more appropriate management objective to ensure that the ecosystem processes and functions are maintained to provide desired riparian and instream conditions in managed

settings.

There are three general approaches to achieve this objective that are promoted in the reviewed literature.

1. Riparian Reserves utilize large buffers so that mature to late-seral stand conditions are eventually achieved.
2. Resource Optimization seeks to balance appropriate protections against other management objectives.
3. Advanced Recovery/Enhancement manages growth and disturbance risks to influence ecosystem processes that create conditions favorable to salmonids over the short- and long-term.

The report concludes:

> "*our synthesis of the reviewed literature leads us to the conclusion that the importance of maintaining ecosystem functions, including those associated with disturbance, dynamics, growth, and spatial variability, point to the need for an evolutionary step in the design and application of riparian management strategies. A more holistic strategy would integrate landscape-scale concepts into local decision criteria. A wide array of analytical tools for evaluating watershed-scale processes and conditions are available, and the reviewed literature suggests that there is considerable scientific data to inform such tools.*"

However, DFG finds that many important subjects are not addressed by the Sound Water Consulting literature review including; inner gorge protection, slope specific buffer widths, site potential tree height relative to LWD recruitment/buffer width, winter period operations, water drafting, salvage of trees, site preparation, effects of channel changes on anadromous salmonid ecology and conservation, channel morphology, habitat diversity, off-channel and floodplain habitats, reference conditions and monitoring.

COMPARISON OF GUIDELINES FOR ESTABLISHING RIPARIAN ZONES AND CANOPY RETENTIONS BY DIFFERENT AGENCIES

Table 5.1 presented below compares riparian zone width guidelines made by different federal and state agencies in California and the Pacific Northwest.

The recommended guidelines for Class I streams are similar for most agencies, measured at 150', while the NWF Plan recommends two site-potential tree-heights, or 300'. Similarly, most agencies recommend retaining the 10 largest trees to provide LWD, while overstory canopy retention ranges from 65-85%. NMFS recommends one site-specific tree-height (SPTH) for Class I and II streams, starting at the outer edge of the flood prone zone. Riparian width guidelines for Class II streams are generally less than for Class I, being 50-100', depending on slope. Again, the recommended widths for the NWF Plan are greater, at 150'. Canopy retention guidelines are similar for most agencies. Class III streams are the least protected for all agencies, except for the NWF Plan, which requires a

riparian width of 100' to be retained, and NOAA which recommends a width of 0.5 SPTH for bank stability and sediment buffer.

Table 5.1. Riparian width and canopy retention guidelines recommended by the Northwest Forest Plan, Current Califonria Forest Practice Rules, California Department of Fish and Game 2112 Rules for coho salmon, agencies

	Northwest Forest Plan	**Current California Threatened and Impaired Watershed Rules**	**Department of Fish and Game 2112 rules for coho salmon**	**WPRC (SRP review, Ligon et al., 1999)**	**National Marine Fisheries Service recommendations (2002)**
Class I Riparian width	2 tree heights slope width 300’	WLPZ 150’ min	WLPZ 150’	WLPZ 150’	1 site potential tree-height (for LWD)
Class I Riparian canopy/LWD retention	2 tree heights slope width 300’	0-75’ – 85% 75-150’ – 65% 75% surface cover 10 largest trees retained for LWD Inner gorge special treatment	65-85% overstory canopy retention. Retain 10 largest dbh conifers per 330’ stream	65-85% overstory canopy retain 10 largest trees for every 100m	1 site potential tree-height (for LWD)
Class II Riparian width	1 tree height slope width 150’	WLPZ 50’ – 100’ for <30 - >50% slopes	WLPZ 100’	WLPZ 100’	1 site potential tree-height (for LWD)

	Northwest Forest Plan	Current California Threatened and Impaired Watershed Rules	Department of Fish and Game 2112 rules for coho salmon	WPRC (SRP review, Ligon et al., 1999)	National Marine Fisheries Service recommendations (2002)
Class II Riparian canopy /LWD retention	1 tree height slope width 150’	50% total canopy 25% overstory canopy No LWD retention or inner gorge special treatment	65-85% overstory canopy retention No LWD retention required?	65-85% overstory canopy	1 site potential tree-height (for LWD)
Class III Riparian width	1 tree height slope width 100’	At discretion of forester	25’-50’ ELZ depending on slope	30-50’ ELZ	0.5 site potential tree-height (for LWD)
Class III Riparian canopy /LWD retention	1 tree height slope width 100’	No canopy retention required	Retain snags, LWD, live trees 10” dbh or less; 50% understory retention	30-50’ ELZ	0.5 site potential tree-height (for LWD)

JUSTIFICATIONS FOR CHANGES IN T/I RULINGS ON RIPARIAN BUFFER WIDTHS TO BENEFIT ANADROMOUS SALMONIDS

As stated earlier, specific recommendations for riparian buffer widths must be determined by the specified management goals. In the case of anadromous salmonids, the goals must be to maintain and restore suitable instream and riparian habitat conditions for fish survival and growth. The importance of riparian vegetation in providing essential habitat for anadromous salmonids is well established, as described earlier. Justification for increasing the riparian buffer width must consider the following important habitat factors which would be likely to be affected by changes in riparian buffer width;

- Modifications to shade and water temperature provided by reduced canopy cover.
- Changes to instream cover/habitat complexity provided by large woody debris.
- Nutrients and food provided by extra canopy cover and woody debris.
- Sediment input.

In addition, each of these habitat factors varies in importance and function according to stream size and classification. As stated earlier, the current scientific view of river ecosystem functioning is as a continuum from the headwaters down to the lower reaches and estuary (Vannote et al. 1980; Minshall et al.1985). As noted elsewhere in this document, there is growing scientific recognition of the importance of headwater Class III streams, which may be fishless, in the functioning of river ecosystems and in maintaining the survival and abundance of downstream fish populations (Naiman and Latterrell 2005; Wipfli 2005). Also, the importance of off-channel and floodplain habitats for the survival and abundance of salmonids, particularly coho salmon, was discussed elsewhere in this document and in the scientific literature (Swales and Levings 1989; Sommer et al. 2001).

In their report on a proposed ecosystem approach to salmonid conservation, Spence et al. (1996) considered that litter inputs and bank stability are generally provided by trees within 0.5 potential tree heights of the channel. Shading and large woody debris are provided by trees further from the stream channel; in some instances, significant amounts of large wood may be carried to the channel in landslides or debris flows originating outside of the riparian zone. The effect of vegetation on sediment and nutrient inputs may extend even farther from the channel, though these influences are more difficult to define. Complete protection of salmonid habitats requires that all these functions are maintained. Cederholm (cited in Spence et al. 1996) proposed that riparian zones should be identified and buffer zones should be established around the riparian zone to prevent modification of riparian function. This proposal is in line with the guidelines proposed by NCRWQCB to protect the riparian zone and reduce sediment load to watercourses (*see* Section 8.4).

<u>Water Temperature</u>

Water temperature is an important feature of the aquatic environment in the continued survival of anadromous salmonids in the streams and rivers of California and the Pacific Northwest (Hicks et al. 1991). The removal of riparian vegetation canopy may result in

increased solar radiation which may increase stream temperature, light levels and primary production. In Oregon, Ringler and Hall (1975) found that clearcut logging resulted in increased temperature of intra-gravel water in salmon and trout spawning beds and decreased concentrations of dissolved oxygen. The changes were related largely to a reduction in forest cover over the stream surface and to deposition of fine sediment in the gravel. Consequently, it is essential that a suitable amount of riparian canopy cover be retained to maintain suitable water temperature conditions.

The extent of riparian cover required to satisfy these conditions varies according to channel width, with wider channels being less affected by shading provided by riparian vegetation compared to smaller streams, where riparian vegetation may shade most of the channel width. Increased water temperature through the loss of riparian vegetation may be more of a problem in California, where anadromous salmonids are at the limits of their ranges, than in northern cooler areas such as Alaska, where studies have found that stream temperature was increased by clear-cutting by up to 5°C (Meehan et al. 1969). For salmonids the most severe effects of riparian zone forest loss occur in the southern portions of their ranges where populations may be constrained by temperature conditions, even when there are no logging activities (Beschta et al. 1987). Sub-lethal effects of increased water temperature may also be important as fish emerge earlier from incubating eggs (Hartman 2004; Tschapalinski & Hartman, 1983). Also, even if not acutely lethal, high stream temperatures can reduce available rearing habitat, impede movements, increase susceptibility to diseases and influence competition (Beschta et al. 1987)

In the Alsea Watershed in Oregon, the complete clear-cut of Needle Branch resulted in substantial changes in habitat conditions for salmonids. In the year after logging, maximum stream temperature reached 30°C, compared with the previous maximum of 16°C (Hall and Lantz 1969). Rapid revegetation of the riparian zone moderated the high temperatures and by 1973 stream temperatures had returned to pre-logging levels (Moring and Lantz 1975). The riparian buffers left in the patch-cut watershed protected the stream from significant increase in solar radiation and there was only a minor increase in temperature. One of the principal contributions of the prelogging study in the Alsea study was to document the importance of small headwater streams to both anadromous and resident salmonids (Hall, 2008).

Clear-cut logging of 41% of the basin of Carnation Creek, British Columbia, resulted in increased stream temperatures in all months of the year, and increases above prelogging temperatures ranged from 0.7 °C to 3.2°C (Hartman & Scrivener, 1990; Hartman, 2004). Earlier emergence of coho salmon fry associated with the temperature increases lengthened their summer growing season by up to six weeks. Modest increases in water temperature during winter decreased the time required for egg incubation, shortened the time to fry emergence, and permitted a longer growing season for the young fish. Modest temperature increases during summer increased growth rates, and decreased the age at which young coho salmon moved to sea (Tschapalinski et al. 1998). Temperature increases during spring caused earlier movement to the ocean, and reduced marine survival (Holtby 1988; Hartman and Scrivener 1990).

Abundance and growth of salmonids can actually be enhanced by increased primary production and warmer stream temperatures if streams are relatively cool to begin with (Hawkins et al. 1983; Holtby 1988; Bilby and Bisson 1992). However, such benefits of logging may be negated if habitat is degraded by excessive sedimentation, stream temperatures are elevated to lethal levels, or large wood is lost (Moring and Lantz 1975; Hartman and Scrivener 1990; Hicks et al. 1991).

Large Woody Debris (LWD)

LWD is now recognized as an important component of salmonid habitat through providing instream cover, increased habitat complexity, protection from high flows, creating pool habitat and the provision of food and organic debris. Decreases in fish abundance have been documented following wood removal (Bryant 1983; Dolloff 1986; Elliot 1986; Bilby and Bisson 1998), while increases in fish abundance have been reported following deliberate additions of LWD (Cederholm et al. 1997; Roni and Quinn 2001. Riparian vegetation is an important source of LWD through treefall into the channel and bankside margins. In Alaska, most large woody debris is derived from with 30 m of the stream channel, through stream undercutting, windthrow, mortality, landslides and beaver activity (Murphy and Koski 1989).

The highest densities of juvenile salmonids are often associated with LWD and pool habitat (Murphy et al. 1986) and loss of wood reduces available habitat for juvenile salmonids (Dolloff 1986). A study of streams draining old-growth, clear-cut and second-growth forests in southwestern Washington found that the amount of LWD decreased as stream size increased in the three stand types, and was greatest at old-growth sites (Bilby and Ward 1991). In British Columbia, Young et al. (1999) investigated the status of resident cutthroat trout and their habitat twenty-five years after riparian logging. The results suggested that large pieces of wood that are left in and over small streams after logging may help protect resident trout populations following riparian logging.

Reeves et al. (1993) examined the relationships of timber harvest, stream habitat complexity, and diversity of juvenile salmonid assemblages in 14 small to intermediate-sized basins in coastal Oregon between 1985 and 1989. Diversity of assemblages in streams in basins with low harvest levels was greater than in streams with high harvest levels. Streams in basins with low timber harvest had more complex habitat, as manifest by more large pieces of wood per 100-meters.

LWD not only provides cover directly, but also forms 80-90 % of pools in valley bottom streams (Heifetz et al. 1986) and helps maintain water levels during low flow periods (Lisle 1986). In Washington, Grette (1985) studied long-term trends in abundance of large wood in streams and changes in juvenile salmonid rearing habitat. Large wood from old growth was more abundant in unlogged streams than in young, middle-aged, or old second-growth streams. Densities of older-aged juvenile steelhead and cutthroat trout correlated positively with area of pool cover formed by large wood in summer. Densities of coho salmon fry were not correlated with area of cover at summer low flows, but fry numbers in winter were closely related to the amount of wood (cited by Hall et al. 2004).

Since winter habitat is frequently a bottleneck in freshwater production of salmon smolts, clear-cutting without adequate buffers may have its most detrimental effects at this point (Koski et al. 1984; Murphy et al. 1986). Thedinga et al. (1989) reported that in Alaska streams although summer density of coho salmon fry was greater in both clear-cut streams and those with buffer zones than it was in old-growth streams, pre-smolts in late winter were less abundant in clear-cuts than in old growth, whereas buffered streams maintained the highest pre-smolt density. The disadvantage in clear-cuts was a reduction in pools and LWD; the advantage in buffered reaches was a combination of both enhanced food abundance because of more open canopy in summer and increased LWD cover in winter (Murphy et al. 1986).

Cederholm and Reid (1987) concluded that forestry-related mortality in the Clearwater basin was primarily caused by increased sediment load and by alterations in the riparian environment that reduced woody debris and denied access to rearing tributaries in winter (cited by Hall et al. 2004). In another study of channel morphology and woody debris in logged and unlogged basins of western Washington, timber harvest did not affect the number of pieces of wood within stream channels, but the size of individual pieces was smaller in harvested basins (Ralph et al. 1994). In harvested segments, debris was located toward channel margins and was less likely to provide instream cover during low flow periods.

Nutrients

In Washington streams, Cederholm and Reid (1987) determined that woody debris was important for retaining spawned-out salmon carcasses, making them more available as food for a myriad of fish and wildlife consumers (Cederholm and Peterson 1985; Cederholm et al. 1989). Logging practices and stream clean-out had depleted woody debris in some study streams, reducing potential for carcass retention. Recent studies have show that salmon carcasses provide an important source of nutrients to both aquatic and forest ecosystems and that reductions in salmon populations may reduce forest survival and growth (Willson et al.1998; Hall et al. 2004). LWD also provides a source of organic matter, nutrients and invertebrate food.

Removing the forest canopy can increase food availability by increasing aquatic primary productivity. Where food is limiting, summer density of coho salmon fry tends to be higher in clear-cut than old-growth areas (Murphy et al. 1986). Hall et al. (2004) suggested that the potential long-term decreases in production caused by increased shading by a dense second-growth canopy in late successional stages is probably more important than the short-term increases in production after clear-cutting (Bjornn et al. 1992). Also, although timber harvest tends to increase fry abundance in summer by opening the canopy, this positive effect can be nullified by reduced winter habitat (Murphy et al. 1986).

In the Smith and Klamath river basins in northern California, Wilzbach et al. (2005) studied the concurrent effects of riparian canopy opening and salmon carcass addition on salmonid biomass and growth rates over two years. Differences in specific growth rates of cutthroat and rainbow trout between open and closed canopy reaches were greater in sites

without carcasses than in sites with carcasses. It was suggested that in light-limited settings where temperature gains associated with canopy openings are not problematic for aquatic resources, gains in salmonid production might be achieved by selective trimming of riparian hardwoods.

Allan et al. (2003) examined the influence of streamside vegetation on inputs of terrestrial invertebrate to salmonid food webs. Terrestrial and aquatic prey composed approximately equal fractions of prey ingested. It was concluded that management of riparian vegetation is likely to influence the food supply of juvenile coho salmon and the productivity of stream food webs.

Sediment

Sediment input to a stream can be damaging to salmonid populations through smothering developing eggs within redds, increasing egg mortality, and hindering the emergence of alevins, so reducing juvenile recruitment. In the Harris River in Alaska, reduced egg mortality caused by sedimentation of spawning gravel was a principal cause of egg-to-fry mortality, with up to two to four times more fine sediment in the river during timber harvest (McNeil and Ahnell 1964). Compared with sediment production through roads, tree felling and yarding away from stream banks are thought to usually produce negligible sediment because coarse soils with high permeability and rapid revegetation help limit surface erosion after felling and yarding (Hall et al. 2004). Sediment production from landslides, however, can be increased by clear-cutting because increased snow accumulation in clear-cuts increases down-slope weight (USDA 1995).

SUMMARY OF FINDINGS AND RECOMMENDATIONS

In this publication, several recommendations are made to revise the T&I rules of the FPR to benefit the survival and abundance of anadromous salmonids, such as coho salmon. These include requiring adequate riparian protected zones (WLPZ) and canopy cover measures for all watercourses, providing increased protection to off-channel floodplain areas and headwater (Class II or III) streams. These measures are justified by scientific evidence which documents the adverse effects of forest management practices on shading and stream temperature regime, sediment input, large woody debris, and nutrient input to the stream.

FPRs in California and the Pacific Northwest continue to evolve as further scientific information becomes available. However, there is still considerable divergence in the standards recommended by different state and federal agencies. The guidelines recommended in the ACS of the NWF Plan do however currently appear to set the standard for the most effective approach to setting appropriate riparian zone widths and canopy closures for coastal streams in the Pacific Northwest. In particular, the approach taken by the ACS in identifying four key components to aquatic conservation strategies i.e. riparian reserves, key watersheds, watershed analysis, watershed restoration, appears to

have considerable merit (Reeves, 2006).

Because of the widespread losses of riparian vegetation and the multiple benefits it provides, riparian restoration has been promoted as a key strategy for restoring the critical processes that create and maintain fish habitat (Beechie and Bolton 1999; Roni et al. 2002). For example, Opperman & Merenlender (2004) examined the effectiveness of riparian restoration for improving channel morphology and fish habitat in four hardwood-dominated streams in Mendocino County, California. These streams support populations of steelhead and contain reaches that were restored through exclusionary fencing implemented 10-20 years earlier.

Channel morphology, LWD and late-summer water temperature were compared between restored exclosure reaches and geomorphically similar control reaches. Channels within exclosures were significantly narrower and had greater heterogeneity than control reaches. Frequencies of LWD and debris jams were considerably greater in exclosure reaches than control reaches and were comparable to values from similar streams with mature forests. Late-summer water temperatures in exclosures were within the acceptable range for steelhead, whereas water temperature in control reaches was warmer and potentially detrimental to steelhead. Riparian restoration in exclosures had resulted in quantitatively improved habitat characteristics and qualitatively different channel morphologies as compared to control reaches.

There is considerable scientific evidence providing justification for the increased protection of headwater streams habitats. Headwater streams, although often "fishless", have important functions in maintaining river ecosystem dynamics, particularly in providing organic matter and detritus to drive ecological processes in downstream reaches and also in providing invertebrate food for fish in downstream reaches. In this relation, the notion that "fishless" headwater streams are inseparable from fish-bearing rivers downstream appears to have considerable scientific merit.

Similarly, abundant studies have demonstrated the importance of side-channels and off-channel habitats, such as ponds, floodplain wetlands and other shallow waterbodies, in providing overwintering habitats for juvenile coho salmon and other juvenile salmonids. Several studies have also reported success in artificially recreating such areas in habitat improvement programs (Solazzi et al. 2000; Morley et al. 2005; Roni et al. 2006). Juvenile coho migrating from off-channel areas as smolts are often larger and show higher survival than smolts rearing in other areas.

As scientific understanding of the vital role played by these habitats increases, the restoration of riparian, floodplain and off-channel habitats forms an increasingly important component to stream and fish habitat restoration projects in the Pacific Northwest and elsewhere (Kauffman et al. 1997; Solazzi et al., 2000Giannico and Hinch, 2003; Roni et al., 2002, 2006; Rosenfeld et al. 2008). Reeves and others (1995) proposed a new paradigm as a template for forest management in the Pacific Northwest, based on the observation that landscape disturbance caused by timber harvest differs in several important ways from the natural disturbance regime. The outcome of the present regime of

disturbance by timber harvest has been a reduction in the complexity of stream habitat. The Reeves proposal suggests altering timber harvest and its accompanying disturbance to more closely mimic the character, timing and spatial scale of the natural disturbance regime to which fish populations have adapted, thereby regaining some of the lost habitat complexity. Specific management recommendations include:

- Increased riparian protection in headwall first and second order tributaries so that the legacy of hill-slope failures will include more large wood;
- Longer intervals between timber harvests

Concentrated rather than dispersed management that more closely mimic the pattern generated by natural disturbance.

Long-term conservation of salmonids requires protecting not only the immediate functions that riparian vegetation provides, but the ecological conditions within the riparian zone needed to maintain natural vegetation communities (e.g. soil productivity, microclimate) as well (Spence et al.1996). Although riparian buffers alone are insufficient to ensure healthy salmonid communities, there is consensus in the scientific community that protection of riparian ecosystems should be central to all salmonid conservation efforts on both public and private lands (FEMAT 1993; Murphy et al.,1995).

Everest & Reeves (2007) point out that full recovery of riparian structure and function from modified forest management practices may require a century or more while riparian vegetation recovers sufficiently to again contribute large woody structure and bank stability to aquatic systems. In the meantime, federal Endangered Species Act listings of more salmonid stocks and other aquatic species may occur, and additional extinctions are possible. Moyle et al. (2008) also predict that most or all coho salmon populations in coastal streams in both the CCC and SONCC ESUs will be extinct within 25-50 years. This underlines the extreme importance of restoring suitable habitats for threatened salmonid species in California and the Pacific Northwest and minimizing any adverse effects from land and water management practices.

In October 2009, BOF formally adopted a joint submission from CalFire and DFG to revise the "Threatened & Impaired" rulings of the California Forest Practice Rules. The revised T&I rulings will henceforth be known as the *"Anadromous Salmonid Protection Rules"* and will afford increased lasting protection to anadromous salmonid habitat in the state of California.

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