Endangered Species Act (ESA) Section 7(a)(2) Biological Opinion
and
Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation

Mad River Hatchery and Genetic Management Plan
NMFS Consultation Number: *WCR-2016-5423*

Action Agency: *National Marine Fisheries Service*
Program operator: *California Department of Fish and Wildlife*

Affected Species and NMFS' Determinations:

ESA-Listed Species	Status	Is Action Likely to Adversely Affect Species or Critical Habitat?	Is Action Likely To Jeopardize the Species?	Is Action Likely To Destroy or Adversely Modify Critical Habitat?
NC Steelhead (*Oncorhynchus mykiss*)	Threatened	Yes	No	No
California coastal Chinook (*O. tshawytscha*)	Threatened	Yes	No	No
SONCC coho salmon (*O. kisutch*)	Threatened	Yes	No	No
Southern Pacific Eulachon (*Thaleichthys pacificus*)	Threatened	No	n/a	n/a

Fishery Management Plan That Describes EFH in the Project Area	Does Action Have an Adverse Effect on EFH?	Are EFH Conservation Recommendations Provided?
Pacific Coast Salmon	No	No

Consultation Conducted By: National Marine Fisheries Service, West Coast Region

Issued By: for

Barry A. Thom
Regional Administrator

Date: DEC 2 2 2016

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1 INTRODUCTION

This Introduction section provides information relevant to the other sections of this document and is incorporated by reference into Sections 2 and 3, below.

The proposed action is NOAA's National Marine Fisheries Service's (NMFS) decision on a request submitted by the California Department of Fish and Wildlife (CDFW) for authorization under Limit 5 of the 4(d) rule for the Mad River Hatchery's winter-run steelhead program. This biological opinion does not predetermine the outcome of the 4(d) decision and only provides NMFS' opinion on the anticipated effects of the proposed action and whether it is likely to jeopardize listed species and/or adversely modify critical habitat. In the event that the ultimate 4(d) decision differs markedly from that proposed and analyzed here, NMFS will reinitiate consultation. CDFW operates the Mad River Hatchery and neither this opinion nor a proposed approval provides any authorization for those programs. The 4(d) rule exempts the take of salmon and steelhead listed as threatened species under the Endangered Species Act (ESA) if the entity follows a Hatchery and Genetics Management Plan (HGMP) that meets the 4(d) rule criteria and is approved by NMFS (July 10, 2000; 65 FR 42422, amended June 28, 2005, 70 FR 37160)—that approval step is informed by but separate from the analysis and conclusion of this biological opinion.

1.1 Background

NMFS prepared the biological opinion (opinion) and incidental take statement portions of this document in accordance with section 7(b) of the Endangered Species Act (ESA) of 1973 (16 USC 1531 *et seq*.), and implementing regulations at 50 CFR 402.

We also completed an essential fish habitat (EFH) consultation on the proposed action, in accordance with section 305(b)(2) of the Magnuson-Stevens Fishery Conservation and Management Act (MSA) (16 U.S.C. 1801 et seq.) and implementing regulations at 50 CFR 600.

We completed pre-dissemination review of this document using standards for utility, integrity, and objectivity in compliance with applicable guidelines issued under the Data Quality Act (section 515 of the Treasury and General Government Appropriations Act for Fiscal Year 2001, Public Law 106-554). The document will be available through NMFS' Public Consultation Tracking System at *https://pcts.nmfs.noaa.gov/pcts-web/homepage.pcts*. A complete record of this consultation is on file at NMFS' Arcata California Coastal Office.

1.2 Consultation History

NMFS first received a draft HGMP from CDFW in 2006. Since that time, NMFS has had regular discussions with CDFW and drafts have been exchanged and commented on and revised with the culmination of the November 4, 2014, determination by NMFS that CDFW had provided sufficient information in their HGMP. "Sufficient" means that an HGMP meets the criteria listed at 50 CFR 223.203(b)(5)(i), which include (1) the purpose of the hatchery program is described in meaningful and measureable terms, (2) available scientific and commercial information and data are included, (3) the Proposed Action, including any research, monitoring, and evaluation, is clearly described both spatially and temporally, (4) application materials provide an analysis of effects on ESA-listed species, and (5) preliminary review suggests that the program has addressed criteria for issuance of ESA authorization such that public review of the application materials would be meaningful.

The HGMP and a draft Environmental Assessment (EA) pursuant to the National Environmental Policy Act (NEPA) were made available for public comment upon publication of a notice of availability in the Federal Register on March 28, 2016 (81 FR 17143) and extended 15 days on May 4, 2016 (81 FR 26775). The public comment period expired on May 19, 2016. NMFS met with CDFW on May 25, 2016, to discuss the public comments and potential changes to the EA and HGMP. NMFS met with the Blue Lake Rancheria on June 2, 2016, to discuss their comments on the EA and HGMP. Public comments on the draft EA and HGMP have resulted in some minor changes to the proposed action since the November 4, 2014, draft of the HGMP and are reflected in the proposed action described in section 1.3, below (CDFW 2016).

1.3 Proposed Action

"Action" means all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by Federal agencies (50 CFR 402.02). The proposed action is the NMFS's decision as to whether to approve the implementation of the Mad River Hatchery's winter-run steelhead program, as described in the HGMP submitted by CDFW, pursuant to Limit 5 of the 4(d) rule for the Mad River Hatchery's winter-run steelhead program. In this section we describe: the proposed hatchery programs that are part of the "proposed action" using information provided in the HGMP.

NMFS describes a hatchery program as a group of fish that have a separate purpose and that may have independent spawning, rearing, marking and release strategies (NMFS 2008). The operation and management of every hatchery program is unique in time, and specific to an identifiable stock and its native habitat (Flagg *et al.* 2004). In this case, the Proposed Action is NMFS' proposed approval of the CDFW's Mad River HGMP (CDFW 2016) that proposes to collect adult winter steelhead and release juvenile steelhead into the Mad River near Blue Lake, California. This opinion analyses the direct and indirect effects from the implementation of the Proposed Action on ESA-listed species and their critical habitats.

In November 2014, the CDFW submitted a final HGMP pursuant to the 4(d) Rule for the Mad River Hatchery (MRH) winter-run steelhead program to NMFS's Northern California Office in Arcata, California. The CDFW requested final review and approval of the HGMP under the 4(d) Rule Limit 5. The 2014 HGMP was then modified in response to public comments and resubmitted to NMFS to facilitate this consultation (CDFW 2016). The Mad River HGMP (2016) outlines the winter-run NC steelhead supportive breeding and associated monitoring and evaluation actions that would occur in the lower Mad River watershed. The MRH is currently operating as per a court settlement agreement and releases winter-run NC steelhead into the lower Mad River. The proposed HGMP actions include:

1. Broodstock would be collected at MRH and throughout the Mad River watershed using seining, angling, volitional entry into the fish ladder, and weir collection methods. All natural-origin steelhead in excess of broodstock needs will be immediately released, at the collection location. Broodstock would include both hatchery and natural fish.

Natural broodstock would be incorporated into the spawning population in the same proportions as collected, such that 50-100 percent of the hatchery broodstock, with a target of 67%, would be of natural origin. Collections will be made throughout the run. Since the MRH may take up to 100 percent of their broodstock from the natural population, the number of natural fish collected for broodstock will follow the same rules for spawning at the hatchery, which means they will be collected based on a bell-shaped curve or normal distribution so that it is representative of the natural run, which means the collection will be apportioned based on the expected number of fish that comprise the run over time. Up to 250 adult steelhead or up to approximately 10 percent of the natural spawning population would be collected for broodstock. Collection methods may include volitional entry into the MRH fish ladder, seining, angling, or weir operations. Collection will primarily rely on volitional entry into the ladder; however, if the goal of using at least 50% natural-origin spawners cannot be met, then angling, seining, or weirs will be employed, in that order. Weirs would consist of temporary pipe weirs placed in tributary streams and anytime weirs are in operation they would be manned and non-target fish would be immediately placed upstream of the weir. Weirs would only operate to catch the target goal of broodstock and would not be used for enumeration or other purposes. Spawning would occur at the Mad River Hatchery. The hatchery would release adult fish, of both natural and hatchery origin, not used in the broodstock process back into the Mad River. Additionally, natural-origin fish used for spawning would be rehabilitated and released to encourage survival and repeat spawning. Any mortalities that occur in the hatchery ladder or spawning facility will be relocated into the Mad River above the hatchery to promote ecosystem function.

2. Egg incubation and juvenile fish would be reared at the MRH for approximately one year prior to being released.
3. The MRH would release up to 150,000 juvenile steelhead into the Mad River during March and April each year. Before they are released, all juvenile steelhead will have their adipose fin clipped off to mark them as hatchery fish. Clipping the adipose fin of 100 percent of the hatchery-origin juveniles prior to release would make these fish distinguishable from naturally produced fish, and provide options for management of fisheries that can selectively target hatchery-produced fish.
4. Monitoring and evaluation activities would assess the performance of the program in meeting conservation, harvest augmentation, and listed fish risk minimization objectives. Monitoring activities may include use of DIDSON or other sonar equipment to count fish; mark-recapture and run apportionment activities using seining, angling, and snorkeling; and collection of adult and juvenile steelhead using traps, seines, or other methods for genetic analysis and population monitoring. Run apportionment is necessary because the DIDSON does not discern fish by species so additional observations are necessary to determine what proportion of fish observed by the DIDSON belong to which species. Broodstock collection activities that require the use of a seine or angling will be scheduled to occur at the same time as run apportionment activities, if possible, to reduce the capture of coho salmon, Chinook salmon, and steelhead.
5. Based on a recommendation from the CDFW and NMFS technical-team meeting on August 25, 2009, the hatchery would be operated as an integrated hatchery program. The Proposed Action would also be consistent with the *Steelhead Restoration and Management Plan for California* (McEwan and Jackson 1996). MRH spawning protocol

would use one male for each sub-lot (two lots per female) derived from two different females. Mad River Hatchery would also incubate each lot separately to afford equalization (and documentation) of each family group contribution, if needed[1].

6. No construction would occur.

The number and species of fish expected to be collected or otherwise affected by broodstock collection and monitoring programs is found in Table 1 and Table 2. Pertinent operational elements of the Mad River HGMP (CDFW 2016) not listed above will be discussed and any effects analyzed in detail within the Effects of the Action (section 2.4) section of this Opinion.

Table 1. The number and species of adult, natural-origin steelhead, coho salmon, and Chinook salmon that may be collected annually during broodstock collection and monitoring operations under the Mad River HGMP. Expected mortalities (morts) are in parentheses and are based on observed mortalities in this and other similar programs.

	Ladder (morts)	Angling (morts)	Seining (morts)	Weirs (morts)
Steelhead*	175-300 (1)	175-300 (1)	175-300 (1)	175-300 (1)
Coho salmon	3 (0)	3 (0)	10 (0)	3 (0)
Chinook salmon	5 (0)	40 (1)	300 (1)	5 (0)

* The number of NC steelhead collected by each method will vary depending on the effectiveness of using the preferred method. The preferred method for broodstock collection is the ladder, angling, seining, and weirs, in that order. As such, the collection of coho salmon and Chinook salmon will also vary depending on which method or combination of methods is used. In addition, monitoring activities that require the capture of adult salmon and steelhead will be scheduled to coincide with broodstock collection activities, if necessary and when possible, to reduce the number of salmonids captured and potentially injured or killed. No more than 125-250 adult steelhead may be taken for broodstock and, at this level, up to another 50 may be captured during ME&R activities

[1] Culling options may require the participation of the NMFS Southwest Fisheries Science Center.

Table 2. The number and species of juvenile steelhead, Chinook salmon, and coho salmon annually collected as part of monitoring, evaluation and research that may be conducted as part of the HGMP implementation. Most fish would be captured, enumerated and released, but a certain proportion will be marked and used to develop capture statistics and population estimates. The maximum expected injuries/mortalities from all activities are in parentheses.

	Fry	Juvenile	Smolt
Steelhead	45000 (450)	65000 (650)	15000 150
Chinook salmon	42500 (425)	N/A	256000 (2560)
Coho salamon	3600 (36)	5000 (50)	6000 (60)

1.4 Interrelated and Interdependent Actions

"Interrelated actions" are those that are part of a larger action and depend on the larger action for their justification. "Interdependent actions" are those that have no independent utility apart from the action under consideration (50 CFR 402.02). NMFS has identified the recreational steelhead fishery in the Mad River as an interrelated action. There are no known interdependent actions identified.

The fishery on the Mad River is managed to focus on the recreational harvest of adult hatchery steelhead that are produced at the MRH. The fishery allows for the retention of steelhead identified as hatchery-origin steelhead by the absence of an adipose fin, which is removed prior to their release as smolts into the Mad River. Retention of natural-origin steelhead, Chinook salmon, and coho salmon is not allowed and they are required to be immediately released following capture. Despite the focus of the fishery on non-listed hatchery steelhead, some natural-origin steelhead, Chinook salmon, and coho salmon are subjected to angling-related injury and mortality during the catch and release fishery for these fish. Therefore, the effects of the fishery on listed natural-origin steelhead, Chinook salmon, and coho salmon will be further considered in section 2.4. Additionally, CDFW has committed to completing a draft Fishery Management and Evaluation Plan (FMEP) for this recreational fishery for authorization under the 4(d) rule within one year of approval of the HGMP—such a plan will help guide ongoing consideration and management of the effects of the fishery targeting the fish produced under the proposed action.

1.5 Action Area

"Action area" means all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action (50 CFR 402.02). The action area for the Mad River HGMP includes all areas of the Mad River accessible to steelhead adults and juveniles that are produced at the Mad River Hatchery, which can be defined as all mainstem and tributaries of the Mad River below Ruth Dam that are accessible or may become accessible in the future as a result of natural or human events. NMFS acknowledges that steelhead from the Mad River

Hatchery are also be present in the Pacific Ocean and a very small number of fish may stray to streams outside of the Mad River watershed. However, NMFS believes that the effects of either straying or hatchery steelhead presence in the Pacific Ocean is negligible due to the low number of fish that stray and the relatively small number of fish that the steelhead from the Mad River represent in the Pacific Ocean.

2 Endangered Species Act: Biological Opinion And Incidental Take Statement

The ESA establishes a national program for conserving threatened and endangered species of fish, wildlife, plants, and the habitat upon which they depend. As required by section 7(a)(2) of the ESA, Federal agencies must ensure that their actions are not likely to jeopardize the continued existence of endangered or threatened species, or adversely modify or destroy their designated critical habitat. Per the requirements of the ESA, Federal action agencies consult with NMFS and section 7(b)(3) requires that, at the conclusion of consultation, NMFS provides an opinion stating how the agency's actions would affect listed species and their critical habitat. If incidental take is expected, section 7(b)(4) requires NMFS to provide an incidental take statement (ITS) that specifies the impact of any incidental taking and includes non-discretionary reasonable and prudent measures and terms and conditions to minimize such impacts.

We have determined that the proposed action is not likely to adversely affect Southern Pacific Eulachon or its critical habitat. Our determination is documented in section 2.11, "Not Likely to Adversely Affect" Determinations, below.

2.1 Approach to the Analysis

This biological opinion includes both a jeopardy analysis and an adverse modification analysis. The jeopardy analysis relies upon the regulatory definition of "to jeopardize the continued existence of a listed species," which is "to engage in an action that would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species" (50 CFR 402.02). Therefore, the jeopardy analysis considers both survival and recovery of the species. NMFS has developed a viable salmonid population (VSP) concept which includes the parameters of population abundance, population growth rate, population spatial structure, and population diversity for defining a viable population which is an independent Pacific salmonid population that has a negligible risk of extinction due to threats from demographic variation, local environmental variation, and genetic diversity changes over a 100-year time period. An ESU/DPS is typically made up of multiple independent populations.

The adverse modification analysis considers the impacts of the Federal action on the conservation value of designated critical habitat. This biological opinion relies on the definition of "destruction or adverse modification," which "means a direct or indirect alteration that appreciably diminishes the value of critical habitat for the conservation of a listed species. Such alterations may include, but are not limited to, those that alter the physical or biological features essential to the conservation of a species that preclude or significantly delay development of such features" (81 FR 7214).

We use the following approach to determine whether a proposed action is likely to jeopardize listed species or destroy or adversely modify critical habitat:

- identify the rangewide status of the species and critical habitat likely to be adversely affected by the proposed action (section 2.2);
- describe the environmental baseline in the action area (section 2.3);
- analyze the effects of the proposed action on both species and their habitat using an “exposure-response-risk” approach (section 2.4);
- describe any cumulative effects in the action area (section 2.5);
- integrate and synthesize the above factors by: (1) Reviewing the status of the species and critical habitat; and (2) adding the effects of the action, the environmental baseline, and cumulative effects to assess the risk that the proposed action poses to species and critical habitat (section 2.6);
- if necessary, define a reasonable and prudent alternative to the proposed action.

For the Mad River HGMP consultation, NMFS examined an extensive amount of information from a variety of sources, including the final SONCC Coho Salmon Recovery Plan (NMFS 2014), the Public Draft of the Multispecies Recovery Plan (NMFS 2015), and the Final Mad River HGMP (CDFW 2016).

2.2 Rangewide Status of the Species and Critical Habitat

This opinion examines the status of each species that would be adversely affected by the proposed action. The status is determined by the level of extinction risk that the listed species face, based on parameters considered in documents such as recovery plans, status reviews, and listing decisions. This informs the description of the species’ likelihood of both survival and recovery. The species status section also helps to inform the description of the species’ current “reproduction, numbers, or distribution” as described in 50 CFR 402.02. The opinion also examines the condition of critical habitat throughout the designated area, evaluates the conservation value of the various watersheds and coastal and marine environments that make up the designated area, and discusses the current function of the essential physical and biological features that help to form that conservation value.

2.2.1 Life History and Range

2.2.1.1 Coho Salmon

Coho salmon adults migrate to and spawn in small streams that flow directly into the ocean, or tributaries and headwater creeks of larger rivers (Sandercock 1991, Moyle 2002). Adults migrate upstream to spawning grounds from September through late December, peaking in October and November. Spawning occurs mainly November through December, with fry emerging from the gravel in the spring, approximately three to four months after spawning. Juvenile rearing usually occurs in tributary streams with a gradient of 3 percent or less, although they may move up to streams of 4 percent or 5 percent gradient. Juveniles have been found in streams as small as 1 to 2 meters wide. They may spend one to two years rearing in freshwater (Bell and Duffy 2007), or emigrate to an estuary shortly after emerging from spawning gravels (Tschaplinski 1988). With the onset of fall rains, coho salmon juveniles are also known to redistribute into non-natal rearing streams, lakes, or ponds, where they overwinter (Peterson 1982). At a length of 38–45 mm, fry may migrate upstream a considerable distance to reach lakes or other rearing areas (Sandercock 1991, Nickelson *et al.* 1992). Emigration from streams to the estuary and ocean generally takes place from March through June.

The SONCC Coho Salmon ESU includes all naturally spawned populations of coho salmon in coastal streams from the Elk River, Oregon, through the Mattole River, California. It also includes three artificial propagation programs: Cole Rivers Hatchery in the Rogue River Basin, and the Trinity and Iron Gate Hatcheries in the Klamath-Trinity River Basin.

2.2.1.2 Chinook Salmon

Chinook salmon follow the typical life cycle of Pacific salmon in that they hatch in freshwater, migrate to the ocean, and return to freshwater to spawn. Diversity within this life cycle exists, however, in the time spent at each stage. Juvenile Chinook salmon are classified into two groups, ocean-type and stream-type, based on the period of freshwater residence (Healey 1991). Ocean-type Chinook salmon spend a short period of time in freshwater after emergence, typically migrating to the ocean within their first year of life. Stream-type Chinook salmon reside in freshwater for a longer period, typically a year or more, before migrating to the ocean. After emigration, Chinook salmon remain in the ocean for two to five years (Healey 1991) tending to stay in the coastal waters of California and Oregon. Chinook salmon are also characterized by the timing of adult returns to freshwater for spawning, with the most common types referred to as fall-run and spring-run fish. Typically, spring-run fish have a protracted adult freshwater residency, sometimes spawning several months after entering freshwater, and produce stream-type progeny. Fall-run fish spawn shortly after entering freshwater and generally produce ocean-type progeny. Historically, both spring-run and fall-run fish existed in the CC Chinook Salmon ESU. At present, only fall-run fish appear to be extant in the ESU.

Fall-run Chinook salmon are decidedly ocean-type (Moyle 2002), specifically adapted for spawning in lowland reaches of big rivers and their tributaries (Moyle 2002, Quinn 2005). Adults move into rivers and streams from the ocean in the fall or early winter in a sexually mature state and spawn within a few weeks or days upon arrival on the spawning grounds (Moyle 2002). Juveniles emerge from the gravel in late winter or early spring and within a matter of months, migrate downstream to the estuary and the ocean (Moyle 2002, Quinn 2005). This life history strategy allows fall-run Chinook salmon to utilize quality spawning and rearing areas in the valley reaches of rivers, which are often too warm to support juvenile salmonid rearing in the summer (Moyle 2002).

The CC Chinook Salmon ESU includes all naturally spawned populations of Chinook salmon from rivers and streams south of the Klamath River (exclusive) to the Russian River (inclusive). Seven artificial propagation programs are considered part of the ESU: the Humboldt Fish Action Council (Freshwater Creek), Yager Creek, Redwood Creek, Hollow Tree, Van Arsdale Fish

Station, Mattole Salmon Group, and Mad River Hatchery fall-run Chinook hatchery programs, but these programs were discontinued over a decade ago.

2.2.1.3 Steelhead

Steelhead probably have the most diverse life history of any of any salmonid (Quinn 2005). There are two basic steelhead life history patterns: winter-run and summer-run (Quinn 2005, Moyle 2002). Winter-run steelhead enter rivers and streams from December to March in a sexually mature state and spawn in tributaries of mainstem rivers, often ascending long distances (Moyle 2002). Summer steelhead (also known as spring-run steelhead) enter rivers in a sexually immature state during receding flows in spring, and migrate to headwater reaches of tributary streams where they hold in deep pools until spawning the following winter or spring (Moyle 2002). Spawning for all runs generally takes place in the late winter or early spring. Eggs hatch in 3 to 4 weeks and fry emerge from the gravel 2 to 3 weeks later (Moyle 2002). Juveniles spend 1 to 4 years in freshwater before migrating to estuaries and the ocean where they spend 1 to 3 years before returning to freshwater to spawn. Another expression of the life history diversity of steelhead is the “half pounder” - sexually immature steelhead that spend about 3 months in estuaries or the ocean before returning to lower river reaches on a feeding run (Moyle 2002). Half pounders then return to the ocean where they spend 1 to 3 years before returning to freshwater to spawn. This steelhead life history form has only been observed in the Rogue and Klamath Rivers (of the Klamath Mountain Province Steelhead DPS) and the Mad and Eel Rivers (of the NC Steelhead DPS, Busby *et al.* 1996). Unlike Pacific salmon, steelhead are iteroparous, or capable of spawning more than once before death (Busby *et al.* 1996). However, it is rare for steelhead to spawn more than twice before dying; most that do so are females (Busby *et al.* 1996). Some steelhead "residualize," becoming resident trout and never adopting the anadromous life history.

The NC Steelhead DPS includes all naturally spawned populations of steelhead in California coastal river basins from Redwood Creek (inclusive) southward to the Russian River (exclusive). Two artificial propagation programs are considered part of the DPS: the Yager Creek Hatchery and the North Fork Gualala River Hatchery (Gualala River Steelhead Project), but these programs were discontinued over a decade ago.

2.2.2 Status of the Species

2.2.2.1 SONCC Coho salmon

The following summary is from Williams *et al.* 2016, the most recent biological viability report for SONCC coho salmon:

> Although long-term data on coho abundance in the SONCC Coho Salmon ESU are scarce, all available evidence from more recent trends since the 2011 assessment (Williams *et al.* 2011) indicate little change since the 2011 assessment. The two population-unit scale time series for the ESU both have a trend slope not different from zero. The composite estimate for the Rogue Basin populations was not significantly different from zero ($p > 0.05$) over the past 12 years and significantly positive over the 35 years of the data set ($p = 0.01$). The continued lack of appropriate data remains a concern,

although the implementation of the Coastal Monitoring Program (CMP) for California populations is an extremely positive step in the correct direction in terms of providing the types of information to assess and evaluate population and ESU viability. The lack of population spatial scale monitoring sites in Oregon is of great concern and increases the uncertainty when assessing viability. Additionally, it is evident that many independent populations are well below low-risk abundance targets, and several are likely below the high-risk depensation thresholds specified by the TRT and the Recovery Plan (NMFS 2014). Though population-level estimates of abundance for most independent populations are lacking, it does not appear that any of the seven diversity strata currently supports a single viable population as defined by the TRT's viability criteria, although all occupied.

The SONCC Coho Salmon ESU is currently considered likely to become endangered. Of particular concern is the low number of adults counted entering the Shasta River in 2014-15. The lack of increasing abundance trends across the ESU for the populations with adequate data are of concern. Moreover, the loss of population spatial scale estimates from coastal Oregon populations is of great concern. The new information available since the 2011, while cause for concern, does not appear to suggest a change in extinction risk at this time.

2.2.2.2 CC Chinook Salmon

The following summary is from Williams *et al.* 2016, the most recent biological viability report for CC Chinook salmon.

The lack of long-term population-level estimates of abundance for Chinook salmon populations continues to hinder assessment of status, though the situation has improved with implementation of the CMP in the Mendocino Coast Region and portions of Humboldt County. The available data, a mixture of short-term (6-year or less) population estimates or expanded redd estimates and longer-term partial population estimates and spawner/redd indexes, provide no indication that any of the independent populations (likely to persist in isolation) are approaching viability targets. In addition, there remains high uncertainty regarding key populations, including the Upper and Lower Eel River populations and the Mad River population, due to incomplete monitoring across the spawning habitat of Chinook salmon in these basins (O'Farrell *et al.* 2012). Because of the short duration of most time series for independent populations, little can be concluded from trend information. The longest time series, video counts in the Russian River, indicates the population has remained steady during the 14-year period of record. The longer time series associated with index reaches or partial populations suggest mixed patterns, with some showing significant negative trends (Prairie Creek, Freshwater Creek, Tomki Creek), one showing a significant positive trend (Van Arsdale Station), and the remainder no significant trends.

At the ESU level, the loss of the spring-run life history type represents a significant loss of diversity within the ESU, as has been noted in previous status reviews (Good *et al.* 2005, Williams *et al.* 2011). Concern remains about the extremely low numbers of Chinook salmon in most populations of the North-

> Central Coast and Central Coast strata, which diminishes connectivity across the ESU. However, the fact that Chinook salmon have regularly been reported in the Ten Mile, Noyo, Big, Navarro, and Garcia rivers represents a significant improvement in our understanding of the status of these populations in watersheds where they were thought to have been extirpated. These observations suggest that spatial gaps between extant populations are not as extensive as previously believed.

In summary, Williams *et al.* (2016) concludes "there is a lack of compelling evidence to suggest that the status of these populations has improved or deteriorated appreciably since the previous status review" and that "the new available information does not appear to suggest there has been a change in the extinction risk of this ESU."

2.2.2.3 Steelhead

The following summary is from Williams *et al.* 2016, the most recent biological viability report for NC steelhead.

> The availability of information on steelhead populations in the NC Steelhead DPS has improved considerably in the past 5 years, due to implementation of the CMP across a significant portion of the DPS. Nevertheless, significant information gaps remain, particularly in the Lower Interior and North Mountain Interior diversity strata, where there is very little information from which to assess status (Figure 2). Overall, the available data for winter-run populations—predominately in the North Coastal, North-Central Coastal, and Central Coastal strata— indicate that all populations are well below viability targets, most being between 5% and 13% of these goals…for the two Mendocino Coast populations with the longest time series, Pudding Creek and Noyo River, the 13-year trends have been negative and neutral, respectively (Williams *et al.* 2016). However, the short-term (6-year) trend has been generally positive for all independent populations in the North-Central Coastal and Central Coastal strata, including the Noyo River and Pudding Creek (Williams *et al.* 2016). Data from Van Arsdale Station likewise suggests that, although the long-term trend has been negative, run sizes of natural-origin steelhead have stabilized or are increasing (Williams *et al.* 2016). Thus, we have no strong evidence to indicate conditions for winter-run have worsened appreciably since the last status review.
>
> Summer-run populations continue to be of significant concern because of how few populations currently exist. The Middle Fork Eel River population has remained remarkably stable for nearly five decades and is closer to its viability target than any other population in the DPS (Williams *et al.* 2016). Although the time series is short, the Van Duzen River appears to be supporting a population numbering in the low hundreds. However, the Redwood Creek and Mattole River populations appear small, and little is known about other populations including the Mad River and other tributaries of the Eel River (*i.e.*, Larabee Creek, North Fork Eel, and South Fork Eel).

> In summary, the available information for winter-run and summer-run populations of NC steelhead do not suggest an appreciable increase or decrease in extinction risk since publication of the last status reviews…most populations for which there are population estimates available remain well below viability targets; however, the short-term increases observed for many populations, despite the occurrence of a prolonged drought in northern California, suggests this DPS is not at immediate risk of extinction.

2.2.3 Factors for Decline (ESU or DPS Scale)

2.2.3.1 Timber Harvest

Timber harvest and associated activities occur over a large portion of the range of the affected species. Timber harvest has caused widespread increases in sediment delivery to channels through both increased landsliding and surface erosion from harvest units and log decks. Much of the largest riparian vegetation has been removed, reducing future sources of large woody debris (LWD) needed to form and maintain stream habitat that salmonids depend on during various life stages. In the smaller streams, recruited wood does not usually wash away, so logs remain in place and act as check-dams that store sediment eroded from hillsides (Reid 1998). Sediment storage in smaller streams can persist for decades (Nakamura and Swanson 1993).

In fish-bearing streams, LWD originating from mature coniferous forests is important for storing sediment, halting debris flows, and decreasing downstream flood peaks, and its role as a habitat element becomes directly relevant for Pacific salmon species (Reid 1998). LWD alters the longitudinal profile and reduces the local gradient of the channel, especially when log dams create slack pools above or plunge pools below them, or when they are sites of sediment accumulation (Swanston 1991).

Cumulatively, the increased sediment delivery and reduced LWD supply have led to widespread impacts on stream habitats and salmonids. These impacts include reduced spawning habitat quality, loss of pool habitat for adult holding and juvenile rearing, loss of velocity refugia, and increases in the levels and duration of turbidity that reduce the ability of juvenile fish to feed. These changes in habitat have led to widespread decreases in the carrying capacity of streams that support salmonids.

2.2.3.2 Road Construction

Road construction, whether associated with timber harvest or other activities, has caused widespread impacts on salmonids (Furniss *et al.* 1991). Where roads cross salmonid-bearing streams, improperly placed culverts have blocked access to many stream reaches. Land sliding and chronic surface erosion from road surfaces are large sources of sediment across the affected species' ranges. Roads also have the potential to increase peak flows and reduce summer base flows with consequent effects on the stability of stream substrates and banks. Roads have led to widespread impacts on salmonids by increasing the sediment loads. The consequent impacts on habitat include reductions in spawning, rearing, and holding habitat, and increases in turbidity. The delivery of sediment to streams can be generally considered as either chronic, or episodic. Chronic delivery refers to surface erosion that occurs from rain splash and overland flow. More episodic delivery, on the order of every few years, occurs in the form of mass wasting events, or landslides, that deliver large volumes of sediment during large storm events.

Construction of road networks can also greatly accelerate erosion rates within a watershed (Haupt 1959; Swanson and Dyrness 1975; Swanston and Swanson 1976; Reid and Dunne 1984; Hagans and Weaver 1987). Once constructed, existing road networks are a chronic source of sediment to streams (Swanston 1991) and are generally considered the main cause of accelerated surface erosion in forests across the western United States (Harr and Nichols 1993). Processes initiated or affected by roads include landslides, surface erosion, secondary surface erosion (landslide scars exposed to rain splash), and gullying. Roads and related ditch networks are often connected to streams via surface flow paths, providing a direct conduit for sediment. Where roads and ditches are maintained periodically by blading, the amount of sediment delivered continuously to streams may temporarily increase as bare soil is exposed and ditch roughness features, which store and route sediment and armor the ditch, are removed. Hagans and Weaver (1987) found that fluvial hillslope erosion associated with roads in the lower portions of the Redwood Creek watershed produced about as much sediment as landslide erosion between 1954 and 1980. In the Mattole River watershed, the Mattole Salmon Group (1997) found that roads, including logging haul roads and skid trails, were the source of 76 percent of all erosion problems mapped in the watershed. This does suggest that, overall, roads are a primary source of sediment in managed watersheds.

Road surface erosion is particularly affected by traffic, which increases sediment yields substantially (Reid and Dunne 1984). Other important factors that affect road surface erosion include condition of the road surface, timing of when the roads are used in relation to rainfall, road prism moisture content, location of the road relative to watercourses, methods used to construct the road, and steepness on which the road is located.

2.2.3.3 Hatcheries

Releasing large numbers of hatchery fish can pose a threat to wild salmon and steelhead stocks through genetic impacts, competition for food and other resources, predation of hatchery fish and wild fish, and increased fishing pressure on wild stocks as a result of hatchery production (Waples 1991). The genetic impacts of artificial propagation programs are primarily caused by the straying of hatchery fish and the subsequent hybridization of hatchery and wild fish. Artificial propagation threatens the genetic integrity and diversity that protects overall productivity against changes in environment (61 FR 56138, October 31, 1996). The potential adverse impacts of artificial propagation programs are well-documented (Waples 1991; Waples 1999; National Research Council 1995). The effects of the Mad River Hatchery program are the explicit focus of the effects analysis in this opinion in the action area. However, there are other hatchery programs that exist within the range of the listed ESUs/DPS.

2.2.3.4 Water Diversions and Habitat Blockages

Stream-flow diversions are common throughout the species' ranges. Unscreened diversions for agricultural, domestic, and industrial uses are a significant factor for salmonid declines in many basins. Reduced stream-flows due to diversions reduce the amount of habitat available to salmonids and can degrade water quality, such as causing elevated water temperatures.

Reductions in water quantity can reduce the carrying capacity of the affected stream reach by reducing the amount of available habitat, including by causing discontinuous flow and subsequent disconnected pools. Where warm return flows enter the stream, fish may seek reaches with cooler water, thus increasing competitive pressures in these areas.
Habitat blockages have occurred in relation to road construction as discussed previously. In addition, hydropower, flood control, and water supply dams of different municipal and private entities, have permanently blocked or hindered salmonid access to historical spawning and rearing grounds. The percentage of habitat blocked by dams is likely greatest for steelhead because steelhead were more extensively distributed upstream than Chinook or coho salmon. Because of migrational barriers, salmon and steelhead populations have been confined to lower elevation mainstems that historically only were used for migration and rearing. Population abundances have declined in many streams due to decreased quantity, quality, and spatial distribution of spawning and rearing habitat (Lindley *et al.* 2007).

2.2.3.5 Predation

Predation likely did not play a major role in the decline of salmon populations; however, it may have substantial impacts at local levels. For example, Higgins *et al.* (1992) and CDFG (1994) reported that Sacramento River pikeminnow (*Ptychocheilus grandis*) accidentally introduced to the Eel River basin are a major competitor and predator of the native salmonids found there.

2.2.3.6 Disease

Disease has not been identified as a major factor in the decline of ESA-listed salmonids. However, disease may have substantial impacts in some areas and may limit recovery of local salmon populations. Although naturally occurring, many of the disease issues salmon and steelhead currently face have been exacerbated by human-induced environmental factors such as water regulation (damming and diverting) and habitat alteration. Natural populations of salmonids have co-evolved with pathogens that are endemic to the areas salmonids inhabit and have developed levels of resistance to them. In general, diseases do not cause significant mortality in native salmonid stocks in natural habitats (Bryant 1994, Shapovalov and Taft 1954). However, when this natural habitat is altered or degraded, outbreaks can occur. For example, ceratomyxosis, which is caused by *Ceratonova shasta*, has been identified as one of the most significant diseases for juvenile salmon in the Klamath Basin due to its prevalence and impacts there (Nichols *et al.* 2007) that are related to reduced flows and increased water temperatures.

2.2.3.7 Commercial and Recreational Fisheries

Salmon and steelhead once supported extensive tribal, commercial, and recreational fisheries. NMFS has identified over-utilization as a significant factor in their decline. This harvest strongly affected salmonid populations because, each year, it removed adult fish from the ESU before they spawned, reducing the numbers of offspring in the next generation. In modern times, steelhead are rarely caught in ocean salmon fisheries. Directed ocean Chinook salmon fisheries are currently managed by NMFS to achieve Federal conservation goals for west coast salmon in the Pacific Coast Salmon Fishery Management Plan (FMP). The goals specify the numbers of adults that must be allowed to spawn annually, or maximum allowable adult harvest rates. In addition to the FMP goals, salmon fisheries must meet requirements developed through NMFS' intra-agency section 7 consultations, including limiting the incidental mortality rate of ESA-listed salmonids.

2.2.3.8 Climate Change

Global climate change presents a potential threat to salmonids and their critical habitats. Impacts from global climate change are already occurring in California. For example, average annual air temperatures, heat extremes, and sea level have all increased in California over the last century (Kadir *et al.* 2013). Snowmelt from the Sierra Nevada Mountains has declined (Kadir *et al.* 2013). However, total annual precipitation amounts have shown no discernible change (Kadir *et al.* 2013). Listed salmonids may have already experienced some detrimental impacts from climate change. NMFS believes the impacts on listed salmonids to date are likely fairly minor because natural, and local, climate factors likely still drive most of the climatic conditions steelhead experience, and many of these factors have much less influence on steelhead abundance and distribution than human disturbance across the landscape.

The threat to listed salmonids from global climate change will increase in the future. Modeling of climate change impacts in California suggests that average summer air temperatures are expected to continue to increase (Lindley *et al.* 2007, Moser *et al.* 2012). Heat waves are expected to occur more often, and heat wave temperatures are likely to be higher (Hayhoe *et al.* 2004, Moser *et al.* 2012. Kadir *et al.* 2013). Total precipitation in California may decline; critically dry years may increase (Lindley *et al.* 2007, Schneider 2007, and Moser *et al.* 2012). Wildfires are expected to increase in frequency and magnitude (Westerling *et al.* 2011, Moser *et al.* 2012).

For Northern California, most models project heavier and warmer precipitation. Extreme wet and dry periods are projected, increasing the risk of both flooding and droughts (DWR 2013). Estimates show that snowmelt contribution to runoff in the Sacramento/San Joaquin Delta may decrease by about 20 percent per decade over the next century (Cloern *et al.* 2011). Many of these changes are likely to further degrade listed salmonid habitat by, for example, reducing stream flow during the summer and raising summer water temperatures. Estuaries may also experience changes detrimental to salmonids. Estuarine productivity is likely to change based on changes in freshwater flows, nutrient cycling, and sediment amounts (Scavia *et al.* 2002, Ruggiero *et al.* 2010). In marine environments, ecosystems and habitats important to juvenile and adult salmonids are likely to experience changes in temperatures, circulation, water chemistry, and food supplies (Brewer and Barry 2008, Feely 2004, Osgood 2008, Turley 2008, Abdul-Aziz *et al.* 2011, and Doney *et al.* 2012). The projections described above are for the mid to late 21st Century. In shorter time frames, climate conditions not caused by the human addition of carbon dioxide to the atmosphere are more likely to predominate (Cox and Stephenson 2007, Santer *et al.* 2011).

2.2.3.9 Ocean Conditions

Variability in ocean productivity affects fisheries production both positively and negatively (Chavez *et al.* 2003). Beamish and Bouillion (1993) showed a strong correlation between North Pacific salmon production and marine environmental factors from 1925 to 1989. Beamish *et al.* (1997a) noted decadal-scale changes in the production of Fraser River sockeye salmon that they attributed to changes in the productivity of the marine environment. Warm ocean regimes are characterized by lower ocean productivity (Behrenfeld *et al.* 2006, Wells *et al.* 2006), which may affect salmon by limiting the availability of nutrients regulating the food supply, thereby increasing competition for food (Beamish and Mahnken 2001). Data from across the range of coho salmon on the coast of California and Oregon reveal there was a 72 percent decline in returning adults in 2007/08 compared to the same cohort in 2004/05 (MacFarlane *et al.* 2008). The Wells Ocean Productivity Index, an accurate measure of Central California ocean productivity, revealed poor conditions during the spring and summer of 2006, when juvenile coho salmon and Chinook salmon from the 2004/05 spawn entered the ocean (McFarlane *et al.* 2008). Data gathered by NMFS suggests that strong upwelling in the spring of 2007 may have resulted in better ocean conditions for the 2007 coho salmon cohort (NMFS 2008). The quick response of salmonid populations to changes in ocean conditions (MacFarlane *et al.* 2008) strongly suggests that density dependent mortality of salmonids is a mechanism at work in the ocean (Beamish *et al.* 1997b, Levin *et al.* 2001, Greene and Beechie 2004).

Predictions for adult returns of coho salmon and Chinook salmon in 2016 are poor and intermediate, respectively, given the primarily poor conditions (as reflected in ocean ecosystem indicator ratings) for juvenile coho salmon survival in the ocean in 2015, and the intermediate conditions for juvenile Chinook salmon in the ocean in 2016 (Peterson *et al.* 2015). The poor conditions reflect warmer than average sea surface and deep-sea temperatures associated with a relative lack of lipid-rich species of zooplankton, and krill biomass that was the lowest in the last 20 years (Peterson *et al.* 2015). These warm ocean conditions are attributed to a strengthening El Niño in addition to anomalously warm conditions (the "warm blob") that began in 2013 (Peterson *et al.* 2015).

The smolt to adult return rate for coho salmon at Freshwater Creek, a tributary of Humboldt Bay in Northern California, was less than 3 percent from 2011 to 2013 (Anderson *et al.* 2015). Bradford *et al.* (2000) found that the average coastal coho salmon population would be unable to sustain itself when marine survival rates fall below about 3 percent. Ocean conditions are not necessarily the only influence of marine survival; however, if marine survival is below 3 percent, the SONCC Coho Salmon ESU will have difficulty sustaining itself. Therefore, poor ocean conditions and low marine survival poses a key threat to the SONCC Coho Salmon ESU. This is likely the case for other ESUs and DPSs that use the California Current.

2.2.3.10 Drought

The following language is taken from Williams *et al.* 2016, which provides the most recent description of the effects of recent drought conditions on listed salmonids in California. California has experienced well below average precipitation in each of the past four water years (2012, 2013, 2014, and 2015), record high surface air temperatures the past two water years (2014 and 2015), and record low snowpack in 2015. Some paleoclimate reconstructions suggest that the current four-year drought is the most extreme in the past 500 or perhaps more than 1000 years. Anomalously high surface temperatures have made this a "hot drought," in which high surface temperatures substantially amplified annual water deficits during the period of below average precipitation. Four consecutive years of drought and the past two years of exceptionally high air, stream, and upper-ocean temperatures have together likely had negative impacts on the freshwater, estuary, and marine phases for many populations of Chinook salmon, coho salmon, and steelhead.

2.2.3.11 Marine-Derived Nutrients

Marine-derived nutrients (MDN) are nutrients that are accumulated in the biomass of salmonids while they are in the ocean and are then transferred to their freshwater spawning sites where the salmon die. The return of salmonids to rivers makes a significant contribution to the flora and fauna of both terrestrial and riverine ecosystems (Gresh *et al.* 2000), and has been shown to be vital for the growth of juvenile salmonids (Bilby *et al.* 1996, 1998). Evidence of the role of MDN and energy in ecosystems suggests a deficit of MDN may result in an ecosystem failure contributing to the downward spiral of salmonid abundance (Bilby *et al.* 1996). Reduction of MDN to watersheds is a consequence of the past century of decline in salmon abundance (Gresh *et al.* 2000).

2.2.4 Critical Habitat

NMFS is responsible for designating critical habitat for species listed under its jurisdiction. In designating critical habitat, NMFS considers the following requirements of the species: (1) space for individual and population growth, and for normal behavior; (2) food, water, air, light, minerals, or other nutritional or physiological requirements; (3) cover or shelter; (4) sites for breeding, reproduction, or rearing offspring; and, generally, (5) habitats that are protected from disturbance or are representative of the historic geographical and ecological distributions of this species (see 50 CFR 424.12(b)). In addition to these factors, NMFS focuses on the known physical and biological features (PBFs) within the designated area that are essential to the conservation of the species and that may require special management considerations or protection. The designation of critical habitat for species uses the term primary constituent element or essential features—the new critical habitat regulations (81 FR 7414) replace this term with physical or biological features (PBFs). The shift in terminology does not change the approach used in conducting our analysis, whether the original designation identified primary constituent elements, physical or biological features, or essential features. In this biological opinion, we use the term PBF to mean PCE or essential feature, as appropriate for the specific critical habitat. Section 4 of the ESA requires that economic, national security and other relevant impacts are taken into consideration when designating critical habitat. Moreover, section 7 of the ESA requires that Federal agencies (via consultation with NMFS) ensure any action they authorize, fund, or carry out will not result in the destruction or adverse modification of critical habitat. Designated critical habitat for all the species listed below overlaps with the action area.

This opinion analyzes the effects of the hatchery program on critical habitat for SONCC coho salmon, CC Chinook salmon, and NC steelhead. The ESA defines conservation as "to use all methods and procedures which are necessary to bring any endangered species or threatened species to the point at which the measures provided pursuant to the ESA are no longer necessary." As a result, NMFS approaches its "destruction and adverse modification" determinations by examining the effects of actions on the conservation value of the designated critical habitat—that is, the value of the critical habitat for the conservation of threatened or endangered species.

2.2.4.1 SONCC Coho Salmon Critical Habitat

Description
Designated critical habitat for SONCC coho salmon encompasses accessible reaches of all rivers (including estuarine areas and tributaries) between the Mattole River in California and the Elk River in Oregon, inclusive (May 5, 1999, 64 FR 24049). Excluded are: (1) areas above specific dams identified in the Federal Register notice; (2) areas above longstanding natural impassible barriers (*i.e.*, natural waterfalls); and (3) tribal lands. The area described in the final rule represented the current freshwater and estuarine range of coho salmon. Land ownership patterns within the coho salmon ESU analyzed in this document and spanning southern Oregon and northern California are 53% private lands, 36% Federal lands, 10% State and local lands, and 1% tribal lands.

The designated critical habitat for SONCC coho salmon is separated into the five PBFs of the species' life cycle. The five PBFs (essential habitat types) include: (1) juvenile summer and winter rearing areas; (2) juvenile migration corridors; (3) areas for growth and development to adulthood; (4) adult migration corridors; and (5) spawning areas. Within these areas, PBFs (essential features) of SONCC coho salmon critical habitat include adequate: (1) substrate, (2) water quality, (3) water quantity, (4) water temperature, (5) water velocity, (6) cover/shelter, (7) food, (8) riparian vegetation, (9) space and (10) safe passage conditions (64 FR 24049; May 5, 1999).

Current Condition
The condition of SONCC coho salmon critical habitat at the ESU scale, specifically its ability to provide for the species' conservation, has been degraded from conditions known to support viable salmonid populations that contribute to survival and recovery of the species. NMFS determined that present depressed population conditions are, in part, the result of human-induced factors affecting critical habitat, including: intensive timber harvesting, agricultural and mining activities, urbanization, stream channelization, dams, wetland loss, and water withdrawals for irrigation. All of these factors were identified when SONCC coho salmon were listed as threatened under the ESA, and they continue to affect this ESU (NMFS 2014). However, efforts to improve coho salmon critical habitat have been widespread and are expected to benefit the ESU over time (NMFS 2014).

Within the SONCC recovery domain, from 2000 to 2006, the following improvements were completed: 242 stream miles have been treated, 31 stream miles of instream habitat were stabilized, 41 cubic feet per second of water has been returned for instream flow, and thousands of acres of upland, riparian, and wetland habitat have been treated (NMFS 2007b). Therefore, the condition of SONCC coho salmon critical habitat is likely improved or trending toward improvement compared to when it was designated in 1999.

SONCC coho salmon are dependent upon complex, low gradient habitats for winter rearing, and will express diversity by overwintering in low-gradient, off-channel and estuarine habitats when they are available. The lack of complex aquatic habitat, and much decreased access to floodplains and low gradient tributaries are common features of current critical habitat conditions within the SONCC Coho Salmon ESU (NMFS 2014). The Recovery Plan also describes that land use activities (*e.g.*, timber harvest, road building, *etc*.) that occur upstream of low gradient streams, still affect the habitat within low gradient streams by reducing the amount of large wood and shade available and by increasing the amount of sediment that routes through the valley bottom habitats.

2.2.4.2 CC Chinook Salmon Critical Habitat

Description
Designated critical habitat for CC Chinook salmon includes the stream channels up to the ordinary high-water line (50 CFR Part 226.211). In areas where the ordinary high-water line has not been defined pursuant to 50 CFR Part 226.211, the lateral extent is defined by the bankfull elevation. Critical habitat in estuaries is defined by the perimeter of the water body as displayed on standard 1:24,000 scale topographic maps or the elevation of extreme high water, whichever is greater.

Critical habitat for CC Chinook salmon was designated as occupied watersheds from the Redwood Creek watershed, south to and including the Russian River watershed (70 FR 52488, September 2, 2005). Humboldt Bay and the Eel River estuary are designated as critical habitat for the CC Chinook Salmon ESU. Some areas within the geographic range were excluded due to economic considerations. Critical habitat was not designated on Indian lands. Designated critical habitat for CC Chinook salmon overlaps the action area. In designating critical habitat for CC Chinook salmon, NMFS focused on areas that are important for the species' overall conservation by protecting quality growth, reproduction, and feeding. The critical habitat designation for these species identifies the known PBFs that are necessary to support one or more Chinook salmon life stages, including: (1) freshwater spawning, (2) freshwater rearing, (3) freshwater migration, (4) estuarine areas, (5) nearshore marine areas, and (6) offshore marine areas. Within the PBFs, essential elements of CC Chinook salmon critical habitats include adequate (1) substrate, (2) water quality, (3) water quantity, (4) water temperature, (5) water velocity, (6) cover/shelter, (7) food, (8) riparian vegetation, (9) space, (10) safe passage conditions, and (11) salinity conditions (70 FR 52488, September 2, 2005).

Current Condition
The condition of CC Chinook salmon critical habitat, specifically its ability to provide for their conservation, is degraded from conditions known to support viable salmonid populations. NMFS has determined that present depressed population conditions are, in part, the result of the following human-induced factors affecting critical habitat: logging, agricultural and mining activities, urbanization, stream channelization, dams, freshwater and estuarine wetland loss, and water withdrawals for irrigation. All of these factors were identified when CC Chinook salmon were listed as threatened under the ESA, and they all continue to affect this ESU. However, efforts to improve CC Chinook salmon critical habitat have been widespread and are expected to benefit the ESU.

2.2.4.3 NC Steelhead Critical Habitat

Description
NMFS designated critical habitat for seven of the ESUs/DPSs of Pacific salmon and steelhead, including NC steelhead in September 2005 (70 FR 52488, September 2, 2005). Specific PBFs, that are essential for the conservation of each species, were identified as: freshwater spawning

sites; freshwater rearing sites; freshwater migration corridors; estuarine areas; nearshore marine areas; and offshore marine areas. Within the PBFs, essential elements of NC steelhead critical habitats include adequate (1) substrate, (2) water quality, (3) water quantity, (4) water temperature, (5) water velocity, (6) cover/shelter, (7) food, (8) riparian vegetation, (9) space, (10) safe passage conditions, and (11) salinity conditions (70 FR 52488, September 2, 2005).

Habitat areas within the geographic range of the ESU/DPSs having these attributes and occupied by the species were considered for designation. Steelhead critical habitat was designated throughout the watersheds occupied by the ESU/DPSs. In general, the extent of critical habitat conforms to the known distribution of NC steelhead in streams, rivers, lagoons and estuaries (NMFS 2005). In some cases, streams containing NC steelhead were not designated because the economic benefit of exclusion outweighed the benefits of designation, as in the North Fork Eel River. Native American tribal lands and U.S. Department of Defense lands were also excluded. Designated critical habitat for NC steelhead and CC Chinook salmon steelhead includes the stream channels up to the ordinary high-water line (50 CFR 226.211). In areas where the ordinary high-water line has not been defined pursuant to 50 CFR 226.211, the lateral extent is defined by the bankfull elevation. Critical habitat in estuaries is defined by the perimeter of the water body as displayed on standard 1:24,000 scale topographic maps or the elevation of extreme high water, whichever is greater.

Critical habitat for NC steelhead was designated as occupied watersheds from the Redwood Creek watershed, south to and including the Gualala River watershed. Humboldt Bay and the Eel River estuary are designated as critical habitat for the NC Steelhead DPS. Some areas within the geographic range were excluded due to economic considerations. Critical habitat was not designated on Indian lands. Designated critical habitat for NC steelhead overlaps the action area. In designating critical habitat for NC steelhead, NMFS focused on areas that are important for the species' overall conservation by protecting quality growth, reproduction, and feeding.

Current Condition

Similar to the current condition of SONCC coho salmon critical habitat, the current condition of NC steelhead critical habitat is degraded throughout most of the range of this species. Estuaries and lower river habitats are greatly reduced, in both area and condition, as the valley bottoms near the mouths of rivers are where most of the agricultural and urban development is concentrated. Levees constrain most estuaries and lower rivers in this DPS and prevent access to important off-channel rearing habitat. Upstream land uses increase the amount of sediment and warm water that enters low gradient streams and decreases the availability of large wood in these habitats.

The condition of NC steelhead critical habitat, specifically its ability to provide for their conservation, is degraded from conditions known to support viable salmonid populations. NMFS determined that present depressed population conditions are, in part, the result of the following human-induced factors affecting critical habitat: logging, agricultural and mining activities, urbanization, stream channelization, dams, freshwater and estuarine wetland loss, and water withdrawals for irrigation. All of these factors were identified when NC steelhead were listed as threatened under the ESA, and they all continue to affect this DPS. However, efforts to improve NC steelhead critical habitat have been widespread and are expected to benefit the DPS.

2.2.4.4 Conservation Value of Critical Habitat

The PBFs of designated critical habitat for SONCC and CCC coho salmon, NC, CCC, and S-CCC steelhead, and CC Chinook salmon are those accessible freshwater habitat areas that support spawning, incubation and rearing, migratory corridors free of obstruction or excessive predation, and estuarine areas with good water quality and that are free of excessive predation. Timber harvest and associated activities, road construction, urbanization and increased impervious surfaces, migration barriers, water diversions, and large dams throughout a large portion of the freshwater range of the ESUs and DPSs continue to result in habitat degradation, reduction of spawning and rearing habitats, and reduction of stream flows. The result of these continuing land management practices in many locations has limited reproductive success, reduced rearing habitat quality and quantity, and caused migration barriers to both juveniles and adults. These factors likely limit the conservation value (*i.e.*, limiting the numbers of salmonids that can be supported) of designated critical habitat within freshwater habitats at the ESU/DPS scale.

Although watershed restoration activities have improved freshwater critical habitat conditions in isolated areas, reduced habitat complexity, poor water quality, and reduced habitat availability because the same land management practices persist in many locations.

2.2.4.5 Summary

Although watershed restoration activities have improved freshwater and estuarine critical habitat conditions in isolated areas, reduced habitat complexity, poor water quality, and reduced habitat availability that resulted from historical and ongoing land management practices persist in many locations, and are limiting the conservation value of designated critical habitat within these freshwater and estuarine habitats at the ESU and DPS scales.

2.3 Environmental Baseline

The "environmental baseline" includes the past and present impacts of all Federal, state, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of state or private actions which are contemporaneous with the consultation in process (50 CFR 402.02).

2.3.1 Status of listed species in the action area

The Mad River is part of the Central Coast diversity stratum for SONCC coho salmon, and the North Coastal diversity stratum for CC Chinook salmon and NC winter steelhead (Spence *et al.* 2008, Williams *et al.* 2008). In addition, the Mad River is part of the Northern Coastal/North Mountain Interior diversity stratum for NC summer steelhead. For coho salmon, CC Chinook salmon, and NC steelhead, the Mad River is identified as an area that should ultimately support a viable population (one at low risk of extinction) because these populations are expected to play a key role in recovery of the ESU or DPS. In order for an ESU or DPS to be viable and eligible for delisting, all diversity strata that make up that ESU or DPS must be viable (Spence *et al.* 2008, Williams *et al.* 2008). Given the current expected roles of each population in recovery, the

Mad River must support a viable population in order for the Central Coastal and Northern Coastal diversity strata of coho salmon and Chinook salmon and NC steelhead, respectively, to be viable. Table 3 provides a summary of the status of coho salmon, steelhead, and Chinook salmon in the action area (Mad River).

Table 3. Status of the three ESA-listed salmonid species' populations found within the action area—the Mad River—as outlined in each species recovery, or draft recovery plans.

	SONCC Coho Salmon	CC Chinook Salmon Fall-Run	NC Steelhead (Winter-Run)	NC Steelhead (Summer-run)
Population within the Action Area	Mad River	Mad River	Mad River	Mad River
Diversity Stratum	Central Coastal	North Coastal	North Coastal/North Mountain Interior	North Coastal/North Mountain Interior
Role within ESU/DPS	Functionally Independent	Functionally Independent	Functionally Independent	Functionally Independent
Extinction Risk	High	Low*	Low*	High*
Depensation Threshold	Likely below	Above*	Above*	Below*
Spawner Abundance Target	9,300 adults	3,000 adults	Lower Mad River=3,200 adults Upper Mad River=6,100 adults	Effective populations size N_e>=500
Watershed Size/Potential Habitat	494 square miles 135 IP-KM	494 Square miles 94 IP-KM	494 Square miles Lower Mad River= 146 IP-KM; Upper Mad River= 304 IP-KM	494 Square miles Lower Mad River= 146 IP-KM; Upper Mad River= 304 IP-KM
Limiting Stresses	Altered Sediment Supply; Lack of Floodplain and Channel Structure	Estuary: Quality and Extent; Water Quality: Turbidity; Habitat Complexity: Large Wood, Shelter and Pools	Water Quality: Temperature and turbidity; Riparian Vegetation: Canopy Cover and Tree Diameter; Habitat Complexity: Large Wood	Water Quality: Temperature and turbidity; Riparian Vegetation: Canopy Cover and Tree Diameter; Habitat Complexity: Large Wood

	SONCC Coho Salmon	CC Chinook Salmon Fall-Run	NC Steelhead (Winter-Run)	NC Steelhead (Summer-run)
Limiting Threats	Roads, Mining/gravel extraction	Channel Modification; roads	Channel Modification; Logging and Wood harvesting; Roads	Channel Modification; Logging and Wood harvesting; Roads
Most recent 5-Year Viability report	Williams *et al.*, 2016	Williams *et al.*, 2016	Williams *et al.*, 2016	Williams *et al.*, 2016

*The Multispecies Recovery Plan did not assign extinction risk categories or address depensation levels, so professional judgement was used to assign these categories to be consistent with the SONCC Coho Salmon Recovery Plan.

Actual population estimates for coho salmon, summer-and winter- steelhead, and Chinook salmon are limited. CDFW has been operating sonar and apportioning results to species in the Lower Mad River since 2013. Preliminary estimates for 2013-2014 are 2,174 adult (does not include jacks) Chinook salmon and 7,785 winter steelhead of which 4,336 were hatchery origin and 3,449 were naturally produced (Michael Sparkmann-CDFW, personal communication, 2016). In addition, snorkel surveys for summer steelhead observed 282 summer steelhead in 2013 and 322 in 2014. Numbers for 2015 are not yet compiled; however, at least 1,900 Chinook salmon were counted in the lower Mad River during a one-time snorkel survey suggesting the numbers are likely similar to 2013-2014 (Michael Sparkmann-CDFW, personal communication, 2016). Expansion of coho salmon sonar and apportionment data has not been conducted due to the low number of coho salmon observed.

2.3.2 On-going effects on critical habitat in the action area

The Mad River is designated critical habitat for SONCC coho salmon, CC Chinook salmon, and NC steelhead. The key limiting stresses for each species are identified above in Table 3. Timber harvest, road building, gravel mining, grazing and water diversion/impoundment are the land and water uses that have had the most pronounced effect on salmon and steelhead habitat in the Mad River basin. Much of the North Fork watershed and the lower and middle portions of the Mad River basin are owned by Green Diamond Resource Company (GDRC) and are used for timber production. Grazing occurs on large ranches throughout the Mad River basin, as well as more concentrated grazing along the reaches of the lower river and its tributaries. Most of the upper basin is part of the Six Rivers National Forest and is managed using an ecosystem-based approach that provides for resource protection under the Northwest Forest Plan (Forest Ecosystem Management Assessment Team 1993). The Humboldt Bay Municipal Water District (HBMWD) constructed Matthews Dam in 1961 at river mile (RM) 84 in the upper basin, well upstream of historic coho salmon and Chinook salmon habitat, but it did block some steelhead habitat. The HBMWD also pumps groundwater and diverts surface water for municipal and industrial use at its Essex facility in the lower Mad River.

Extensive instream gravel mining occurs throughout the lower Mad River; mining practices have greatly improved since the 1970s. The majority of large gravel bars on the lower mainstem Mad River between Blue Lake and Highway 299 are mined each year, and annual mining typically removes the estimated mean annual recruitment of gravel coming into the mining reach. Although the Army Corps of Engineers permits gravel mining with numerous mitigation measures, such as a head-of-bar buffer to maintain river flow around the gravel bar and a skim floor elevation that maintains low to moderate channel confinement, gravel mining reduces the availability of complex rearing habitat in the lower Mad River (NMFS 2010). The communities of Arcata, Blue Lake, and McKinleyville are located along the lowermost reach of the Mad River, near the mouth. Many of the impacts of urbanization are in the form of development and associated road construction and land clearing, resulting in increased run-off and sedimentation.

The land uses described above have reduced available salmon and steelhead habitat throughout the basin. Increased sediment production from logged hill slopes and roads, especially as occurred during the 1955 and 1964 flood events, have filled the Mad River with sediment, creating chronically high turbidity levels. Although the Mad River basin has naturally high rates of sediment delivery due to unstable hill slopes prone to landslides and high rates of surface erosion, the U.S. Environmental Protection Agency (USEPA) estimated that 64 percent of total sediment delivered to streams was attributed to human and land management related activities, with roads being the dominant sediment source (USEPA 2007). In the lower Mad River and North Fork areas, total sediment loading is currently five times greater than natural sediment loading (USEPA 2007).

Compounding the increase in sediment delivery, loss of riparian vegetation has reduced shading and created a lack of instream large wood. These land uses have resulted in warm, shallow and wide instream habitat conditions that have severely impacted salmonids. Most of the basin is now comprises forest stands of smaller diameter trees, with a greater percentage of hardwoods that provide different ecological functions than those found historically (GDRC 2006).

Improved salmonid access to lower river tributaries such as Lindsay Creek is occurring through culvert upgrades and removal, but some of the lower river tributaries still have habitat blocked by road-stream crossings. Water impoundment has resulted in greater than naturally occurring summer flows in the middle and lower sections of the river, potentially increasing habitat availability during summer and early fall months. Screened water diversions at Essex in the lower river create fluctuations in the rate of flows in the summer and early fall. The impacts of this diversion are negligible in most instances; however, peak flows in the fall are dampened and this may make adult migration more difficult.

The Mad River is listed as "Impaired" for sediment and temperature under section 303(d) of the Clean Water Act (NMFS 2014). NMFS (2014) describes stresses to the Mad River salmonid populations as: lack of floodplain and channel structure, impaired water quality, altered sediment supply, degraded riparian conditions, and altered hydrologic function. Salmonid habitat in the Mad River is generally degraded. There is excessive sediment supply coming from roads and other land disturbances, which fills pools and interferes with spawning success. Suitable instream structure, as well as off-channel habitat, is extremely limited. These habitat features are essential to rearing juveniles. Insufficient riparian cover means there is not enough large wood falling into the stream to create this structure. Degraded riparian condition also leads to impaired water temperatures due to a lack of shade. Water temperatures in the lethal to stressful range have been observed Mad River (NMFS 2014). Tributary stream flows have been adversely affected by diversion of streams and springs for rural domestic and marijuana farming (NMFS 2014)

2.3.3 Factors affecting species environment within the action area

The key limiting threats, those that most affect the viability of the population by influencing stresses, are roads and mining/gravel extraction, and timber harvest. Several other threats with somewhat lower potential to affect survival and recovery are also present in the action area, as summarized below.

Roads

Road density is very high throughout the basin, ranging from 4.4 to 6.3 miles of road per square mile in the lower Mad River and North Fork areas (USEPA 2007). Roads are a substantial source of both chronic and catastrophic sediment input to streams in the basin, affecting the quality and quantity of available salmon and steelhead habitat in the Mad River and its tributaries. In 2007, the USEPA developed the TMDL for sediment and turbidity for the Mad River (USEPA 2007). An estimated 64 percent of the total sediment delivered to streams was attributed to human and land management-related activities, and road-related sediment contributes approximately 62 to 73 percent of the anthropogenic sediment in the basin (USEPA 2007).

Mining/Gravel Extraction

Historic gravel extraction was very damaging to the habitat in the lower Mad River until 1994. Current instream mining practices are much improved over past practices. The current mining is permitted by the Army Corps of Engineers and the permit contains numerous minimization measures to reduce the effects of gravel extraction on fish habitat, such as a head-of-bar buffer to provide for channel steering around skimmed gravel bars, provisions to provide low to moderate flow channel confinement, mining volumes that are scaled to annual water yield, and annual estimates of sediment recruitment to the lower Mad River. However, even with minimization measures, gravel extraction reduces overall habitat complexity. Given the sensitivity of the channel to disturbance (*i.e.*, current lack of floodplain and channel structure; low levels of instream wood), and the use of the gravel extraction reach by salmon and steelhead juveniles for rearing, gravel extraction is a high threat to salmon and steelhead in the Mad River.

Channelization/Diking

Channelization and diking presents a high threat to the Mad River population. Levees confine some of the lower mainstem river and the lower North Fork and disconnect the lower river channel from its floodplain and wetlands, reducing the availability of off-channel winter rearing habitat in the lower basin and reducing the ability of the channel to meander and create new habitats.

Timber Harvest

Timber harvest is a medium to high threat to the salmon and steelhead populations in the Mad River. Many of the changes that have occurred to instream and riparian conditions in the basin reflect legacy effects of more intensive harvest from previous decades. Although current timber harvest practices are more protective of salmonid habitat than before, timber harvest likely threatens the persistence of the salmonid populations by increasing sediment yield and reducing streamside shading and potential large wood recruitment. The majority of the private timberland in the Mad River basin is owned by Green Diamond and will continue to be harvested for timber. Within Green Diamond property, harvest occurs at a moderate level and under the direction of the company's Aquatic Habitat Conservation Plan (AHCP; GDRC 2006). This plan lays out goals and objectives to minimize and mitigate effects from timber harvest through measures related to road and riparian management, slope stability, and harvesting activities. Although the private timberland is managed under an AHCP that reduces the effects of timber harvest, increased sediment yield, decreased sources of instream wood, and decreased stream shading are still expected to occur.

Dams/Diversions

Dams and diversions pose a substantial threat to the Mad River salmonid populations. Diversions and groundwater pumping at the HBMWD Essex facility (RM 9 to 10) cause daily flow fluctuations during summer and fall months; however observations by NMFS staff and analysis of gage data (NMFS 2005c) show negligible impacts on juvenile salmonids, with water level never dropping more than 0.3 feet. Due to riffle grade control, it is unlikely that the amount of available habitat is decreased for rearing coho salmon and stranding has never been documented (HBMWD and Trinity Associates 2004). Changes in flows, however, may affect migration of adults during the fall. The impoundment of the Mad River at Matthews Dam has also increased summer and fall flows throughout most of the mainstem Mad River and increased habitat availability from RM 84 to RM 10.

Marijuana cultivation has increased in many areas of the SONCC coho, CC Chinook salmon, and NC steelhead salmon recovery domains in recent years. Although the number of plants grown each year is unknown, the water diversion required to support these plants is placing a high demand on a limited supply of water (Bauer 2013a). Most diversions for marijuana cultivation occur at headwater springs and streams, thereby removing the coldest, cleanest water in the summer and early fall which is the most stressful time of the year for juvenile salmonids (Bauer 2013b). Based on an estimate from the medical marijuana industry, each marijuana plant can consume 900 gallons of water per growing season (HGA 2010). A recent systematic survey of 60 out of 112 watersheds that were either in or bordered Humboldt County determined that up to 700,000 cubic meters of water would be consumed for marijuana cultivation (Butsic and Brenner 2016). At this time, the magnitude of these diversions in the Mad River watershed is unknown as the number of plants grown is increased or decreased and previously unpermitted diversions are permitted and winter storage of water is encouraged.

Agricultural Practices

Agricultural practices pose an overall medium threat to salmonids. Grazing occurs throughout the basin and may contribute to increased sediment generation and delivery and to decreased riparian vegetation. Other agriculture, such as the cultivation of hay, also occurs in the lower basin. Marijuana cultivation has become abundant in many areas of the Mad River. Although the number of plants grown each year is unknown, the herbicides, pesticides, and fertilizers and ground clearing activities used to support these plants are likely impairing water quality in salmonid habitat. Specific information on the magnitude of these activities is limited.

High Severity Fire

Altered vegetation characteristics throughout the basin pose a moderate threat to salmonids from high severity fires. Most of the basin contains forests of small diameter trees that are close together. These types of previously logged forests burn with greater intensity than late seral forest stands, and high severity forest fires create an erosion hazard. The increased sediment yield from high severity fires would likely deliver sediment to salmonid habitat in the basin, filling pools and reducing habitat complexity. Riparian vegetation would also be reduced or eliminated, and issues associated with inadequate riparian cover, including increased water temperatures and decreased macroinvertebrate abundance would be aggravated.

Climate Change

Climate change poses a threat to salmonid populations in northern California. Although the current climate is generally cool, modeled regional average temperature shows a relatively large increase over the next 50 years (the period to which the model applies) (PRBO 2011). Average air temperature could increase by up to 2°C in the summer and by 1°C in winter. Annual precipitation in this area is predicted to change little over the next century. The vulnerability of the estuary and coast to sea level rise is moderate in this population. Juvenile and smolt rearing are most at risk due to increasing temperatures and changes in the amount and timing of precipitation, which will affect water quality and hydrologic function in the summer. The range and degree of temperature and precipitation is likely to increase in all populations in the Mad River, and adult salmonids will be negatively affected by ocean acidification and changes in ocean conditions and prey availability (Feely *et al.* 2008).

Urban/Residential/Industrial Development

Population growth and development, especially in the Arcata and McKinleyville area, will continue to present a medium threat to salmonids in the Mad River because it results in removal of vegetation, increased sediment delivery, introduction of exotic species, and increased landscape coverage with impervious surfaces that alters water transport on land and subsequently affects instream flows. Most of the growth within Humboldt County is in the Arcata and McKinleyville area (projected at 0.6 percent annually), resulting in more water diverted from the lower Mad River. All of these activities are expected to result in a degradation of habitat for salmonids in the action area

Fishing and Collecting

Based on estimates of the fishing exploitation rate, as well as the status of the population relative to depensation and the status of NMFS approval for any monitoring-related scientific collection, these activities pose a medium threat to adult salmonids which means that the populations will be reduced. These fishery impacts have been ongoing and will be further discussed in section 2.4.2.7, as will the monitoring associated with the HGMP in section 2.4.2.5.

Road-Stream Crossing Barriers

Road-stream crossing barriers impede juvenile and adult salmonid migration and are considered a low threat to the population. Many of the road-stream crossing barriers in the lower Mad River and its tributaries have been addressed through culvert upgrades or other improvements.

Summary

The current status of habitat in the action area is improving relative to past conditions that lead to the listing of coho salmon, steelhead, and Chinook salmon in the Mad River. Timber harvest practices and road building have changed to reduce sediment inputs and increase future LWD recruitment to the stream channel. Some road systems on private timber land have been upgraded to reduce sediment. Gravel extraction practices have been changed to better control the volume of gravel extracted based on annual sediment recruitment estimates and protect the natural morphology of the stream. The lower Mad River is still influenced by levees and some sections of the river are restricted from occupying floodplains. However, localized restoration efforts including culvert replacement and other barrier removal activities, LWD enhancement, and creation of off-channel habitats will further improve conditions for listed salmon and steelhead in the Mad River.

Population monitoring of salmon and steelhead in the Mad River has been limited until recently. However, this limited monitoring suggests Chinook salmon and steelhead populations are likely increasing over previous estimates with the Chinook salmon being at least 70% of the recovery goal of 3,000 adults and the natural steelhead population at approximately 40% of the 9,300 goal. The steelhead population has measurably improved since 2001. The abundance of the coho salmon population is still unknown, but considered at high risk of extinction.

2.4 Effects of the Action

Under the ESA, "effects of the action" means the direct and indirect effects of an action on the species or critical habitat, together with the effects of other activities that are interrelated or interdependent with that action, that will be added to the environmental baseline (50 CFR 402.02). Indirect effects are those that are caused by the proposed action and are later in time, but still are reasonably certain to occur.

2.4.1 Factors That are Considered When Analyzing Hatchery Effects

NMFS has substantial experience with hatchery programs and has developed and published a series of guidance documents for designing and evaluating hatchery programs following best available science. These documents are available upon request from the NMFS. "Pacific Salmon and Artificial Propagation under the Endangered Species Act" (Hard *et al.* 1992) was published shortly following the first ESA-listings of Pacific salmon on the West Coast and it includes information and guidance that is still relevant today. In 2000, NMFS published "Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units" (McElhany *et al.* 2000) and then followed that with a "Salmonid Hatchery Inventory and Effects Evaluation Report" for hatchery programs up and down the West Coast (NMFS 2004b). In 2005, NMFS published a policy that provided greater clarification and further direction on how it analyzes hatchery effects and conducts extinction risk assessments (NMFS 2005b). NMFS then updated its inventory and effects evaluation report for hatchery programs on the West Coast (Jones 2006) and followed that with "Artificial Propagation for Pacific Salmon: Assessing Benefits and Risks & Recommendations for Operating Hatchery Programs Consistent with Conservation and Sustainable Fisheries Mandates" (NMFS 2008b).

A key factor in analyzing a hatchery program for its effects, positive and negative, on the status of salmon and steelhead is the genetic resources that reside in the program. Genetic resources that represent the ecological and genetic diversity of a species can reside in a hatchery program. "Hatchery programs with a level of genetic divergence relative to the local natural population(s) that is no more than what occurs within the ESU are considered part of the ESU and will be included in any listing of the ESU" (NMFS 2005b). NMFS monitors hatchery practices for whether they promote the conservation of genetic resources included in an ESU or steelhead DPS and updates the status of genetic resources residing in hatchery programs every five years. Generally speaking, hatchery programs that are reproductively connected or "integrated" with a natural population, if one still exists, and that promote natural selection over selection in the hatchery, contain genetic resources that represent the ecological and genetic diversity of a species and are included in a steelhead DPS. However, based on past integration of Eel River stocks in the Mad River broodstock and the apparent divergence of the MRH broodstock from native stocks, the MRH winter steelhead stock was not considered part of the ESU. The most recent status review continued this status, but acknowledged that the change in hatchery practices to create an integrated program may result in a change in status with the next status review update, depending on the success of the integration (Williams *et al* 2016).

For Pacific salmon, NMFS evaluates extinction processes and effects of the Proposed Action beginning at the population scale (McElhany *et al.* 2000). NMFS defines population performance measures in terms of natural-origin fish and four key parameters or attributes: abundance, productivity, spatial structure, and diversity and then relates effects of the Proposed Action at the population scale and ultimately to the survival and recovery of an entire ESU or DPS.

"Because of the potential for circumventing the high rates of early mortality typically experienced in the wild, artificial propagation may be useful in the recovery of listed salmon species. However, artificial propagation entails risks as well as opportunities for salmon conservation" (Hard *et al.* 1992). A Proposed Action is analyzed for effects, positive and negative, on the attributes that define population viability (viable salmonid population, or VSP), including abundance, productivity, spatial structure, and diversity. The effects of a hatchery program on the status of an ESU or steelhead DPS "will depend on which of the four key attributes are currently limiting the ESU, and how the hatchery fish within the ESU affect each of the attributes" (NMFS 2005b). The presence of hatchery fish within the ESU can positively affect the overall status of the ESU by increasing the number of natural spawners, by serving as a source population for repopulating unoccupied habitat and increasing spatial distribution, and by conserving genetic resources. "Conversely, a hatchery program managed without adequate consideration can affect a listing determination by reducing adaptive genetic diversity of the ESU, and by reducing the reproductive fitness and productivity of the ESU" (NMFS 2005b). NMFS also analyzes and takes into account the effects of hatchery facilities, for example, weirs and water diversions, on each VSP attribute and on designated critical habitat.

NMFS' analysis of the Proposed Action is in terms of effects it would be expected to have on ESA-listed species and on designated critical habitat, based on the best scientific information available on the general type of effect of that aspect of hatchery operation in the context of the specific application in the Mad River. This allows for quantification (wherever possible) of the various factors of hatchery operation to be applied to each applicable life-stage of the listed species at the population level (in Section 2.4.2), which in turn allows the combination of all such effects with other effects accruing to the species to determine the likelihood of posing jeopardy to the species as a whole (Section 2.6).

The effects, positive and negative, for the two categories of hatchery programs are summarized in Table 4. Generally speaking, effects range from positive to negative for programs that use local fish for hatchery broodstock and from negligible to negative when a program does not use local fish for broodstock. Hatchery programs can benefit population viability but only if they use genetic resources that represent the ecological and genetic diversity of the target or affected natural population(s). For the MRH winter steelhead program (as explained in section 2.4.2 below), NMFS expects that the effects will be somewhat mid-range between the two categories with a trend towards a program where the hatchery broodstock originates from the local population and results in decreasing effects on natural population parameters.

Table 4. An overview of the range of effects on natural population viability parameters from the two categories of hatchery programs.

Natural population viability parameter	Hatchery broodstock originate from the local population and are included in the ESU or DPS	Hatchery broodstock originate from a non-local population or from fish that are not included in the same ESU or DPS
Productivity	**Positive to negative effect** Hatcheries are unlikely to benefit productivity except in cases where the natural population's small size is, in itself, a predominant factor limiting population growth (*i.e.*, productivity) (NMFS 2004b).	**Negligible to negative effect** This is dependent on differences between hatchery fish and the local natural population (*i.e.*, the more distant the origin of the hatchery fish the greater the threat), the duration and strength of selection in the hatchery, and the level of isolation achieved by the hatchery program (*i.e.*, the greater the isolation the closer to a negligible affect).
Diversity	**Positive to negative effect** Hatcheries can temporarily support natural populations that might otherwise be extirpated or suffer severe bottlenecks and have the potential to increase the effective size of small natural populations. Broodstock collection that homogenizes population structure is a threat to population diversity.	**Negligible to negative effect** This is dependent on the differences between hatchery fish and the local natural population (*i.e.*, the more distant the origin of the hatchery fish the greater the threat) and the level of isolation achieved by the hatchery program (*i.e.*, the greater the isolation the closer to a negligible affect).
Abundance	**Positive to negative effect** Hatchery-origin fish can positively affect the status of an ESU by contributing to the abundance and productivity of the natural populations in the ESU (70 FR 37204, June 28, 2005, at 37215).	**Negligible to negative effect** This is dependent on the level of isolation achieved by the hatchery program (*i.e.*, the greater the isolation the closer to a negligible effect), handling, maintenance, evaluation, and research and facility operation, maintenance and construction effects.
Spatial Structure	**Positive to negative effect** Hatcheries can accelerate recolonization and increase population spatial structure, but only in conjunction with remediation of the factor(s) that limited spatial structure in the first place. "Any benefits to spatial structure over the long term depend on the degree to which the hatchery stock(s) add to (rather than replace) natural populations" (70 FR 37204, June 28, 2005 at 37213).	**Negligible to negative effect** This is dependent on facility operation, maintenance, and construction effects and the level of isolation achieved by the hatchery program (*i.e.*, the greater the isolation the closer to a negligible affect).

The term "local fish" is defined to mean fish with a level of genetic divergence relative to the local natural population(s) that is no more than what occurs within the ESU or steelhead DPS (70 FR 37215, June 28, 2005).   Exceptions include restoring extirpated populations and gene banks.

Analysis of an HGMP or Proposed Action for its effects on ESA-listed species and on designated critical habitat depends on seven factors. These factors are:

(1) the hatchery program does or does not remove fish from the natural population and use them for hatchery broodstock,

(2) hatchery fish and the progeny of naturally spawning hatchery fish on spawning grounds and encounters with natural-origin and hatchery fish at adult collection facilities,

(3) hatchery fish and the progeny of naturally spawning hatchery fish in juvenile rearing areas,

(4) hatchery fish and the progeny of naturally spawning hatchery fish in the migration corridor, estuary, and ocean,

(5) Monitoring, evaluation and research (ME&R) that exists because of the hatchery program,

(6) the operation, maintenance, and construction of hatchery facilities that exist because of

(7) the hatchery program, and

(8) fisheries that exist because of the hatchery program, including terminal fisheries intended to reduce the escapement of hatchery-origin fish to spawning grounds.

The analysis assigns an effect for each factor from the following categories. The categories are:
(1) positive or beneficial effect on population viability,
(2) negligible effect on population viability, and
(3) negative effect on population viability.

"The effects of hatchery fish on the status of an ESU will depend on which of the four key attributes are currently limiting the ESU, and how the hatchery within the ESU affect each of the attributes" (NMFS 2005b). The category of affect assigned is based on an analysis of each factor weighed against the affected population(s) current risk level for abundance, productivity, spatial structure and diversity, the role or importance of the affected natural population(s) in ESU or steelhead DPS recovery, the target viability for the affected natural population(s), and the Environmental Baseline including the factors currently limiting population viability.

2.4.1.1 Factor 1. The hatchery program does or does not remove fish from the natural population and use them for hatchery broodstock (demographic effect)

This factor considers the risk to a natural population from the removal of natural-origin fish for hatchery broodstock. The level of effect for this factor ranges from neutral or negligible to negative.

A primary consideration in analyzing and assigning effects for broodstock collection is the origin and number of fish collected. The analysis considers whether broodstock are of local origin and the biological pros and cons of using ESA-listed fish (natural or hatchery-origin) for hatchery broodstock. It considers the maximum number of fish proposed for collection and the proportion of the donor population tapped to provide hatchery broodstock. "Mining" a natural population to supply hatchery broodstock can reduce population abundance and spatial structure. Also considered here is whether the program "backfills" with fish from outside the local or immediate area. The physical process of collecting hatchery broodstock and the effect of the process on ESA-listed species is considered under Factor 2.

2.4.1.2 Factor 2. Hatchery fish and the progeny of naturally spawning hatchery fish on spawning grounds and encounters with natural-origin and hatchery fish at adult collection facilities (genetic and ecological effects)

NMFS also analyzes the effects of hatchery fish and the progeny of naturally spawning hatchery fish on the spawning grounds. The level of effect for this factor ranges from positive to negative. There are two aspects to this part of the analysis: genetic effects and ecological effects. NMFS generally views genetic effects as detrimental because, at this time, based on the weight of available scientific information, we believe that artificial breeding and rearing is likely to result in some degree of genetic change and fitness reduction in hatchery fish and in the progeny of naturally spawning hatchery fish relative to desired levels of diversity and productivity for natural populations. Hatchery fish can thus pose a risk to diversity and to natural population rebuilding and recovery when they interbreed with fish from natural populations. However, NMFS recognizes that there are benefits as well, and that the risks just mentioned may be outweighed under circumstances where demographic or short-term extinction risk to the population is greater than risks to population diversity and productivity. Conservation hatchery programs may accelerate recovery of a target population by increasing abundance faster than may occur naturally (Waples 1999). Hatchery programs can also be used to create genetic reserves for a population to prevent the loss of its unique traits due to catastrophes (Ford 2011). Furthermore, NMFS also recognizes there is considerable debate regarding genetic risk. The extent and duration of genetic change and fitness loss and the short and long-term implications and consequences for different species, for species with multiple life-history types, and for species subjected to different hatchery practices and protocols remains unclear and should be the subject of further scientific investigation. As a result, NMFS believes that hatchery intervention is a legitimate and useful tool to alleviate short-term extinction risk, but otherwise managers should seek to limit interactions between hatchery and natural-origin fish and implement hatchery practices that harmonize conservation with applicable laws and policies (NMFS 2011c).

Hatchery fish can have a variety of genetic effects on natural population productivity and diversity when they interbreed with natural-origin fish. Although there is biological interdependence between them, NMFS considers three major areas of genetic effects of hatchery programs: within-population diversity, outbreeding effects, and hatchery-influenced selection. As we have stated above, in most cases, the effects are viewed as risks, but in small populations these effects can sometimes be beneficial, reducing extinction risk.

Within-population genetic diversity is a general term for the quantity, variety and combinations of genetic material in a population (Busack and Currens 1995). Within-population diversity is gained through mutations or gene flow from other populations (described below under outbreeding effects) and is lost primarily due to genetic drift, a random loss of diversity due to population size. The rate of loss is determined by the population's effective population size (N_e), which can be considerably smaller than its census size. For a population to maintain genetic diversity reasonably well, the effective size should be in the hundreds (*e.g.*, Lande and Barrowclough 1987), and diversity loss can be severe if N_e drops to a few dozen. Hatchery programs, simply by virtue of creating more fish, can increase N_e. In very small populations this can be a benefit, making selection more effective and reducing other small population risks (*e.g.*, Lacy 1987; Whitlock 2000; Willi *et al.* 2006). Conservation hatchery programs can thus serve to protect genetic diversity; several, such as the Snake River sockeye salmon program are important genetic reserves. However, hatchery programs can also directly depress N_e by two principal methods. One is by the simple removal of fish from the population so that they can be used in the hatchery. If a substantial portion of the population is taken into a hatchery, the hatchery becomes responsible for that portion of the effective size, and if the operation fails, the effective size of the population will be reduced (Waples and Do 1994). N_e can also be reduced considerably below the census number of broodstock by using a skewed sex ratio, spawning males multiple times (Busack 2007), and by pooling gametes. Pooling semen is especially problematic because when semen of several males is mixed and applied to eggs, a large portion of the eggs may be fertilized by a single male (Gharrett and Shirley 1985; Withler 1988). Factorial mating schemes, in which fish are systematically mated multiple times, can be used to increase N_e (Fiumera *et al.* 2004; Busack and Knudsen 2007). An extreme form of N_e reduction is the Ryman-Laikre effect (Ryman and Laikre 1991; Ryman *et al.* 1995), when N_e is reduced through the return to the spawning grounds of large numbers of hatchery fish from very few parents. Inbreeding depression, another N_e-related phenomenon, is caused by the mating of closely related individuals (*e.g.*, sibs, half-sibs, cousins). The smaller the population, the more likely spawners will be related. Related individuals are likely to contain similar genetic material, and the resulting offspring may then have reduced survival because they are less variable genetically or have double doses of deleterious mutations. The lowered fitness of fish due to inbreeding depression accentuates the genetic risk problem, helping to push a small population toward extinction.

Outbreeding effects are caused by gene flow from other populations. Gene flow occurs naturally among salmon and steelhead populations, a process referred to as straying (Quinn 1993; 1997). Natural straying serves a valuable function in preserving diversity that would otherwise be lost through genetic drift and in re-colonizing vacant habitat, and straying is considered a risk only when it occurs at unnatural levels or from unnatural sources. Hatchery programs can result in straying outside natural patterns for two reasons. First, hatchery fish may exhibit reduced homing fidelity relative to natural-origin fish (Grant 1997; Quinn 1997; Jonsson *et al.* 2003; Goodman 2005), resulting in unnatural levels of gene flow into recipient populations, either in terms of sources or rates. Second, even if hatchery fish home at the same level of fidelity as natural-origin fish, their higher abundance can cause unnatural straying levels into recipient populations. One goal for hatchery programs should be to ensure that hatchery practices do not lead to higher rates of genetic exchange with fish from natural populations than would occur naturally (Ryman 1991). Rearing and release practices and ancestral origin of the hatchery fish can all play a role in straying (Quinn 1997).

Gene flow from other populations can have two effects. It can increase genetic diversity (*e.g.*, Ayllon *et al.* 2006) (which can be a benefit in small populations) but it can also alter established allele frequencies (and co-adapted gene complexes) and reduce the population's level of adaptation, a phenomenon called outbreeding depression (Edmands 2007; McClelland and Naish 2007). In general, the greater the geographic separation between the source or origin of hatchery fish and the recipient natural population, the greater the genetic difference between the two populations (ICTRT 2007), and the greater potential for outbreeding depression. For this reason, NMFS advises hatchery action agencies to develop locally derived hatchery broodstocks. Additionally, unusual rates of straying into other populations within or beyond the population's ESU or steelhead DPS can have an homogenizing effect, decreasing intra-population genetic variability (*e.g.*, Vasemagi *et al.* 2005), and increasing risk to population diversity, one of the four attributes measured to determine population viability. Reduction of within-population and among-population diversity can reduce adaptive potential.

The proportion of hatchery fish (pHOS) among natural spawners is often used as a surrogate measure of gene flow. Appropriate cautions and qualifications should be considered when using this proportion to analyze outbreeding effects. Adult salmon may wander on their return migration, entering and then leaving tributary streams before finally spawning (Pastor 2004). These "dip-in" fish may be detected and counted as strays, but may eventually spawn in other areas, resulting in an overestimate of the number of strays that potentially interbreed with the natural population (Keefer *et al.* 2008). Caution must also be taken in assuming that strays successfully reproduce. It is important to reiterate that, as NMFS analyzes them, outbreeding effects are a risk only when the hatchery fish are from a different population than the naturally produced fish. If they are from the same population, then the risk is from hatchery-influenced selection. Non-native hatchery fish may also contribute to hatchery-influenced selection and contribute genetically in proportion to their abundance. Several studies demonstrate little genetic impact from straying despite a considerable presence of strays in the spawning population (Saisa *et al.* 2003; Blankenship *et al.* 2007). The causative factors for poorer breeding success of strays are likely similar to those identified as responsible for reduced productivity of hatchery-origin fish in general—*e.g.*, differences in run and spawn timing, spawning in less productive habitats, and reduced survival of their progeny (Reisenbichler and McIntyre 1977; Leider *et al.* 1990; McLean *et al.* 2004; Williamson *et al.* 2010b).

Hatchery-influenced selection (often called domestication) occurs when selection pressures imposed by hatchery spawning and rearing differ greatly from those imposed by the natural environment and causes genetic change that is passed on to natural populations through interbreeding with hatchery-origin fish. These differing selection pressures can be a result of differences in environments or a consequence of protocols and practices used by a hatchery program. Hatchery-influenced selection can range from relaxation of selection that would normally occur in nature, to selection for different characteristics in the hatchery and natural environments, to intentional selection for desired characteristics (Waples 1999).

Genetic change and fitness reduction resulting from hatchery-influenced selection depends on: (1) the difference in selection pressures; (2) the exposure or amount of time the fish spends in the hatchery environment; and (3) the duration of hatchery program operation (*i.e.*, the number of generations that fish are propagated by the program). On an individual level, exposure time in large part equates to fish culture, both the environment experienced by the fish in the hatchery and natural selection pressures, independent of the hatchery environment. On a population basis, exposure is determined by the proportion of natural-origin fish in the hatchery broodstock (called pNOB) and the proportion of natural spawners consisting of hatchery-origin fish (Lynch and O'Hely 2001; Ford 2002), and then by the number of years the exposure takes place. In assessing risk or determining impact, all three levels must be considered. Strong selective fish culture with low hatchery-wild interbreeding can pose less risk than relatively weaker selective fish culture with high levels of interbreeding.

Most of the empirical evidence of fitness depression due to hatchery-influenced selection comes from studies of species that are reared in the hatchery environment for an extended period – one to two years – prior to release (Berejikian and Ford 2004). Exposure time in the hatchery for fall and summer Chinook salmon and Chum salmon is much shorter, just a few months. One especially well-publicized steelhead study (Araki *et al.* 2007; Araki *et al.* 2008), showed dramatic fitness declines in the progeny of naturally spawning Hood River hatchery steelhead. Researchers and managers alike have wondered if these results could be considered a potential outcome applicable to all salmonid species, life-history types, and hatchery rearing strategies.

Besides the Hood River steelhead work, a number of studies are available on the relative reproductive success (RRS) of hatchery-origin and natural-origin fish (*e.g.,*Berntson *et al.* 2011; Theriault *et al.* 2011; Ford *et al.* 2012; Hess *et al.* 2012b). All have shown that generally hatchery-origin fish have lower reproductive success, though the differences have not always been statistically significant and in some years in some studies the opposite is true. Lowered reproductive success of hatchery-origin fish in these studies is typically considered evidence of hatchery-influenced selection. Although RRS may be a result of hatchery-influenced selection, studies must be carried out for multiple generations to unambiguously detect a genetic effect. To date, only the Hood River steelhead (Araki *et al.* 2007; Christie *et al.* 2011) and Wenatchee spring Chinook salmon (Ford *et al.* 2012) RRS studies have reported multiple-generation effects.

Critical information for analysis of hatchery-influenced selection includes the number, location and timing of naturally spawning hatchery fish, the estimated level of gene flow between hatchery-origin and natural-origin fish, the origin of the hatchery stock (the more distant the origin compared to the affected natural population, the greater the threat), the level and intensity of hatchery selection and the number of years the operation has been run in this way. Efforts to control and evaluate the risk of hatchery-influenced selection are currently largely focused on gene flow between natural-origin and hatchery-origin fish.

An HSRG team recently reviewed California hatchery programs and developed guidelines that differed considerably from those developed by the earlier group (California HSRG 2012). The California HSRG (2012) felt that truly isolated programs in which no hatchery-origin returnees interact genetically with natural populations were impossible in California, and was "generally unsupportive" of isolated programs. They rejected development of overall pHOS guidelines for integrated programs because the optimal pHOS will depend upon multiple factors, such as "the amount of spawning by natural-origin fish in areas integrated with the hatchery, the value of pNOB, the importance of the integrated population to the larger stock, the fitness differences between hatchery- and natural-origin fish, and societal values, such as angling opportunity". They recommended that program-specific plans be developed with corresponding population specific targets and thresholds for pHOS, pNOB, and PNI that reflect these factors. However, they did state that PNI should exceed 50% in most cases, although in supplementation or reintroduction programs the acceptable pHOS could be much higher than 5%, even approaching 100% at times. They also recommended for conservation programs that pNOB approach 100%, but pNOB levels should not be so high they pose demographic risk to the natural population.

Ecological effects for this factor (*i.e.*, hatchery fish and the progeny of naturally spawning hatchery fish on the spawning grounds) refer to effects from competition for spawning sites and redd superimposition, contributions to marine-derived nutrients, and the removal of fine sediments from spawning gravels. Ecological effects on the spawning grounds may be positive or negative. To the extent that hatcheries contribute added fish to the ecosystem, there can be positive effects. For example, when anadromous salmonids return to spawn, hatchery-origin and natural-origin alike, they transport marine-derived nutrients stored in their bodies to freshwater and terrestrial ecosystems. Their carcasses provide a direct food source for juvenile salmonids and other fish, aquatic invertebrates, and terrestrial animals, and their decomposition supplies nutrients that may increase primary and secondary production (Kline *et al.* 1990; Piorkowski 1995; Larkin and Slaney 1996; Gresh *et al.* 2000; Murota 2003; Quamme and Slaney 2003; Wipfli *et al.* 2003). As a result, the growth and survival of juvenile salmonids may increase (Hager and Noble 1976; Bilton *et al.* 1982; Holtby 1988; Ward and Slaney 1988; Hartman and Scrivener 1990; Johnston *et al.* 1990; Larkin and Slaney 1996; Quinn and Peterson 1996; Bradford *et al.* 2000; Bell 2001; Brakensiek 2002).

Additionally, studies have demonstrated that perturbation of spawning gravels by spawning salmonids loosens cemented (compacted) gravel areas used by spawning salmon (*e.g.*, Montgomery *et al.* 1996). The act of spawning also coarsens gravel in spawning reaches, removing fine material that blocks interstitial gravel flow and reduces the survival of incubating eggs in egg pockets of redds.

The added spawner density resulting from hatchery-origin fish spawning in the wild can have negative consequences in that to the extent there is spatial overlap between hatchery and natural spawners, the potential exists for hatchery-derived fish to superimpose or destroy the eggs and embryos of ESA-listed species. Redd superimposition has been shown to be a cause of egg loss in pink salmon and other species (*e.g.*, Fukushima *et al.* 1998).

Broodstock Collection

The analysis also considers the effects from encounters with natural-origin fish that are incidental to the method of broodstock collection. Here, NMFS analyzes effects from sorting, holding, and handling natural-origin fish in the course of broodstock collection. Some programs collect their broodstock from fish volunteering into the hatchery itself, typically into a ladder and holding pond, while others sort through the run at large, usually at a weir, ladder, or sampling facility. Generally speaking, the more a hatchery program accesses the run at large for hatchery broodstock – that is, the more fish that are handled or delayed during migration – the greater the negative effect on natural-origin and hatchery-origin fish that are intended to spawn naturally and to ESA-listed species. The information NMFS uses for this analysis includes a description of the facilities, practices, and protocols for collecting broodstock, the environmental conditions under which broodstock collection is conducted, and the encounter rate for ESA-listed fish.

Weirs may delay migration, increase the handling of non-target salmonids, and increase the potential for predation. Weirs may also result in physical habitat changes to the stream and riparian areas. NMFS also analyzes the effects of structures, either temporary or permanent, that are used to collect hatchery broodstock. NMFS analyzes effects on fish, juveniles and adults, from encounters with these structures and effects on habitat conditions that support and promote viable salmonid populations. NMFS wants to know, for example, if the spatial structure, productivity, or abundance of a natural population is affected when fish encounter a structure used for broodstock collection, usually a weir or ladder. NMFS also analyzes changes to riparian habitat, channel morphology and habitat complexity, water flows, and in-stream substrates attributable to the construction/installation, operation, and maintenance of these structures.

2.4.1.3 Factor 3. Hatchery fish and the progeny of naturally spawning hatchery fish in juvenile rearing areas (ecological effects)

NMFS also analyzes the potential for competition, predation, and premature emigration when the progeny of naturally spawning hatchery fish and hatchery releases share juvenile rearing areas. The level of effect for this factor ranges from neutral or negligible to negative. Generally speaking, competition and a corresponding reduction in productivity and survival may result from direct interactions when hatchery-origin fish interfere with the accessibility to limited resources by natural-origin fish or through indirect means, when the utilization of a limited resource by hatchery fish reduces the amount available for fish from the natural population (SIWG 1984). Naturally produced fish may be competitively displaced by hatchery fish early in life, especially when hatchery fish are more numerous, are of equal or greater size, when hatchery fish take up residency before naturally produced fry emerge from redds, and if hatchery fish residualize. Hatchery fish might alter naturally produced salmon behavioral patterns and habitat use, making them more susceptible to predators (Hillman and Mullan 1989; Steward and Bjornn 1990).

Hatchery-origin fish may alter naturally produced salmonid migratory responses or movement patterns, leading to a decrease in foraging success (Hillman and Mullan 1989; Steward and Bjornn 1990). Actual impacts on naturally produced fish would thus depend on the degree of dietary overlap, food availability, size-related differences in prey selection, foraging tactics, and differences in microhabitat use (Steward and Bjornn 1990). Specific hazards associated with competitive impacts of hatchery salmonids on listed naturally produced salmonids may include competition for food and rearing sites (NMFS 2012a). In an assessment of the potential ecological impacts of hatchery fish production on naturally produced salmonids, the Species Interaction Work Group (SIWG 1984) concluded that naturally produced coho salmon, Chinook salmon and steelhead are all potentially at “high risk” due to competition (both interspecific and intraspecific) from hatchery fish of any of these three species.

Several factors influence the risk of competition posed by hatchery releases: whether competition is intra- or interspecific; the duration of freshwater co-occurrence of hatchery and natural-origin fish; relative body sizes of the two groups; prior residence of shared habitat; environmentally induced developmental differences; and density in shared habitat (Tatara and Berejikian 2012). Intraspecific competition would be expected to be greater than interspecific, and competition would be expected to increase with prolonged freshwater co-occurrence. Although newly released hatchery smolts are commonly larger than natural-origin fish, and larger fish usually are superior competitors, natural-origin fish have the competitive advantage of prior residence when defending territories and resources in shared natural freshwater habitat. Tatara and Berejikian (2012) further reported that developmental differences between hatchery-origin fish and natural-origin fish of various life stages are variable and can favor both hatchery- and natural-origin fish. They concluded that of all factors, fish density of the composite population in relation to habitat carrying capacity likely exerts the greatest influence.

En masse hatchery salmon smolt releases may cause displacement of rearing naturally produced juvenile salmonids from occupied stream areas, leading to abandonment of advantageous feeding stations, or premature out-migration (Pearsons *et al.* 1994). Pearsons *et al.* (1994) reported small-scale displacement of juvenile natural-origin rainbow trout from stream sections by hatchery steelhead. Small-scale displacements and agonistic interactions observed between hatchery steelhead and naturally produced juvenile trout were most likely a result of size differences and not something inherently different about hatchery fish.

A proportion of the smolts released from a hatchery may not migrate to the ocean but rather reside for a period of time in the vicinity of the release point. These non-migratory smolts (residuals) may directly compete for food and space with natural-origin juvenile salmonids of similar age. They also may prey on younger, smaller-sized juvenile salmonids. Although this behavior has been studied and observed, most frequently in the case of hatchery steelhead, residualism has been reported as a potential issue for hatchery coho and Chinook salmon as well. Therefore, for all species, monitoring of natural stream areas in the vicinity of hatchery release points may be necessary to determine the potential effects of hatchery smolt residualism on natural-origin juvenile salmonids.

Critical to analyzing competition risk is information on the quality and quantity of spawning and rearing habitat in the action area, including the distribution of spawning and rearing habitat by quality and best estimates for spawning and rearing habitat capacity. Additional important information includes the abundance, distribution, and timing for naturally spawning hatchery fish and natural-origin fish; the timing of emergence; the distribution and estimated abundance for progeny from both hatchery and natural-origin natural spawners; the abundance, size, distribution, and timing for juvenile hatchery fish in the action area; and the size of hatchery fish relative to co-occurring natural-origin fish.

Another potential ecological effect of hatchery releases is predation. Salmon and steelhead are piscivorous and can prey on other salmon and steelhead. Predation, either direct (direct consumption) or indirect (increases in predation by other predator species due to enhanced attraction), can result from hatchery fish released into the wild. Considered here is predation by hatchery-origin fish and by the progeny of naturally spawning hatchery fish and by avian and other predators attracted to the area by an abundance of hatchery fish. Hatchery fish originating from egg boxes and fish planted as non-migrant fry or fingerlings can prey upon fish from the local natural population during juvenile rearing. Hatchery fish released at a later stage, so they are more likely to emigrate quickly to the ocean, can prey on fry and fingerlings that are encountered during the downstream migration. Some of these hatchery fish do not emigrate and instead take up residence in the stream (residuals) where they can prey on stream-rearing juveniles over a more prolonged period. The progeny of naturally spawning hatchery fish also can prey on fish from a natural population and pose a threat. In general, the threat from predation is greatest when natural populations of salmon and steelhead are at low abundance and when spatial structure is already reduced, when habitat, particularly refuge habitat, is limited, and when environmental conditions favor high visibility.

SIWG (1984) rated most risks associated with predation as unknown, because there was relatively little documentation in the literature of predation interactions in either freshwater or marine areas. More studies are now available, but they are still too sparse to allow many generalizations to be made about risk. Newly released hatchery-origin yearling salmon and steelhead may prey on juvenile fall Chinook and steelhead, and other juvenile salmon in the freshwater and marine environments (Hargreaves and LeBrasseur 1986; Hawkins and Tipping 1999; Pearsons and Fritts 1999). Low predation rates (0 to 0.5 fish/hatchery smolt) have been reported for released steelhead juveniles (Hawkins and Tipping 1999; Naman and Sharpe 2012). Hatchery steelhead timing and release protocols used widely in the Pacific Northwest were shown to be associated with negligible predation by migrating hatchery steelhead on fall Chinook fry, which had already emigrated or had grown large enough to reduce or eliminate their susceptibility to predation when hatchery steelhead entered the rivers (Sharpe *et al.* 2008). Hawkins (1998) documented hatchery spring Chinook salmon yearling predation on naturally produced fall Chinook salmon juveniles in the Lewis River. Predation on smaller Chinook salmon was found to be much higher in naturally produced smolts (coho salmon and cutthroat, predominately) than their hatchery counterparts.

Predation may be greatest when large numbers of hatchery smolts encounter newly emerged fry or fingerlings, or when hatchery fish are large relative to naturally produced fish (SIWG 1984). Due to their location in the stream or river, size, and time of emergence, newly emerged salmonid fry are likely to be the most vulnerable to predation. Their vulnerability is believed to be greatest immediately upon emergence from the gravel and then their vulnerability decreases as they move into shallow, shoreline areas (USFWS 1994). Emigration out of important rearing areas and foraging inefficiency of newly released hatchery smolts may reduce the degree of predation on salmonid fry (USFWS 1994).

Some reports suggest that hatchery fish can prey on fish that are up to 1/2 their length (Pearsons and Fritts 1999; HSRG 2004) but other studies have concluded that salmonid predators prey on fish 1/3 or less their length (Horner 1978; Hillman and Mullan 1989; Beauchamp 1990; Cannamela 1992; CBFWA 1996). Hatchery fish may also be less efficient predators as compared to their natural-origin conspecifics, reducing the potential for predation impacts (Sosiak *et al.* 1979; Bachman 1984; Olla *et al.* 1998).

2.4.1.4 Factor 4. Hatchery fish and the progeny of naturally spawning hatchery fish in the migration corridor, in the estuary, and in the ocean (ecological effects)

Based on a review of the scientific literature, NMFS' conclusion is that the influence of density dependent interactions on the growth and survival of salmon and steelhead is likely small compared with the effects of large-scale and regional environmental conditions and, while there is evidence that large-scale hatchery production can affect salmon survival at sea, the degree of effect or level of influence is not yet well understood or predictable. The same thing is true for mainstem rivers and estuaries. NMFS will monitor emerging science and information on the frequency, the intensity, and the effect of density-dependent interactions between hatchery and natural-origin fish. NMFS will consider re-initiation of section 7 consultation is required when new information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not considered in this consultation (50 CFR 402.16).

2.4.1.5 Factor 5. Monitoring, evaluation and research (ME&R) that exists because of the hatchery program (demographic effects)

NMFS also analyzes proposed ME&R for its effects on listed species and on designated critical habitat. The level of effect for this factor ranges from positive to negative. Generally, negative effects on the fish from ME&R are weighed against the value or benefit of new information, particularly information that tests key assumptions and that reduces critical uncertainties. ME&R actions including but not limited to collection and handling (purposeful or inadvertent), holding the fish in captivity, sampling (*e.g.,* the removal of scales and tissues), tagging and fin-clipping, and observation (in-water or from the bank) can cause harmful changes in behavior and reduced survival. These effects should not be confused with handling effects analyzed under broodstock collection. In addition, NMFS also considers the overall effectiveness of the ME&R program. There are five factors that NMFS takes into account when it assesses the beneficial and negative effects of hatchery ME&R: (1) the status of the affected species and effects of the proposed ME&R on the species and on designated critical habitat, (2) critical uncertainties over effects of the Proposed Action on the species, (3) performance monitoring and determining the effectiveness of the hatchery program at achieving its goals and objectives, (4) identifying and quantifying collateral effects, and (5) tracking compliance of the hatchery program with the terms and conditions for implementing the program. After assessing the proposed hatchery ME&R and before it makes any recommendations to the action agencies, NMFS considers the benefit or usefulness of new or additional information, whether the desired information is available from another source, the effects on ESA-listed species, and cost.

Hatchery actions also must be assessed for masking effects. For these purposes, masking is when hatchery fish included in the Proposed Action mix with and are not identifiable from other fish. The effect of masking is that it undermines and confuses ME&R and status and trends monitoring. Both adult and juvenile hatchery fish can have masking effects. When presented with a proposed hatchery action, NMFS analyzes the nature and level of uncertainties caused by masking and whether and to what extent listed salmon and steelhead are at increased risk. The analysis also takes into account the role of the affected salmon and steelhead population(s) in recovery and whether unidentifiable hatchery fish compromise important ME&R.

2.4.1.6 Factor 6. Construction, operation, and maintenance, of facilities that exist because of the hatchery program (demographic effects and effects on habitat)

The construction/installation, operation, and maintenance of hatchery facilities can alter fish behavior and can injure or kill eggs, juveniles and adults. It can also degrade habitat function and reduce or block access to spawning and rearing habitats altogether. Here, NMFS analyzes changes to riparian habitat, channel morphology and habitat complexity, in-stream substrates, and water quantity and water quality attributable to operation, maintenance, and construction activities and confirms whether water diversions and fish passage facilities are constructed and operated consistent with NMFS criteria. The level of effect for this factor ranges from neutral or negligible to negative.

2.4.1.7 Factor 7. Fisheries that exist because of the hatchery program (demographic effects)

There are two aspects of fisheries that are potentially relevant to NMFS' analysis of HGMP effects in a Section 7 consultation. One is where there are fisheries that exist because of the HGMP (*i.e.*, the fishery is an interrelated and interdependent action) and listed species are inadvertently and incidentally taken in those fisheries. The other is when fisheries are used as a tool to prevent the hatchery fish associated with the HGMP, including hatchery fish included in an ESA-listed ESU or steelhead DPS from spawning naturally. The level of effect for this factor ranges from neutral or negligible to negative. "Many hatchery programs are capable of producing more fish than are immediately useful in the conservation and recovery of an ESU and can play an important role in fulfilling trust and treaty obligations with regard to harvest of some Pacific salmon and steelhead populations. For ESUs listed as threatened, NMFS will, where appropriate, exercise its authority under Section 4(d) of the ESA to allow the harvest of listed hatchery fish that are surplus to the conservation and recovery needs of the ESU, in accordance with approved harvest plans" (NMFS 2005b). In any event, fisheries must be strictly regulated based on the take, including catch and release effects, of ESA-listed species.

2.4.2 Hatchery Factors Analysis for the Mad River Hatchery HGMP

Analysis of the Proposed Action identified that within the action area, ESA-listed species are likely to be negatively affected and take will occur as a result of five of the seven factors described in Section 2.4.1. They are: the removal of natural-origin adults for broodstock; hatchery fish and the progeny of naturally spawning hatchery fish on spawning grounds and encounters with natural-origin and hatchery fish at adult collection facilities; hatchery fish and progeny of naturally spawning hatchery fish in juvenile rearing areas (*i.e.*, competition, and predation); ME&R that exists because of the hatchery program; and the interdependent effects of fishing. No factors were found to benefit ESA-listed species. An overview of the analysis is described below.

2.4.2.1 Factor 1. The hatchery program removes fish from the natural population and use them for hatchery broodstock (demographic effects)

Negative demographic effects: The removal of natural-origin winter steelhead would reduce the overall abundance of the population, but the effects are expected to be limited due to live-spawning then releasing the fish back to the river and the low removal rate compared to the size of the population. Additionally, a portion of the progeny from hatchery mating may well escape to the spawning grounds once they return as adults and would potentially contribute to the natural spawning population and thereby supplement the number of spawning fish, therefore, partially compensating for the removal of fish for broodstock—monitoring and evaluation (described below) will inform this assumption during the duration of the program. At this time, estimates for survival of live-spawned fish and subsequent spawning in the wild by released males are unknown. Therefore, we assume that none of the broodstock removed contributes in the future. A small number of Chinook salmon and coho salmon will be captured during steelhead broodstock collection efforts as described in Table 1. Up to 19 adult coho salmon are expected to be encountered and handled during steelhead broodstock collection efforts, with no injuries or mortalities (Table 1). Up to 350 Chinook salmon may be encountered and handled during broodstock collection efforts with up to 2 injuries or mortalities (Table 1).

The removal of less than 10% of the Mad River natural-origin winter steelhead population for hatchery broodstock purposes is not expected to reduce the survival and recovery of the Mad River winter steelhead population. Under the Proposed Action, CDFW would annually collect a minimum of 125—and potentially up to 250—natural-origin winter steelhead for broodstock, but only if the natural-origin escapement is expected to exceed 1,250 to 2,500 adults. Under no circumstances would more than 10% of the natural-origin spawning population be removed for hatchery broodstock. The escapement of natural-origin winter steelhead will be monitored during winter steelhead surveys to ensure that the winter steelhead escapement is such that broodstock collection will not exceed 10% of the natural-origin population. Additionally, the natural-origin winter steelhead would be live-spawned and then released back into the Mad River so males could potentially spawn naturally and females could live to exhibit iteroparity and spawn naturally, which will further reduce demographic effects. At this time, however, the rate of iteroparity or future broodstock contributions are unknown so we assume that there is no future contribution for the purposes of evaluating the proposed action against the jeopardy standard.

Steelhead that are removed to be used for broodstock would have a genetic sample (tissue punch) removed prior to release back to the river. This injury may make them more susceptible to infection. However, for the purposes of the effects and jeopardy analysis, all broodstock are considered removed from the system, so this additional injury will not change the effects or jeopardy analysis, which is based on a maximum collection and "death" of up to 250 adult steelhead annually.

The removal of less than 10% of the population for broodstock could be compared to an additional harvest of the Mad River winter steelhead population. Using this harvest analogy, Chilcote (2001) performed a series of Population Viability Analysis (PVA) model runs for 27 steelhead populations to assess the impact of harvest on the status and recovery of steelhead in Oregon. For most populations, the modeling exercise suggested that the probability of extinction was essentially zero as long as mortality rates associated with harvest remained less than 30%. However, when mortality rates became greater than 40%, the probability of extinction increased dramatically. In addition, once the probability of extinction increased beyond 0.05, the transition to an extinction probability of 1.00 was very rapid. Because the transition from low risk to high risk happens so rapidly, there is little room for error (in either the model or measurement of mortality rates). The mortality rate of freshwater fisheries on natural-origin winter steelhead is expected to range from 0.5 to 2.5% of the natural origin returns (CDFW 2016). The less-than-10% additional impact from the removal of natural-origin winter steelhead in addition to the impacts from the freshwater fisheries is expected to be less than 12.5%, which is below the 30% expected to increase the risk of extinction. Additionally, the 10% of fish used for broodstock is a maximum number. During recent years, the number has been lower than 10% and also male fish may go on to spawn in the wild after being spawned in the hatchery and released. Therefore, NMFS believes that the removal of broodstock at the proposed levels, coupled with the effects of fishing, are unlikely to substantially increase the risk of extinction.

2.4.2.2 Factor 2. Hatchery fish and the progeny of naturally spawning hatchery fish on spawning grounds and encounters with natural-origin and hatchery fish at adult collection facilities (genetic effect)

Negative genetic effect: Genetic effects on ESA-listed steelhead populations in the Mad River are a low risk and likely to occur from interactions on the spawning grounds between hatchery fish or progeny of naturally spawning hatchery fish and natural-origin steelhead.

Out-of-basin winter steelhead stocks were planted into the basin for a number of years and the hatchery did not make a determined effort to collect natural-origin broodstock until recently, which likely resulted in the divergence between the hatchery- and natural-origin populations today (Reneski 2012). The Mad River natural-origin winter steelhead population may have suffered outbreeding depression as a result. However, the current program, which began with the 2012 brood year, incorporated natural-origin population steelhead adults into the broodstock. Because of this effort to minimize divergence between natural-origin and hatchery origin winter steelhead populations, NMFS considers the Mad River hatchery winter steelhead and the Mad River natural-origin winter steelhead population to be integrated.

The Proposed Action would manage the winter steelhead hatchery program as an integrated program, with a pNOB of 50% to 100%. These criteria meet the CHSRG's guidelines for an integrated program. Based on recent experience and the proposed operations, NMFS concludes that hatchery-influenced selection from the Mad River Hatchery winter steelhead program pose a low risk to the natural-origin Mad River winter steelhead population.

The release of hatchery steelhead unused during spawning operations to provide additional harvest opportunities (recycling) is not expected to pose a substantial risk to natural origin winter steelhead because many of these fish will be harvested or recycled multiple times and the delay to spawning limits their intermingling on spawning grounds, which are found at some distance upstream of the hatchery. Little information is available to generate valid estimates of steelhead pHOS. CDFW will continue monitoring escapement of natural-origin winter steelhead.

2.4.2.3 Factor 3. Hatchery fish and the progeny of naturally spawning hatchery fish in juvenile rearing areas (ecological effect)

Negligible ecological effect: Hatchery smolts and the juvenile progeny of naturally spawning hatchery steelhead are expected to have a negligible effect on natural-origin juveniles. The most important considerations here are competition and predation by juvenile hatchery fish and the progeny of naturally spawning hatchery fish, and premature emigration of natural-origin fish caused by hatchery fish.

Competition

Competition can occur when hatchery fish and the progeny of naturally spawning hatchery fish compete for rearing areas and food with fish from the local natural population(s) (Williamson *et al.* 2010b; Berntson *et al.* 2011; Theriault *et al.* 2011). Another action that is expected to mitigate the potential for competition between hatchery and natural-origin fish is the release of steelhead at the hatchery, which is low in the watershed and separated from where natural steelhead, Chinook salmon, and coho salmon spawn in tributaries and the upper river. By being downstream of the primary natural production areas for salmon and steelhead in the Mad River, greater spatial separation will occur between hatchery adults, the progeny of naturally spawning hatchery fish, and natural-origin salmon and steelhead in the Mad River. Another mitigating factor is the low production number of 150,000 smolts. Previous estimates of juvenile salmon and steelhead in the Mad River were in the millions (Sparkmann 2001) and, since salmon and steelhead populations are more robust than in 2001, these numbers are undoubtedly higher.

Natural-origin Chinook and coho salmon and steelhead do not smolt and head for the ocean all at once – they instead have a more protracted emigration, leaving rearing areas far upstream in the Mad River over the course of several months. This is in stark contrast to hatchery fish that are relatively uniform in size and behavior and leave the hatchery en masse, and likely will spend only hours or days in the lower Mad River before they enter the Pacific Ocean. This behavior or habit is witnessed and confirmed during outmigration monitoring studies conducted by CDFW (Sparkmann 2001).

Displacement

At other locations, en-masse hatchery salmon smolt releases have been observed to cause the displacement of naturally produced juvenile salmonids leading to the abandonment of advantageous feeding stations or premature out-migration (Pearsons *et al.* 1994). Displacement and premature out-migration would be expected to reduce population spatial structure and abundance. For the Mad River Hatchery, this possibility was considered but rejected because of the short distance to the ocean and limited overlap with natural origin salmonids, the high flows and the high turbidity during releases.

Predation

Predation is dependent upon many factors (Pearsons and Busack 2012), but two major prerequisites are that the predatory fish and their prey must overlap temporally and spatially, and the prey should be less than 1/3 the length of the predatory fish. Because there is little temporal or spatial overlap between hatchery smolts and natural-origin fish, there is little threat from predation or competition. As with the discussion of competition, available data show that hatchery smolts leave the river promptly and that only a small fraction remains in the river 21 days after release. The small number of fish that remain the river would have a negligible effect on ESA-listed natural populations. These fish would be expected to reside in the vicinity of where they were released, miles downstream from the most important salmon and steelhead production areas.

The risk of adverse ecological interactions will be minimized by:

- Releasing hatchery smolts that are physiologically ready to migrate. Hatchery fish released as smolts emigrate seaward soon after liberation, minimizing the potential for competition with juvenile natural-origin fish in freshwater (Steward and Bjornn 1990).

- Operating the hatchery such that smoltification occurs for nearly the entire population (Bugert *et al.* 1991).

- Releasing hatchery smolts in lower river areas, below areas used for stream-rearing natural-origin juveniles.

2.4.2.4 Factor 4. Hatchery fish and the progeny of naturally spawning hatchery fish in the migration corridor, estuary, and ocean (ecological effect)

Negligible ecological effect: Best available information does not indicate that the release of hatchery fish from the Mad River HGMP River programs would exacerbate density-dependent effects on ESA-listed species in the Mad River, in the estuary, or in the Pacific Ocean and thus, NMFS concluded that this factor is not a threat.

There is little definitive information available to directly address the effects of ecological factors on survival and growth in natural populations of Pacific salmon. Thus, many of the ecological consequences of releasing hatchery fish into the wild are poorly defined. More recently, NMFS reviewed the literature for new and emerging scientific information over the role and the consequences of density-dependent interactions. At full production, hatchery releases from the Mad River HGMP program will constitute less than 10% of the juvenile steelhead production expected in the Mad River and likely less than 1% of the juvenile production of all species combined.

From the scientific literature, the general conclusion is that the influence of density dependent interactions on growth and survival is likely small compared with the effects of large scale and regional environmental conditions and while there is evidence that hatchery production, on a scale many times larger than the proposed action, can impact salmon and steelhead survival in the migration corridor, estuary, and ocean, the degree of impact or level of influence is not yet understood or predictable. Regardless, hatchery production on the scale considered in this opinion is very unlikely to substantially affect salmon survival or recovery in these life stages. NMFS will monitor emerging science and information and will request reinitiation Section 7 consultation in the event that new information reveals effects of the action may affect listed species or critical habitat in a manner or to an extent not considered in this consultation (50 CFR 402.16).

2.4.2.5 Factor 5. Research, monitoring, and evaluation that exists because of the hatchery program (demographic effect)

Minor negative demographic effect: The Proposed Action includes ME&R activities that will continue to monitor the Performance Indicators identified in Section 1.10 of the HGMP, ensure compliance with this opinion, and inform future decisions regarding how the hatchery program can be adjusted to meet their goals while further reducing effects on ESA-listed salmon and steelhead.

Limited lethal and sub-lethal effects on ESA-listed natural-origin fish are expected to occur from the handling of adults during DIDSON enumeration activities, which may include the use of seining, angling, or snorkeling. Tables 1 and 2 highlight the number of steelhead, Chinook salmon, and coho salmon juveniles and adults that are expected to be collected or captured with the expected number of mortalities by species and method. Up to 300 natural-origin adult steelhead, 19 adult coho salmon, and 350 Chinook salmon may be captured or otherwise sampled during adult broodstock and ME&R activities (Table 1). It should be noted that broodstock collection and ME&R activities will likely occur coincidentally. Up to 4 steelhead beyond those collected for broodstock and 2 Chinook salmon may succumb to injuries during collections. No adult coho salmon are expected to be injured or killed as a result of ME&R efforts. Juvenile trapping operations including sampling for genetics, mark-recapture studies, and scale analysis may result in the handling and sampling of 125,000 fry, juvenile, and smolt steelhead, 298,500 fry and smolt Chinook salmon, and 14,600 fry, juvenile, and smolt coho salmon, but these mortalities are not expected to rise above 1% of the fish captured (Table 2).

Masking caused by hatchery steelhead is not a threat to ESA-listed salmon and steelhead in the Mad River. Hatchery fish from this program will not confuse or conceal the status of a natural population or the effects of the hatchery program on any natural population because hatchery steelhead will be 100 percent adipose fin-clipped for easy identification.

2.4.2.6 Factor 6. Construction, operation, and maintenance of facilities that exist because of the hatchery programs

Negligible effect: NMFS also evaluated the construction, operation, and the maintenance of hatchery facilities and concluded that this factor has a negligible effect on ESA-listed species. What NMFS evaluates here is how the facilities themselves affect the fish and designated critical habitat. Water intake structures and water withdrawal present another set of potential effects on listed salmonids. The Mad River HGMP Hatchery is operated under NPDES permit # 10598. Effluent from the hatchery is monitored weekly to ensure compliance with permit requirements. These permit requirements are set to ensure that water quality is not reduced to the extent that fisheries or aquatic habitat are adversely affected. The Mad River Hatchery does not use surface water and the wells are deep enough such that no measurable decrease in flows is evident below the hatchery and, therefore, water use in the hatchery has no impact on listed species.

Weirs used for broodstock collection may delay migration, increase the handling of non-target salmonids, and increase the potential for predation. NMFS expects that managing weir operations 24 hours a day and the temporary nature of the weirs will not result in a delay to upstream migration that would result in the death or injury of non-target species or reduce their reproduction. The handling of non-target species will be minimized by operating the weirs during peak steelhead migration timing which are non-peak times for other salmonid species. In addition, handling will be conducted by experienced CDFW personnel. As such, NMFS does not expect injury or death of non-target salmonids during weir operations. CDFW personnel will also be on hand during weir operation so predation is not expected to occur. Weirs may also result in physical habitat changes to the stream and riparian areas. NMFS does not expect any effects to individuals from the minor changes to habitat from the installation and operation of temporary weirs on tributary streams.

2.4.2.7 Factor 7. Fisheries that exist because of the hatchery program (demographic effect)

Minor negative demographic effect: The purpose of the Mad River Hatchery steelhead program is to provide a robust fishery for hatchery-origin steelhead in the Mad River. Catch and release of ESA-listed Mad River natural-origin steelhead also occurs in this fishery (Sparkman 2003, CDFW 2015). The majority of the anglers in the Mad River are focused on catching hatchery fish, so the bulk of the angling occurs within a few miles upstream and downstream of the hatchery (Sparkman 2003, CDFW 2015). The 2014 abundance of hatchery fish in the Mad River was estimated at 4,336 adults, which is approximately 56% of the total population of winter steelhead in the Mad River. CDFW estimated the catch and release of natural-origin steelhead in the Mad River for the years 2006-2011 was approximately 356 per year, of which most, if not all, were released (CDFW 2015). We estimate that up to 5% of natural-origin steelhead that are caught and released will die or otherwise fail to successfully reproduce (Nelson *et al.* 2005), which is estimated at approximately 18 steelhead per year or 0.5% of the population estimate.

Chinook salmon and coho salmon are typically not targeted by fisheries in the Mad River, but they are occasionally caught and released during fisheries for hatchery steelhead (Sparkman 2003). Since CDFW estimated the number of natural-origin steelhead that are caught and released at 356 per year, NMFS expects that the number of Chinook salmon and coho salmon incidentally caught during these fisheries to be much lower given the differences in run timing between Chinook salmon and steelhead in the Mad River and the lower angler effort because of regulatory restrictions that focus the effort in the Mad River on hatchery steelhead. Therefore, NMFS expects the number of coho salmon and Chinook salmon that perish as a result of catch and release fishing to be lower than the number (18) of steelhead that would be expected to perish as a result of catch and release fishing. NMFS estimates up to 10 Chinook salmon may perish as a result of catch and release fishing. NMFS does not expect any coho salmon will perish as a result of incidental capture during fishing because coho salmon are less susceptible to harvest in the Mad River and few are caught based on creel surveys (Sparkman 2003).

2.4.3 Effects of the Action on Critical Habitat

Negligible effect: This consultation analyzed the Proposed Action for its effects on designated critical habitat and has determined that operation of the hatchery program will have a negligible effect on PBFs in the action area, but may have an overall beneficial effect in the Mad River Basin. The beneficial effects on critical habitat in the Mad River HGMP River are from the introduction of marine-derived nutrients from naturally spawning hatchery fish that perish and from hatchery steelhead carcasses from fish that perish in the hatchery. The hatchery carcasses provide a direct food source for juvenile salmonids and other fish, aquatic invertebrates, and terrestrial animals, and their decomposition supplies nutrients that may increase primary and secondary production. These marine-derived nutrients can increase the growth and survival of the ESA-listed species by affecting PBFs in the Mad River associated with juvenile rearing such as increasing forage species (*i.e.*, aquatic and terrestrial insects), aquatic vegetation, and riparian vegetation to name a few. The continued input of hatchery salmon and steelhead carcasses is expected to benefit the recovery of natural-origin populations in the Mad River Basin.

Other possible effects on critical habitat from the Proposed Action would occur in freshwater migration corridors during the operation of weirs. Weirs would result in a short-term (less than 12 hours) delay in the migration of adult steelhead, Chinook salmon, and coho salmon. The hatchery facility itself would not require additional construction or disturbance of riparian or streambed habitat, and any effects of water withdrawal and effluent are expected to be small and transitory. Operation of the Mad River Hatchery is not expected to reduce the amount of water in the Mad River because it does not divert surface water and the wells are deep enough such that no effect on river flows as a result of well use has been observed (CDFW 2016). In addition, water is not consumed during hatchery operations and is allowed to percolate into the ground or discharged to the river at the point of use. Operation of the Mad River Hatchery is not expected to degrade water quality because the hatchery operates under an NPDES permit, which requires that no adverse effects on beneficial uses, including fish and their habitats, will occur.

Habitat impacts from the installation and operation of the weirs are expected to be limited to the weir location, and to be of a short duration. Habitat will be temporarily impacted by the placement of the weirs. Each weir is designed to be installed and removed annually, eliminating the requirement for permanent structures in the river. When the weirs are operational, they will impact the PBFs for migration as follows:

- The weirs may be encountered by coho salmon, steelhead, and Chinook salmon.

- Impacts on coho salmon, Chinook salmon, and steelhead would occur on that proportion of the adult returns that enter the Mad River prior to the removal of the weirs. Impacts are expected to be low because only a few coho salmon, and Chinook salmon would be handled. Only those steelhead necessary for spawning would be handled. If large numbers of non-target species congregate at the weirs, the fish will be allowed to ascend upstream of the weir unhandled and unharmed and the weir location and timing will be changed to reduce interactions with non-target species. Effects on natural-origin fish that are discovered will be reduced by adjustments in weir design and placement, the use of trained personnel, and operations that minimize the time salmon and steelhead are held or delayed at the weirs.

Operation and maintenance activities would include building maintenance and ground maintenance. These activities would not be expected to degrade water quality or adversely modify designated critical habitat, because they would occur infrequently, and only result in minor temporary effects. Non-routine maintenance (*e.g.*, construction of facilities or reconstruction of in-river hatchery structures) is not considered in this opinion and would require separate consultation.

2.5 Cumulative Effects

"Cumulative effects" are those effects of future state or private activities, not involving Federal activities, that are reasonably certain to occur within the action area of the Federal action subject to consultation (50 CFR 402.02). Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the ESA.

NMFS expects that urbanization, farming, grazing, timber harvest will continue to affect salmonids and their habitat through avenues discussed previously in the environmental baseline. Recent changes to state and county policies that reduce the effects of development and timber harvest should reduce the effects of these activities. Humboldt County and the State of California are currently developing marijuana permitting laws that should reduce the environmental effects of those activities. The cumulative effects will include those effects attributed to sedimentation, timber harvest, and water withdrawal discussed previously. The further reduction in these effects is expected to continue to allow for the improvement in salmonid habitat conditions that will improve their survival.

2.6 Integration and Synthesis

The Integration and Synthesis section is the final step in our assessment of the risk posed to species and critical habitat as a result of implementing the proposed action. In this section, we add the effects of the action (Section 2.4) to the environmental baseline (Section 2.3) and the cumulative effects (Section 2.5), taking into account the status of the species and critical habitat (section 2.2), to formulate the agency's biological opinion as to whether the proposed action is likely to: (1) reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing its numbers, reproduction, or distribution; or (2) reduce the value of designated or proposed critical habitat for the conservation of the species. NMFS has developed a VSP concept which includes the parameters of population abundance, population growth rate, population spatial structure, and population diversity for defining a viable population which is an independent Pacific salmonid population that has a negligible risk of extinction due to threats from demographic variation, local environmental variation, and genetic diversity changes over a 100-year time period. An ESU/DPS is typically made up of multiple independent populations. Therefore, NMFS must assess whether changes to VSP parameters of the independent population results in a reduction in the numbers, reproduction, or distribution of the ESU /DPS as a whole.

2.6.1 Summary of Environmental Baseline, Status of the Species, and Cumulative Effects

The current status of habitat in the action area is improving relative to past conditions that lead to the listing of coho salmon, steelhead, and Chinook salmon in the Mad River. Timber harvest practices and road building have changed to reduce sediment inputs and increase future LWD recruitment to the stream channel. Some road systems on private timber land have been upgraded to reduce sediment. Gravel extraction practices have been changed to better control the volume of gravel extracted based on annual sediment recruitment estimates and protect the natural morphology of the stream. The lower Mad River is still influenced by levees and some sections of the river are restricted from occupying floodplains. Water use from marijuana cultivation has increased in recent years, but the magnitude of the effects are currently unknown. Future permitting that is required for state and county legal marijuana cultivation should reduce the effects of water use on listed salmonids and their habitats.; however, illicit marijuana growing may continue to decrease the quality and quantity of habitat in affected watersheds. Localized restoration efforts including barrier removal activities such as those recently completed on Powers Creek and a culvert upgrade project currently being designed and funded for Quarry Creek, LWD enhancement, and creation of off-channel habitats during gravel operations and a project that will occur on the Blue Lake Rancheria will further improve conditions for listed salmon and steelhead in the Mad River. NMFS assumes that the productivity of salmonid populations in the Mad River is primarily limited by the current quantity and quality of the salmonid habitat available and that future improvements to habitat conditions would promote their recovery.

Population monitoring of salmon and steelhead in the Mad River has been limited until recently. However, this limited monitoring suggests Chinook salmon and steelhead populations are likely increasing over previous estimates with the Chinook salmon being at least 70% of the recovery goal of 3,000 adults and the natural steelhead population at approximately 40% of the 9,300 goal. The steelhead population has measurably improved since 2001 (Sparkmann 2001; M. Sparkmann, CDFW, pers.comm. 2016), and is higher than the population estimated from fish counts at Sweasey Dam in the 50s. The abundance of the coho salmon population is still unknown, but considered at high risk of extinction.

The cumulative effects of those state, private, and tribal activities that occur in the watershed as discussed in the environmental baseline (*e.g.*, timber harvest) will continue to impair, but not preclude the recovery of, habitat in the action area. NMFS expects that new regulations for marijuana farming, as well as ongoing improvements in legacy effects of poor timber harvest practices and agricultural and urban development will result in improved habitat conditions for listed salmon and steelhead. Additionally, focused recovery actions as identified in the SONCC Coho Salmon Recovery Plan and the Multispecies Recovery Plan are expected to further improve habitat for salmon and steelhead in the Mad River.

2.6.2 NC Steelhead

Based on a review of the proposed Mad River steelhead program, the status of the Mad River steelhead populations, the consideration of the environmental baseline conditions, and the cumulative effects, the interrelated effect of fishing, and the predicted effects of the proposed Mad River steelhead hatchery actions on NC steelhead range from negligible to negative. Of the effects evaluated, the effects of gene flow from natural spawning hatchery fish, the collection of natural broodstock, the ME&R activities, the ecological effects, and the effects of the fishery for hatchery fish are expected to have a negative effect on the ESA-listed Mad River steelhead populations.

Ecological Effects
NMFS expects that there will be minor ecological effects on listed, natural steelhead juveniles by the proposed action. A small number of juveniles may be affected by competition and subject to minor decreases in growth from hatchery fish that do not leave the Mad River and enter the Pacific Ocean or by the progeny of naturally spawning hatchery fish. NMFS expects that this number would be extremely low and not result in a reduction in the number of hatchery or natural steelhead that return as adults. In addition, an extremely low number of steelhead fry may be eaten by hatchery-origin steelhead after release because the hatchery releases occur weeks earlier than natural steelhead fry are expected to emerge from the gravel and older steelhead are larger than would be considered prey (greater than 1/3rd the length of predatory

hatchery fish). NMFS does not expect a reduction in the number of adult steelhead that return to the Mad River as a result of predation because of the likely compensatory effects on survival of remaining fry that will rear at least another two years in the Mad River before entering the ocean.

Genetic Effects
Gene flow between associated natural-origin steelhead populations and fish produced by the Mad River Hatchery program is identified as having negative effects on Mad River steelhead population fitness. Based on NMFS's consideration of best available scientific information, gene flow levels of into natural-origin Mad River steelhead populations will not pose substantial risk because measures will be implemented to minimize unintended natural spawning by hatchery-origin steelhead, and to continue to substantially limit gene flow from the hatchery populations to the natural ESA-listed populations (CDFW 2016). These measures will include no off-station planting and incorporation of at least 50% natural-origin adults into the spawning population and never spawning a hatchery fish with another hatchery fish. Over time, this level of integration of natural-origin fish into the hatchery broodstock population is expected to reduce divergence between the hatchery and natural populations and increase productivity of natural origin and hatchery origin fish spawning in the wild. CDFW intends to monitor the population abundance and genetic information for both natural and hatchery fish to monitor gene flow between populations (CDFW 2016).

As discussed in the Effects analysis, it is impossible at this time to assess the baseline level of genetic change in the affected steelhead populations attributable to past operation of the Mad River Hatchery program. But given the levels of gene flow expected from the proposed action, adding these levels to the baseline fitness levels is not likely to have more than a negligible effect on fitness in the future and is expected to improve it from the existing baseline because of the increased incorporation of the natural population into the broodstock and an expected reduction in divergence and concomitant improvements in genetic diversity.

On the basis of the best available science, the expectation that gene flow effects on natural steelhead genetic diversity is likely low, and considering risk minimization actions that will be implemented, the proposed action is likely to have only minor effects on fitness. NMFS and CDFW will monitor emerging science and information provided by the co-managers and other scientists related to genetic interactions between Mad River Hatchery steelhead and steelhead from natural-origin populations and re-initiation of consultation, under section 7 will be required in the event that new information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not considered in this consultation (50 CFR 402.16).

Broodstock Collection (demographic effect)
CDFW intends to annually collect from 125 to 250 natural-origin steelhead for the hatchery program. The 2014 estimate for the natural steelhead population in the Mad River is 3,449 fish so the broodstock collection represents approximately 7% of the population, assuming the natural-origin steelhead population is at least 3,449 each year.

ME&R (demographic effect)
Tables 1 and 2 highlight the number of adult and juvenile steelhead that will be captured and injured/killed during ME&R activities. NMFS expects some overlap between ME&R activities

and broodstock collection, so these numbers can be expected to represent the maximum number of fish that would be captured and killed. CDFW estimates up to 1% of the fry, juveniles, and smolts captured may be injured or die as a result of capture. This represents approximately 1,250 fry, juveniles and smolts. NMFS thinks that a small fraction of fish killed during ME&R activities may have otherwise returned as adults. Fry, juvenile, or smolt-to-adult return rates are not available for the Mad River, but NMFS assumes that this small number of fry, juvenile, and smolts that are killed during ME&R are unlikely to reduce the number of adults that return to a degree that abundance is reduced enough to affect the Mad River population's viability.

Fishing (demographic effect)
The purpose of the Mad River Hatchery steelhead program is to provide a robust fishery for hatchery-origin steelhead in the Mad River. Catch and release of ESA-listed Mad River natural-origin steelhead also occurs in this fishery. The majority of the anglers in the Mad River are focused on catching hatchery fish so the bulk of the angling occurs within a few miles upstream and downstream of the hatchery. The 2014 abundance of hatchery fish in the Mad River was estimated at 4,336 adults, which is approximately 56% of the total population of winter steelhead in the Mad River for that year. CDFW estimated the catch and release of natural-origin steelhead in the Mad River for the years 2006-2011 was approximately 356 natural-origin steelhead per year of which most, if not all, were released (CDFW 2015). We estimated that up to 5% of natural-origin steelhead that were caught and released would die based on studies of catch and release mortality (Nelson *et al.* 2005). Therefore, NMFS estimated approximately 18 steelhead per year or 0.5% of the population estimate would die as a result of fishing (356 x 5% =18; 18/3,449=0.5%).

Summary
After addition of the effects of the proposed action to the environmental baseline and any cumulative effects, NMFS believes that the ecological, genetic, and demographic effects that are expected to result from the proposed action will slightly reduce the abundance of NC steelhead in the Mad River, but will not otherwise markedly affect VSP attributes including productivity, viability, or spatial structure and, therefore, will not appreciably reduce the survival and recovery of the NC Steelhead DPS.

2.6.3 CC Chinook Salmon

The potential effects of the proposed action on CC Chinook salmon are limited to ecological and demographic effects. These include a minor increase in competition with the progeny of hatchery-origin fish that spawn in the wild. In addition, a negligible increase in predation by hatchery-origin steelhead smolts after release is expected. ME&R activities are expected to result in the mortality of up to approximately 2,985 fry and smolt Chinook salmon, which is approximately 1% of the fish collected during ME&R activities (CDFW 2016; Table 2). Of these 2,985 mortalities, NMFS estimates that an unknown, but comparatively small number of these fish may have survived to return as adult. A small number of adult Chinook salmon are also expected to suffer mortality as a result of fishing for hatchery steelhead in the Mad River, but we expect this number to be less than 10 individuals because of the differences in timing of the Chinook salmon and winter steelhead run timing and the required release of all Chinook salmon in the Mad River, which results in a low fishing contact rate for Chinook salmon in the Mad River. Therefore, we expect an annual reduction in the Mad River Chinook salmon abundance as a result of implementation of the proposed action of up to 10 fish from fishing effects and an unknown, but small number from ME&R. We do not have fry or smolt to adult return rates for Chinook salmon in the Mad River, but assume it would be similar to other rivers in the Pacific Northwest. Therefore, NMFS does not expect that growth rate, spatial structure, or diversity of the Chinook salmon population in the Mad River will be measurably affected by the proposed action or the reduction in abundance of approximately 40 fish/year. Therefore, the proposed action is not expected to appreciably reduce the likelihood of survival and recovery of the CC Chinook Salmon ESU.

2.6.4 SONCC Coho Salmon

The potential effects of the proposed action on SONCC coho salmon are limited to a minor increase in competition with the progeny of hatchery-origin fish that spawn in the wild. In addition, a negligible increase in predation by hatchery-origin steelhead smolts after release is expected. NMFS does not expect either competition or predation to reduce the number of coho salmon adults. A small number of coho salmon adults will be captured during steelhead broodstock collections and ME&R efforts (up to 19 adults if all capture techniques are employed, which is unlikely), but no mortalities or injuries are expected (Table 1). It should be noted that broodstock collection and ME&R efforts will be done simultaneously and provide a dual purpose, when possible. That is, efforts to collect adult steelhead for broodstock will more than likely be done in conjunction with efforts to collect abundance estimates. As such, the take numbers estimated here are higher than anticipated. Since no mortalities are expected, NMFS does not expect any effects on VSP parameters for coho salmon from ecological interactions (competition and predation), broodstock collection, or adult ME&R efforts. Finally, CDFW may operate juvenile traps that will incidentally capture coho salmon. CDFW estimates that up to 3,600 coho salmon fry, 5,000 juveniles, and 6,000 smolts may be collected during juvenile trapping operations (Table 2). The estimated mortalities from these efforts is estimated at 1%. This small number of mortalities is not expected to measurably reduce the abundance or population growth rate and have no effect on spatial structure and diversity. Therefore, the proposed action is not expected to significantly reduce any VSP parameter for coho salmon in the Mad River and, thus, is not expected to reduce the survival or recovery of the SONCC Coho Salmon ESU.

2.6.5 Critical Habitat

NMFS has determined that the effects on critical habitat from the Mad River hatchery steelhead program are limited to only short-term effects on the migratory corridor from operations of weirs, if and when they are used. Such effects on critical habitat would, therefore, be negligible. A small, beneficial effect on PBFs affected by an increase in marine-derived nutrients is expected from the increased number of carcasses retained in the headwater and rearing areas resulting from hatchery-produced adults in those areas. Therefore, the proposed action will not destroy or adversely modify designated critical habitat for SONCC coho salmon, CC Chinook salmon, or NC steelhead.

2.7 Conclusion

After reviewing and analyzing the current status of the listed species and critical habitat, the environmental baseline within the action area, the effects of the proposed action, any effects of interrelated and interdependent activities, and cumulative effects, it is NMFS' biological opinion that the proposed action is not likely to jeopardize the continued existence of the SONCC Coho Salmon ESU, CC Chinook Salmon ESU, or the NC Steelhead DPS and will not destroy or adversely modify their designated critical habitat.

2.8 Incidental Take Statement

Section 9 of the ESA and Federal regulations pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without a special exemption. "Take" is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. "Harm" is further defined by regulation to include significant habitat modification or degradation that actually kills or injures fish or wildlife by significantly impairing essential behavioral patterns, including breeding, spawning, rearing, migrating, feeding, or sheltering (50 CFR 222.102). "Incidental take" is defined by regulation as takings that result from, but are not the purpose of, carrying out an otherwise lawful activity conducted by the Federal agency or applicant (50 CFR 402.02). Section 7(b)(4) and section 7(o)(2) provide that taking that is incidental to an otherwise lawful agency action is not considered to be prohibited taking under the ESA if that action is performed in compliance with the terms and conditions of this incidental take statement.

2.8.1 Amount or Extent of Take

Take of ESA-listed salmon and steelhead would occur as a result of the Proposed Action from (1) broodstock collection, including the operation of weirs; (2) genetic effects from interactions on the spawning grounds; (3) ecological effects (competition and predation) in juvenile rearing areas; and (4) monitoring, evaluation and research (ME&R).

(1) Broodstock Collection

In the course of collecting hatchery broodstock, the proposed action may result in the incidental take of coho salmon and Chinook salmon or excess natural-origin steelhead that volunteer into the hatchery ladder or during other capture methods (weirs, angling, seining) to collect natural-origin steelhead for broodstock throughout the Mad River (Table 4). Few coho salmon and Chinook salmon are expected to be encountered during broodstock collection operations. NMFS cannot reliably estimate the number that may be encountered because of increases or decreases in annual run sizes.

Table 4. The number and species of adult, natural-origin steelhead, coho salmon, and Chinook salmon that may be collected during broodstock collection and monitoring operations under the Mad River HGMP. Expected mortalities are in parentheses.

	Ladder (morts)	Angling (morts)	Seining (morts)	Weirs (morts)
Coho salmon*	3 (0)	3 (0)	10 (0)	3 (0)
Chinook salmon*	5 (0)	40 (1)	300 (1)	5 (0)
Steelhead*	175-300 (1)	175-300 (1)	175-300 (1)	175-300 (1)

* The preferred method for broodstock collection is the ladder, angling, seining, and weirs, in that order. As such, the collection of coho salmon and Chinook salmon will also vary depending on which method or combination of methods are used. In addition, monitoring activities that require the capture of adult salmon and steelhead will be scheduled to coincide with broodstock collection activities, if necessary and when possible, to reduce take.

(2) Genetic Effects

Take of listed steelhead is expected to occur as a result of the release of hatchery-origin fish into the natural environment where they interact with natural-origin steelhead, resulting in the outplanting of the hatchery-induced selection effects and the potential outbreeding effects on the genetic diversity and productivity of natural origin fish that interbreed with the hatchery-origin fish.

An unknown percentage of listed natural-origin Mad River steelhead will experience the genetic effects because listed steelhead returning adults will either be taken into the hatchery and exposed to these genetic effects, or migrate upstream to spawn naturally along with hatchery-origin fish.

It would not be possible to accurately measure genetic effects in a way that would allow for the accurate quantification of take because the genetic effects cannot be detected in a comprehensive, reliable manner. Tissue sample studies can be used to detect certain genetic trends, but studies take several years to complete and identifying trends also takes a number of years of sampling, making them unfit as a compliance tool. Therefore, NMFS will rely on a surrogate take indicator that relates to the productivity of the listed population – the primary factor in determining genetic effects. The surrogate take indicator, therefore, is a failure to attain a productivity rate of 1.0 recruits per spawner for the Mad River steelhead population in at least 1 of 4 consecutive brood years. Productivity will be monitored by CDFW by comparing estimated natural-origin adult steelhead escapement to natural spawning areas in the Mad River watershed with resultant returning spawner brood year escapement.

This indicator has a rational connection to the genetic effects take pathway, for several reasons. First, four consecutive years represents the full life cycle of the species and enables NMFS to detect potential effects above and beyond any single-year anomaly. Secondly, failing to meet 1.0 recruits per spawner would indicate that NMFS' conclusion would merit reconsideration that genetic (and other) effects are not an important limiting factor. While productivity goals may not be met for a variety of reasons besides genetic effects, this indicator would trigger further analysis to determine the causes of low productivity.

(3) Interactions in Juvenile Rearing Areas

Take of listed steelhead, coho salmon, and Chinook salmon is expected to occur as a result of ecological effects including competition and predation as a result of the release of hatchery-origin smolts and the progeny of hatchery-origin steelhead that spawn in the wild.

It is not possible to quantify the take associated with competition and predation in the action area, because it is not possible to meaningfully measure the number of interactions between hatchery-reared and natural origin salmon and steelhead, or between the progeny of hatchery-origin natural spawning fish and natural-origin salmon and steelhead. Therefore, NMFS will rely on a surrogate, which is the 1.0 recruits per spawner productivity threshold discussed above. The surrogate take indicator, therefore, is a failure to attain a productivity rate of 1.0 recruits per spawner for the Mad River steelhead population in at least 1 year over four consecutive years.

(4) Monitoring Evaluation and Research

Take of adult and juvenile Chinook salmon, steelhead, and coho salmon is expected to occur in connection with the monitoring and evaluation actions included in the proposed action (see Table 4 above and Table 5, below). Take associated with monitoring will be identified in annual reports provided by CDFW to NMFS so that effects on listed species can be monitored.

Table 5. The number and species of juvenile steelhead, Chinook salmon, and coho salmon collected as part of monitoring, evaluation and research that may be conducted as part of the HGMP implementation. Most fish would be captured, enumerated and released, but a certain proportion will be marked and used to develop capture statistics and population estimates. The maximum expected injuries/mortalities from all activities are in parentheses.

	Fry	Juvenile	Smolt
Steelhead	45000 (450)	65000 (650)	15000 (150)
Chinook salmon	42500 (425)	N/A	256000 (2560)
Coho salmon	3600 (36)	5000 (50)	6000 (60)

2.8.2 Effect of the Take

In the biological opinion, NMFS determined that the amount or extent of anticipated take, coupled with other effects of the proposed action, is not likely to result in jeopardy to the species or destruction or adverse modification of critical habitat.

2.8.3 Reasonable and Prudent Measures

“Reasonable and prudent measures” are nondiscretionary measures that are necessary or appropriate to minimize the amount or extent of incidental take (50 CFR 402.02).

NMFS concludes that the following reasonable and prudent measures are necessary and appropriate to minimize the impacts from the proposed Mad River Hatchery program on the CC Chinook Salmon ESU, NC Steelhead DPS, and SONCC Coho Salmon ESU:

1. CDFW must ensure implementation of the Mad River Hatchery program as described in the submitted HGMP.
2. CDFW must manage their operations to limit the risk of adverse demographic, ecological, and genetic effects on listed NC steelhead, CC Chinook salmon, and SONCC coho salmon.
3. CDFW must follow criteria and guidelines specified in this opinion for their respective monitoring and evaluation activities within the Mad River.
4. CDFW must provide reports to the NMFS California Coastal Office annually for the Mad River Hatchery, and for all research, monitoring, and evaluation activities associated with the hatchery program.

2.8.4 Terms and Conditions

The terms and conditions described below are non-discretionary, and NMFS or any applicant must comply with them in order to implement the reasonable and prudent measures (50 CFR 402.14). NMFS or any applicant has a continuing duty to monitor the impacts of incidental take and must report the progress of the action and its impact on the species as specified in this incidental take statement (50 CFR 402.14). If the entity to whom a term and condition is directed does not comply with the following terms and conditions, protective coverage for the proposed action would likely lapse.

1. The following terms and conditions implement reasonable and prudent measure 1:

    a. CDFW must ensure implementation of the hatchery programs as described in the submitted HGMP. NMFS must be notified in advance of any change in hatchery operations that would potentially result in increased take of ESA-listed species.

    b. CDFW must complete a draft Fishery Management and Evaluation Plan (FMEP) for either the Mad River specifically or a regional FMEP that includes the Mad River within one year of the approval of the Mad River HGMP.

    c. CDFW shall convene a hatchery team consisting of NMFS and CDFW personnel that will meet on at least an annual basis to discuss the annual reports and any other technical or HGMP-related issues.

2. The following terms and conditions implement reasonable and prudent measure 2:

a. CDFW must ensure monitoring is adequate to detect changes in spawner recruitment ratios, which is a surrogate for take, such that productivity doesn't fall below 1.0 for at least one of each four consecutive years.

3. The following terms and conditions implement reasonable and prudent measure 3:

a. CDFW must take the greatest care when handling listed species including minimizing handling, using anesthesia, salt, ice, and slime maintenance chemicals, as necessary. Any mortalities or injuries must be quantified and submitted to NMFS in the annual report.

4. The following terms and conditions implement reasonable and prudent measure 4:

a. By July 1 of each year, CDFW must send annual reports on (1) the Mad River HGMP monitoring, evaluation, and research results; and (2) spawner: recruit analysis to:

NMFS Northern California Office
1655 Heindon Road
Arcata, California 95521.

2.9 Conservation Recommendations

Section 7(a)(1) of the ESA directs Federal agencies to use their authorities to further the purposes of the ESA by carrying out conservation programs for the benefit of the threatened and endangered species. Specifically, conservation recommendations are suggestions regarding discretionary measures to minimize or avoid adverse effects of a proposed action on listed species or critical habitat or regarding the development of information (50 CFR 402.02). NMFS has the following conservation recommendations:

(1) develop strategies to reduce the effects of domestication (*e.g.*, reducing rearing densities);

(2) develop a strategy to rehabilitate kelts (spawned, natural-origin steelhead) to promote iteroparity;

(3) assess the potential for increasing homing fidelity of hatchery steelhead to the Mad River Hatchery ladder; and

(4) improve monitoring to better assess PHOS, steelhead genetics, and steelhead demographics.

2.10 Reinitiation of Consultation

This concludes formal consultation on NMFS' proposed approval of the Mad River HGMP.

As 50 CFR 402.16 states, reinitiation of formal consultation is required where discretionary Federal agency involvement or control over the action has been retained or is authorized by law and if: (1) the amount or extent of incidental taking specified in the incidental take statement is exceeded, (2) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in this opinion, (3) the agency action is subsequently modified in a manner that causes an effect to the listed species or critical habitat that was not considered in this opinion, or (4) a new species is listed or critical habitat designated that may be affected by the action.

2.11 "Not Likely to Adversely Affect" Determinations

The historical range of Southern Pacific Eulachon (*Thaleichthys pacificus*) (SPE) includes the Mad River, which is the southernmost stream identified. Critical habitat for SPE is also designated in the Mad River. SPE, if present, may be captured in downstream migrant traps and eggs and larvae may be predated upon by hatchery smolts. However, SPE have not been observed in the Mad River in decades and it is unclear whether they were ever found in abundance. Therefore, there is an extremely low likelihood that SPE will be either taken in downstream migrant traps or predated upon by steelhead so this potential effect is discountable. Therefore, implementation of the Mad River HGMP is not likely to adversely affect SPE. Weir construction in the tributaries may result in a minor disturbance to spawning substrate for SPE, however, this disturbance is not expected to reduce the quality of spawning habitat and will be spatially limited. No construction activities are expected to occur and no other hatchery activities are expected to affect critical habitat for SPE. Therefore, adverse effects on critical habitat are not likely to occur.

3 MAGNUSON-STEVENS FISHERY MANAGEMENT ACT

NMFS has determined that adverse effects on Pacific Salmon Essential Fish Habitat (EFH) are not expected. No construction is expected to occur under the proposed action and no other activities are proposed that will rise to the level of adversely affecting EFH. NMFS expects some benefit will accrue from carcasses of hatchery steelhead that will slightly increase the level of marine-derived nutrients in the Mad River. Therefore, consultation is not necessary.

4 DATA QUALITY ACT DOCUMENTATION AND PRE-DISSEMINATION REVIEW

The Data Quality Act (DQA) specifies three components contributing to the quality of a document. They are utility, integrity, and objectivity. This section of the opinion addresses these DQA components, documents compliance with the DQA, and certifies that this opinion has undergone pre-dissemination review.

4.1 Utility

Utility principally refers to ensuring that the information contained in this consultation is helpful, serviceable, and beneficial to the intended users. The intended users of this opinion are NMFS. Other interested users could include CDFW and citizens of California and surrounding states that utilize the Mad River for steelhead fishing. Individual copies of this opinion were provided to NMFS and CDFW. This opinion will be posted on the Public Consultation Tracking System web site (*https://pcts.nmfs.noaa.gov/pcts-web/homepage.pcts*). The format and naming adheres to conventional standards for style.

4.2 Integrity

This consultation was completed on a computer system managed by NMFS in accordance with relevant information technology security policies and standards set out in Appendix III, 'Security of Automated Information Resources,' Office of Management and Budget Circular A-130; the Computer Security Act; and the Government Information Security Reform Act.

4.3 Objectivity

Information Product Category: Natural Resource Plan

Standards: This consultation and supporting documents are clear, concise, complete, and unbiased; and were developed using commonly accepted scientific research methods. They adhere to published standards including the NMFS ESA Consultation Handbook, ESA regulations, 50 CFR 402.01 et seq., and the MSA implementing regulations regarding EFH, 50 CFR 600.

Best Available Information: This consultation and supporting documents use the best available information, as referenced in the References section. The analyses in this opinion contain more background on information sources and quality.

Referencing: All supporting materials, information, data and analyses are properly referenced, consistent with standard scientific referencing style.

Review Process: This consultation was drafted by NMFS staff with training in ESA and reviewed in accordance with West Coast Region ESA quality control and assurance processes.

5 REFERENCES

5.1 Literature Cited

Abdul-Aziz, O. I, N. J. Mantua, K. W. Myers. 2011. Potential climate change impacts on thermal habitats of Pacific salmon (*Oncorhynchus* sp.) in the North Pacific Ocean and adjacent seas. Canadian Journal of Fisheries and Aquatic Sciences 68(9):1660-1680.

Anderson, C.W., G. Scheer, D. Ward. 2015. Results of Freshwater Creek Salmonid Life Cycle Monitoring Station 2014-15. California Department of Fish and Game Anadromous Fisheries Resource Assessment and Monitoring Program. 64 p.

Araki, H., B. Cooper, and M.S. Blouin. 2007. Genetic effects of captive breeding cause a rapid, cumulative fitness decline in the wild. Science 318(5847):100.

Araki, H., B. A. Berejikian, M. J. Ford, and M. S. Blouin. 2008. Fitness of hatchery-reared salmonids in the wild. Evolutionary Applications. 1(2): 342-355.

Ayllon F., J.L. Martinez, and E. Garcia-Vazquez. 2006. Loss of regional population structure in Atlantic salmon, *Salmo salar L*., following stocking. ICES J Mar Sci 63:1269–1273.

Bauer, S., J. Olson, A. Cockrill, M. van Hattern, L. Miller, M. Tauzer, and G. Leppig. 2015. Impacts of surface water diversions for marijuana cultivation on aquatic habitat in four Northwestern California watersheds. PLoS ONE 10(3): e0120016. Doi:10.1371/journal.pone.0120016.

Beamish, R. J., and D. R. Bouillion. 1993. Pacific salmon production trends in relation to climate. Canadian Journal of Fisheries and Aquatic Sciences 50:1002-1016.

Beamish R. J., and C. Mahnken. 2001. A critical size and period hypothesis to explain natural regulation of salmon abundance and the linkage to climate and climate change. Progress in Oceanography 49:423-437.

Beamish, R.J., C. Mahnken, and C.M. Neville. 1997. Hatchery and wild production of Pacific salmon in relation to large-scale, natural shifts in the productivity of the marine environment. ICES Journal of Marine Science 54:1200–1215.

Beckman, B. R., D. A. Larsen, C. S. Sharpe, B. Lee-Pawlak, C. B. Schreck, and W. W. Dickhoff. 2000. Physiological status of naturally reared juvenile spring Chinook salmon in the Yakima River: Seasonal dynamics and changes associated with smolting. Transactions of the American Fisheries Society. 129: 727-753.

Behrenfeld, M.J., R.T. O'Malley, D.A. Siegel, C.R. McClain, J.L. Sarmiento, G.C. Feldman, J. Milligan, P.G. FaBeamish, R. J. and D. R. Bouillion. 1993. Pacific salmon production trends in relation to climate. Canadian Journal of Fisheries and Aquatic Sciences 50:1002-1016.

Bell, E., and W.G. Duffy. 2007. Previously undocumented two-year freshwater residency of juvenile coho salmon in Prairie Creek, California. Transactions of the American Fisheries Society 136: 966-970.

Berejikian, B. A., and M. J. Ford. 2004. Review of relative fitness of hatchery and natural salmon. U.S. Dept. of Commerce, NOAA Tech. Memo. NMFS/NWFSC-61, 43p.

Berntson, E. A., R. W. Carmichael, M. W. Flesher, E. J. Ward, and P. Moran. 2011. Diminished reproductive success of steelhead from a hatchery supplementation program (Little Sheep Creek, Imnaha Basin, Oregon). Transactions of the American Fisheries Society. 140: 685-698.

Bilby, R.E., B.R. Fransen, and P.A. Bisson. 1996. Incorporation of nitrogen and carbon from spawning coho salmon into the trophic system of small streams: evidence from stable isotopes. Canadian Journal of Fisheries and Aquatic Sciences 53:164-173.

Bilby, R.E., B.R. Fransen, P.A. Bisson, and J.K. Walter. 1998. Response of juvenile coho salmon (*Oncorhynchus kisutch*) and steelhead (*Oncorhynchus mykiss*) to the addition of salmon carcasses to two streams in southwestern Washington, USA. Canadian Journal of Fisheries and Aquatic Sciences 55:1909-1918.

Blankenship, S. M., M. P. Small, J. Bumgarner, M. Schuck, and G. Mendel. 2007. Genetic relationships among Tucannon, Touchet, and Walla Walla river summer steelhead (*Oncorhynchus mykiss*) receiving mitigation hatchery fish from Lyons Ferry Hatchery. Olympia, Washington. 39p.

Brewer, P.G., and J. Barry. 2008. Rising acidity in the ocean: The other CO2 problem. Scientific American. October 7, 2008.

Bryant, G.J. 1994. Status review of coho salmon in Scott Creek and Waddell Creek, Santa Cruz County, California. National Marine Fisheries Service, Southwest Region, SW Region, Protected Species Management Division, 102 p.

Busack, C. 2007. The impact of repeat spawning of males on effective number of breeders in hatchery operations. Aquaculture. 270: 523-528.

Busack, C.A., and K.P. Currens. 1995. Genetic risks and hazards in hatchery operations: Fundamental concepts and issues. American Fisheries Society Symposium 15: 71-80.

Busack, C., and C. M. Knudsen. 2007. Using factorial mating designs to increase the effective number of breeders in fish hatcheries Aquaculture. 273: 24-32.

Busby, P. J., T.C. Wainwright, G.J. Bryant, L.J. Lierheimer, R.S. Waples, F.W. Waknitz, and I.V. Lagomarsino. 1996. Status review of west coast steelhead from Washington, Idaho, Oregon, and California. U.S. Department of Commerce, NOAA Technical Memo. NMFS-NWFSC-27.

Butsic, V., and J.C. Brenner. 2016. Cannabis (*Cannabis sativa or C. Indica*) agriculture and the environment: a systematic, spatially-explicit survey and potential impacts. Environmental Research Letters 11:044203.

California HSRG (California Hatchery Scientific Review Group). 2012. California Hatchery Review Statewide Report. Prepared for the US Fish and Wildlife Service and Pacific States Marine Fisheries Commission. April 2012.

Campton, D.E. 1995. Genetic effects of hatchery fish on wild populations of pacific salmon and steelhead: What do we really know? American Fisheries Society Symposium 15: 337-353.

Cannamela, D.A. 1992. Potential Impacts of Releases of Hatchery Steelhead Trout Smolts on Wild and Natural Juvenile Chinook and Sockeye salmon. A White Paper, Idaho Department of Fish and Game, Boise, Idaho.

CDFG (California Department of Fish and Game). 1994. Petition to the California Board of Forestry to list coho salmon (*Oncorhynchus kisutch*) as a sensitive species. California Department of Fish and Game Report. 35 p. plus appendices. (Available from California Board of Forestry, 1416 Ninth, Sacramento, CA 95814).

CDFW. 2015. Steelhead report and restoration card program: 2006-2011. Fisheries Branch Administrative Report 2015-01.

CDFW. 2016. Hatchery and genetic management plan for Mad River hatchery steelhead. Prepared for NMFS by the California Department of Fish and Wildlife, Arcata, CA.

Chavez, F.P., J. Ryan, S.E. Lluch-Cota, and M. Niquen. 2003. From anchovies to sardines and back: Multidecadal change in the Pacific Ocean. Science 299(5604):217-221.

Chilcote, M.W. 2003. Relationship between natural productivity and the frequency of wild fish in mixed spawning populations of wild and hatchery steelhead (*Oncorhynchus mykiss*). Canadian Journal of Fisheries and Aquatic Sciences 60:1057–1067.

Christie, M. R., M. L. Marine, R. A. French, and M. S. Blouin. 2011. Genetic adaptation to captivity can occur in a single generation. Proceedings of the National Academy of Sciences. 109(1): 238–242.

Cloern, J.E., N. Knowles, L.R. Brown, D. Cayan, M.D. Dettinger, T.L.Morgan, D.H. Schoellhamer, M.T. Stacey, M. van der Wegen, R.W. Wagner, and A.D. Jassby. 2011. Projected evolution of California's San Francisco Bay-Delta-River system in a century of climate change. PLoS ONE 6(9):13.

Department of Water Resources (DWR). 2013. San Francisco Bay Hydrologic Region. California Water Plan Update 2013. State of California Natural Resource Agency Department of Water Resources, Sacramento, California.

Dittman, A. H., D. May, D. A. Larsen, M. L. Moser, M. Johnston, and D. E. Fast. 2010. Homing and spawning site selection by supplemented hatchery- and natural-origin Yakima River spring Chinook salmon. Transactions of the American Fisheries Society. 139(4): 1014-1028.

Dittman, A. H., and T. P. Quinn. 2008. Assessment of the Effects of the Yakima Basin Storage Study on Columbia River Fish Proximate to the Proposed Intake Locations A component of Yakima River Basin Water Storage Feasibility Study, Washington. Technical Series No. TS-YSS-13. 179p.

Doney, S. C,M. Ruckelshaus, J.E. Duffy, J.P. Barry, F. Chan, C.A. English, H.M. Galindo, J.M. Grebmeier, A.B. Hollowed, N. Knowlton, J. Polovina, N.N. Rabalais, W.J. Sydeman, L.D. Talley. 2012. Climate change impacts on marine ecosystems. Annual Review of Marine Science 4:11-37.

Dunnigan, J. 2000. Feasibility and risks of coho reintroduction to mid-Columbia tributaries: 1999 annual report. Prepared for: Project number 1996-040-00. Bonneville Power Administration, Portland, Oregon.

Edmands, S. 2007. Between a rock and a hard place: evaluating the relative risks of inbreeding and outbreeding for conservation and management. Molecular Ecology. 16: 463-475.

EPA. 2007. Mad River TMDL. U.S Environmental Protection Agency.

Feely, R.A., C.L. Sabine, K. Lee, W. Berelson, J. Kleypas, V.J. Fabry, and F.J. Millero. 2004. Impact of anthropogenic CO2 on the CaCO3 system in the oceans. Science 305:362-366.

Fiumera, A. C., B. A. Porter, G. Looney, M. A. Asmussen, and J. C. Avise. 2004. Maximizing offspring production while maintaining genetic diversity in supplemental breeding programs of highly fecund managed species. Conservation Biology. 18(1): 94-101.

Flagg, T.A., B.A. Berejikian, J.E. Colt, W.W. Dickhoff, L.W. Harrell, D.J. Maynard, C.E. Nash, M.S. Strom, R.N. Iwamoto, and C.V.W. Mahnken. 2000. Ecological and behavioral impacts of artificial production strategies on the abundance of wild salmon populations. 92 pp. NOAA Technical Memorandum NMFS-NWFSC-41. Northwest Fisheries Science Center Seattle, Washington.

Flagg, T. A., C. V. Mahnken, and R. N. Iwamoto. 2004. Conservation hatchery protocols for Pacific salmon. Pages 603-619 in M. Nickum, P. Mazik, J. Nickum, and D. MacKinlay, editors. Propagated fish in resource management. American Fisheries Society Symposium 44, volume 44. American Fisheries Society Symposium, Bethesda, Maryland.

Ford, M., A. Murdoch, and S. Howard. 2012. Early male maturity explains a negative correlation in reproductive success between hatchery-spawned salmon and their naturally spawning progeny. Conservation Letters. 5: 450-458.

Ford M.J. (ed.), A. Albaugh, K. Barnas, T. Cooney, J. Cowen, J.J. Hard, R.G. Kope, M.M. McClure, P. McElhany, J.M. Myers, N.J. Sands, D. Teel, and L.A. Weitkamp . 2011. Status review update for Pacific salmon and steelhead listed under the Endangered Species Act: Northwest. Draft. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-113. 307 p.

Fulton, L. A., and R. E. Pearson. 1981. Transplantation and Homing Experiments on Salmon, *Oncorhynchus spp*., and Steelhead Trout, *Salmo gairdneri*, in the Columbia River System: Fish of the 1939-44 broods. U.S. Dept. Comm. NOAA Tech. Memo. NMFS F/NWC-12. 97p.

Furniss, M.J., T.D. Roelofs, and C.S. Lee. 1991. Road construction and maintenance. Pages 297–323 in W.R. Meehan, editor. Influences of Forest and Rangeland Management on Salmonid Fishes and their Habitats. American Fisheries Society Special Publication 19. Bethesda, Maryland.

Gharrett, A. J., and S. M. Shirley. 1985. A genetic examination of spawning methodology in a salmon hatchery. Aquaculture. 47: 245-256.

Gleick, P.H. and E.L. Chalecki. 1999. The impacts of climatic changes for water resources of the Colorado and Sacramento-San Joaquin river basins. Journal of the American Water Resource Association 35:1429-1441.

Good, T. P., R. S. Waples, and P. B. Adams. 2005. Updated status of federally listed ESUs of West Coast salmon and steelhead. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-66. 598 pp.

Goodman, D. 2005. Selection equilibrium for hatchery and wild spawning fitness in integrated breeding programs. Canadian Journal of Fisheries and Aquatic Sciences. 62(2): 374-389.

Grant, W. S. 1997. Genetic effects of straying of non-native hatchery fish into natural populations: Proceedings of the workshop. U.S. Department of Commerce, NOAA Tech. Memo. NMFS-NWFSC-30. 130p.

Greene, C.M. and T.J. Beechie. 2004. Consequences of potential density-dependent mechanisms on recovery of ocean-type Chinook salmon (*Oncorhynchus tshawytscha*). Canadian Journal of Fisheries and Aquatic Sciences 61(4):590-602.

Gresh, T., J. Lichatowich, and P. Schoonmaker. 2000. An estimation of historic and current levels of salmon production in the northeast Pacific ecosystem. Fisheries 15(1):15-21.

Hagans, D.K., and W.E. Weaver. 1987. Magnitude, cause and basin response to fluvial erosion, Redwood Creek basin, northern California. Pages 419-428 *in* Beschta, R.L., T. Blinn, G.E. Grant, F.J. Swanson, and G.G. Ice, editors. Erosion and Sedimentation in the Pacific Rim. International Association of Hydrological Sciences (IAHS) Publication No. 165. IAHS Press, Wallingford, Oxfordshire, United Kingdom.

Green Diamond Resource Company (GDRC). 2006. Aquatic habitat conservation plan and candidate conservation agreement with assurances. Volume 1–2, Final report. Prepared for the National Marine Fisheries Service and U.S. Fish and Wildlife Service.

Hard, J.J., R.P. Jones, Jr., M.R. Delarm, and R.S. Waples. 1992. Pacific salmon and artificial propagation under the Endangered Species Act. U.S. Department of Commerce, NOAA Tech. Memo. NMFS-NWFSC-2, 56 p.

Harr, R.D and R.A. Nichols. 1993. Stabilizing forest roads to help restore fish habitats: A Northwest Washington example. Fisheries 18(4):18-22.

Haupt, H.F. 1959. Road and slope characteristics affecting sediment movement from logging roads. Journal of Forestry 57(5):329-339.

Hayhoe, K., D. Cayan, C. B. Field, P. C. Frumhoff, E. P. Maurer, N. L. Miller, S. C. Moser, S. H. Schneider, K. N. Cahill, E. E. Cleland, L. Dale, R. Drapek, R. M. Hanemann, L. S. Kalkstein, J. Lenihan, C. K. Lunch, R. P. Neilson, S. C. Sheridan, and J. H. Verville. 2004. Emissions pathways, climate change, and impacts on California. Proceedings of the National Academy of Sciences of the United States of America, volume 101: 12422-12427.

Healy, M. C. 1991. Life history of Chinook salmon (*Oncorhynchus tshawytscha*). Pages 311-393 in C. Groot, and L. Margolis, editors. Pacific salmon life histories. UBC Press, Vancouver, BC.

Hess, M. A., C. D. Rabe, J. L. Vogel, J. J. Stephenson, D. D. Nelson, and S. R. Narum. 2012. Supportive breeding boosts natural population abundance with minimal negative impacts on fitness of a wild population of Chinook salmon.

Higgins, P., S. Dobush, and D. Fuller. 1992. Factors in northern California threatening stocks with extinction. Unpublished manuscript, Humboldt Chapter American Fisheries Society. 24 p. Available from Humboldt Chapter of the American Fisheries Society, P.O. Box 210, Arcata, California 95521.

Hillman, T. W., and J. W. Mullan, editors. 1989. Effect of hatchery releases on the abundance of wild juvenile salmonids. Report to Chelan County PUD by D.W. Chapman Consultants, Inc., Boise, ID.

ISAB. 2007. Climate Change Impacts on Columbia River Basin Fish and Wildlife. ISAB Climate Change Report, ISAB 2007-2, Northwest Power and Conservation Council, Portland, Oregon.

Jonsson, B., N. Jonsson, and L. P. Hansen. 2003. Atlantic salmon straying from the River Imsa. Journal of Fish Biology. 62: 641-657.

Kadir, T., L. Mazur, C. Milanes, and K. Randles. 2013. Indicators of Climate Change in California. California Environmental Protection Agency, Office of Environmental Health Hazard Assessment. Sacramento, California.

Keefer, M. L., and C. C. Caudill. 2013. Homing and straying by anadromous salmonids: a review of mechanisms and rates. Reviews in Fish Biology and Fisheries.

Keefer, M. L., C. C. Caudill, C. A. Peery, and C. T. Boggs. 2008. Non-direct homing behaviours by adult Chinook salmon in a large, multi-stock river system. Journal of Fish Biology. 72: 27-44.

Lacy, R. C. 1987. Loss of genetic variation from managed populations: Interacting effects of drift, mutation, immigration, selection, and population subdivision. Conservation Biology. 1: 143-158.

Lande, R., and G. F. Barrowclough. 1987. Effective population size, genetic variation, and their use in population management. Pages 87-123 in M. E. Soule, editor. Viable Populations for Conservation. Cambridge University Press, Cambridge and New York.

Leider, S. A., M. W. Chilcote, and J. J. Loch. 1984. Spawning characteristics of sympatric populations of steelhead trout (*Salmo gairdneri*): Evidence for partial reproductive isolation. Canadian Journal of Fisheries and Aquatic Sciences. 41: 1454-1462.

Leider, S. A., P. L. Hulett, J. J. Loch, and M. W. Chilcote. 1990. Electrophoretic comparison of the reproductive success of naturally spawning transplanted and through the returning adult stage. Aquaculture. 88: 239-252.

Levin, P.S., R.W. Zabel, and J.G. Williams. 2001. The road to extinction is paved with good intentions: negative association of fish hatcheries with threatened salmon. Proceedings of the Royal Society of London B-Biological Sciences 268:1153–1158.

Lynch, M., and M. O'Hely. 2001. Captive breeding and the genetic fitness of natural populations. Conservation Genetics. 2: 363-378.

MacFarlane, R.B., S. Hayes, and B. Wells. 2008. Coho and Chinook salmon decline in California during the spawning seasons of 2007/08. National Marine Fisheries Service, Southwest Fisheries Science Center, Fisheries Ecology Division. Santa Cruz, California

Mantua, M., I. Tohver, and A. Hamlet. 2010. Impacts of climate change on key aspects of freshwater salmon habitat in Washington State. Climate Change 102: 187-223.

Mattole Salmon Group. 1997. Mattole Salmon Recovery Progress. Mattole Watershed Document #8. Mattole Salmon Group, Petrolia, California.

McElhany, P., M.H. Ruckelshaus, M.J. Ford, T.C. Wainwright, and E.P. Bjorkstedt. 2000. Viable salmonid populations and the recovery of evolutionarily significant units. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-42. Seattle. 156 p.

McEwan, D. and T.A. Jackson. 1996. Steelhead restoration and management plan for California. California Department of Fish and Game, Inland Fisheries Division. 244 p.

McLean, J. E., P. Bentzen, and T. P. Quinn. 2004. Differential reproductive success of sympatric, naturally spawning hatchery and wild steelhead, Oncorhynchus mykiss. Environmental Biology of Fishes. 69: 359-369.

McClelland, E.K. and K.A. Naish. 2007. What is the fitness outcome of crossing unrelated fish populations? A meta-analysis and an evaluation of future research directions. Conservation Genetics 8: 397–416.

Moser, S., J. Ekstrom, and G. Franco. 2012. Our Changing Climate 2012: Vulnerability and Adaptation to the Increasing Risks from Climate Change in California. A Summary Report on the Third Assessment from the California Climate Change Center. July. CEC-500-20102-007S.

Moyle, P.B. 2002. Inland Fishes of California. Second Edition. University of California Press. Berkeley, California.

(NMFS) National Marine Fisheries Service. 2001b. Status review update for coho salmon (*Oncorhynchus kisutch*) from the Central California Coast and the California portion of the Southern Oregon/Northern California Coast evolutionarily significant units. National Marine Fisheries Service, Southwest Fisheries Science Center, Santa Cruz, California. April 12. 43 pp.

NMFS. 2004b. Salmonid Hatchery Inventory and Effects Evaluation Report (SHIEER). An Evaluation of the Effects of Artificial Propagation on the Status and Likelihood of Extinction of West Coast Salmon and Steelhead under the Federal Endangered Species Act. May 28, 2004. Technical Memorandum NMFS-NWR/SWR. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. Portland, Oregon.

NMFS. 2005. Final Assessment of the National Marine Fisheries Service's Critical Habitat Analytical Review Teams (CHARTs) for Seven Salmon and Steelhead Evolutionarily Significant Units (ESUs) in California. Protected Resources Division, Long Beach, CA.

NMFS. 2010. Biological Opinion on Mad River Batched Gravel Mining. National Marine Fisheries Service, Northern California Office, Arcata, California.

NMFS. 2011. North-Central California Coast Recovery Domain. 5-Year Review: Summary and Evaluation of Central California Coast Steelhead DPS Northern California Steelhead DPS. NMFS Southwest Region, Long Beach, California. 67 p.

NMFS. 2012. Effects of Hatchery Programs on Salmon and Steelhead Populations: Reference Document for NMFS ESA Hatchery Consultations. Craig Busack, Editor. March 7, 2011. NMFS Northwest Regional Office, Salmon Management Division. Portland, Oregon.

NMFS. 2014. Final recovery plan for the Southern Oregon/Northern California Coast evolutionarily significant unit of coho salmon. September 2014. Arcata, California.

NMFS. 2015. Public Draft Coastal Multispecies Recovery Plan. National Marine Fisheries Service, West Coast Region, Santa Rosa, California.

Nelson, T.C., M.L. Rosenau and N.T. Johnson. 2005. Behavior and survival of wild and hatchery-origin winter steelhead spawners caught and released in a recreational fishery. North American Journal Of Fisheries Management, 25:931-943.

NRC (National Research Council). 1995. Science and the Endangered Species Act. National Academy Press, Washington, D.C. 271 p.

Nichols, K., K. True, E. Wiseman, and J.S. Foott. 2007. Incidence of *Ceratomyxa shasta* and *Parvicapsula minibicornis* infections by QPCR and histology in juvenile Klamath River Chinook salmon. Investigational Report. U.S. Fish and Wildlife Service, California-Nevada Fish Health Center, Anderson, California. January.

Nickelson, T.E., J.W. Nicholas, A. M. McGie, R.B. Lindsay, D.L. Bottom, R.J. Kaiser, and S.E. Jacobs. 1992. Status of anadromous salmonids in Oregon coastal basins. Unpublished manuscript. Oregon Department of Fish and Wildlife, Research and Development Section, Corvallis, and Ocean Salmon Management, Newport. 83 pp.

O'Farrell, M. R., W. H. Satterthwaite, and B. C. Spence. 2012. California Coastal Chinook Salmon: Status, data, and feasibility of alternative fishery management strategies. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center: NOAA-TM-NMFSSWFSC-494. December 2012.

Olla, B.L., M.W. Davis, and C.H. Ryer. 1998. Understanding how the Hatchery Environment Represses or Promotes the Development of Behavioral Survival Skills. Bulletin of Marine Science. 62(2):531–550.

Osgood, K.E. (editor). 2008. Climate Impacts on U.S. Living Marine Resources: National Marine Fisheries Service Concerns, Activities and Needs. U.S. Dept. of Commerce. NOAA Technical Memorandum NMFSF/ SPO-89. 118 p.

Pastor, S. M. 2004. An evaluation of fresh water recoveries of fish released from national fish hatcheries in the Columbia River basin, and observations of straying. M. Nickum, P. Mazik, J. Nickum, and D. MacKinlay, editors In Propagated fishes in resource management. American Fisheries Society, Symposium 44, Bethesda, Maryland.

Pearsons, T. N., and C. A. Busack. 2012. PCD Risk 1: A tool for assessing and reducing ecological risks of hatchery operations in freshwater. Environmental Biology of Fishes. 94: 45-65.

Pearsons, T. N., and A. L. Fritts. 1999. Maximum size of Chinook salmon consumed by juvenile coho salmon. North American Journal of Fisheries Management. 19(1): 165-170.

Pearsons, T. N., G. A. McMichael, S. W. Martin, E. L. Bartrand, M.Fischer, S. A. Leider, G. R. Strom, A. R. Murdoch, K. Wieland, and J. A. Long. 1994. Yakima River Species Interaction Studies - Annual report 1993. Division of Fish and Wildlife, Project No. 1989-105, Contract No. DE-BI79-1993BP99852, Bonneville Power Administration, Portland, Oregon.

PFMC (Pacific Fishery Management Council). 1999. Description and identification of essential fish habitat, adverse impacts and recommended conservation measures for salmon. Appendix A to Amendment 14 to the Pacific Coast Salmon Plan. Pacific Fishery Management Council, Portland, Oregon. March.

PFMC. 2014. Appendix A to the Pacific Coast Salmon Fishery Management Plan, as modified by Amendment 18 to the Pacific Coast Salmon Plan: Identification and description of essential fish habitat, adverse impacts, and recommended conservation measures for salmon. Pacific Fishery Management Council, Portland, OR. September 2014. 196 p. + appendices.

Peterson, W.T., J.L. Fisher, C.A. Morgan, J.O. Peterson, B.J. Burke, and K. Fresh. 2015. Ocean ecosystem indicators of salmon marine survival in the Northern California current. National Marine Fisheries Service Northwest Fisheries Science Center. December. 94 p

Piorkowski, R. J. 1995. Ecological effects of spawning salmon on several south central Alaskan streams. Ph.D. dissertation, University of Alaska, Fairbanks, Alaska. 191p.

PRBO Conservation Science. 2011. Projected effects of climate change in California: Ecoregional summaries emphasizing effects to wildlife. Version 1.0.

Quamme, D. L., and P. A. Slaney. 2003. The relationship between nutrient concentration and stream insect abundance. American Fisheries Society Symposium 34. 163-175.

Quinn, T.P. 1984. Homing and Straying in Pacific salmon. D. McCleave, G.P. Arnold, J.J. Dodson, and W.H. Neill (editors). Mechanisms of Migration. In Fishes. J. Plenum Publishing Corp., New York, pages 357-362.

Quinn, T.P. 1993. A review of homing and straying of wild and hatchery-produced salmon. Fisheries Research 18:29-44.

Quinn, T. P. 1997. Homing, straying, and colonization. Pages 73-88 in W. S. Grant, editor. Genetic effects of straying of non-native fish hatchery fish into natural populations: Proceedings of the workshop. U.S. Department of Commerce, NOAA Tech. Memo. NMFS-NWFSC-30.

Quinn, T.P. 2005. The behavior and ecology of Pacific salmon & trout. American Fisheries Society. Bethesda, Maryland.

Quinn, T. P. and N. P. Peterson. 1996. The influence of habitat complexity and fish size on over-winter survival and growth of individually marked juvenile coho salmon (Oncorhynchus kisutch) in Big Beef Creek, Washington. Canadian Journal of Fisheries and Aquatic Sciences 53: 1555-1564.

Reid, L.M. 1998. Review of the: Sustained Yield Plan/Habitat Conservation Plan for the properties of The Pacific Lumber Company, Scotia Pacific Holding Company, and Salmon Creek Corporation. Unpublished report. USDA Forest Service. Pacific Southwest Research Station. Redwood Sciences Laboratory. Arcata, California. 63 p.

Reid, L.M. and T. Dunne. 1984. Sediment production from forest road surfaces. Water Resources Research 20(11):1753-1761.

Reisenbichler, R.R. and J.D. McIntyre. 1977. Genetic differences in growth and survival of juvenile hatchery and wild steelhead trout, *Salmo gairdneri*. Journal of the Fisheries Research Board Canada 34:123–128.

Ruggiero, P., C.A. Brown, P.D. Komar, J.C. Allan, D.A. Reusser, H. Lee, S.S. Rumrill, P. Corcoran, H. Baron, H. Moritz, and J. Saarinen. 2010. Impacts of climate change on Oregon’s coasts and estuaries. Pages 241-256 *in* K.D. Dellow and P.W. Mote, editors. Oregon Climate Assessment Report. College of Oceanic and Atmospheric Sciences, Oregon State University, Corvallis, Oregon.

Ryman, N. 1991. Conservation genetics considerations in fishery management. Journal of Fish Biology. 39 (Supplement A): 211-224.

Ryman, N., P. E. Jorde, and L. Laikre. 1995. Supportive breeding and variance effective population size. Conservation Biology. 9(6): 1619-1628.

Ryman, N., and L. Laikre. 1991. Effects of supportive breeding on the genetically effective population size. Conservation Biology. 5: 325-329.

Saisa, M., M. L. Koljonen, and J. Tahtinen. 2003. Genetic changes in Atlantic salmon stocks since historical times and the effective population size of a long-term captive breeding programme. Conservation Genetics. 4: 613-627.

Sandercock, F.K. 1991. Life history of coho salmon. Pages 397-445 in C. Groot and L. Morgolis, editors. Pacific Salmon Life Histories. UBC Press. Vancouver, British Columbia, Canada.

Santer, B.D., C. Mears, C. Doutriaux, P. Caldwell, P.J. Gleckler, T.M.L. Wigley, S. Solomon, N.P. Gillett, D. Ivanova, T.R. Karl, J.R. Lanzante, G.A. Meehl, P.A. Stott, K.E. Taylor, P.W. Thorne, M.F. Wehner, and F.J. Wentz. 2011. Separating signal and noise in atmospheric temperature changes: The importance of timescale. Journal of Geophysical Research 116:D22105.

Scavia, D., J.C. Field, D.F. Boesch, R.W. Buddemeier, V. Burkett, D.R. Cayan, M. Fogarty, M.A. Harwell, R.W. Howarth, C. Mason, D.J. Reed, T.C. Royer, A.H. Sallenger, and J.G. Titus. 2002. Climate change impacts on U.S. coastal and marine ecosystems. Estuaries 25(2):149-164.

Schneider, S.H. 2007. The unique risks to California from human-induced climate change. California State Motor Vehicle Pollution Control Standards; Request for Waiver of Federal Preemption, presentation May 22, 2007.

Shapovalov, L., and A.C. Taft. 1954. The life histories of the steelhead rainbow trout *Salmo gairdneri gairdneri*) and silver salmon (*Oncorhynchus kisutch*) with special reference to Waddell Creek, California, and recommendations regarding their management. California Department of Fish and Game Fish Bulletin 98. 375 p.

SIWG (Species Interaction Work Group). 1984. Evaluation of Potential Interaction Effects in the Planning and Selection of Salmonid Enhancement Projects. J. Rensel, chairman and K. Fresh, editor. Prepared by the Species Interaction Work Group of the Enhancement Planning Team. Washington Dept. Fish and Wildlife. Olympia, Washington.

Sparkman, M. D. 2002. Mad River winter-run steelhead run-size estimate, 2000-2001 season, Project 1a3. Steelhead Research and Monitoring Program North Coast Northern California Region. California Department of Fish and Game, Arcata, CA.

Sparkman, M.D. 2003. Recreational angler use and catch in the Mad River, Humboldt County, CA, November 2002-March 2003, California Department of Fish and Game Anadromous Fisheries Resource Assessment and Monitoring Program 1g2, 32p.

Spence, B. C., E. P. Bjorkstedt, J. C. Garza, J. J. Smith, D. G. Hankin, D. Fuller, W. E. Jones, R. Macedo, T. H. Williams, and E. Mora. 2008. A framework for assessing the viability of threatened and endangered salmon and steelhead in the north-central California coast recovery domain. U.S. Department of Commerce, National Oceanic and

Atmospheric Administration, National Marine Fisheries Service, Southwest Fisheries Science Center: NOAA-TM-NMFS-SWFSC-423.

Spence, B. C., and J. D. Hall. 2010. Spatiotemporal patterns in migration timing of coho salmon (Oncorhynchus kisutch) smolts in North America. Canadian Journal of Fisheries & Aquatic Sciences 67(8):1316-1334.

Steward, C.R., and T.C. Bjornn. 1990. Supplementation of Salmon and Steelhead Stocks with Hatchery Fish: A Synthesis of Published Literature. In Analysis of Salmon and Steelhead Supplementation, William H. Miller editor. Report to Bonneville Power Administration (BPA). Portland, Oregon. Project No. 88-100.

Swanson, F.J. and C.T. Dyrness. 1975. Impact of clearcutting and road construction on soil erosion and landsliding in the Western Cascade Range, Oregon. Geology 3(7):393-396.

Swanston, D.N. and F.J. Swanson. 1 976. Timber harvesting, mass erosion, and steepland forest geomorphology in the Pacific Northwest. Pages 199-221 *in* D.R. Coates, editor. Geomorphology and Engineering. Dowden, Hutchison, and Ross, Inc. Stroudsburg, PA.

Swanston, D.N. 1991. Natural processes. Pages 139- 179 *in* W.R. Meehan, editor. Influences of forest and rangeland management on salmonid fishes and their habitats. Amer. Fish. Soc. Spec. Pub. 19. 751 p.

Tatara, C. P., and B. A. Berejikian. 2012. Mechanisms influencing competition between hatchery and wild juvenile anadromous Pacific salmonids in fresh water and their relative competitive abilities. Environmental Biology of Fishes. 94(1): 7-19.

Theriault, V., G. R. Moyer, L. S. Jackson, M. S. Blouin, and M. A. Banks. 2011. Reduced reproductive success of hatchery coho salmon in the wild: Insights into most likely mechanisms. Molecular Ecology. 20: 1860-1869.

Tipping, J.M. 1997. Effect of smolt length at release on adult returns of hatchery-reared winter steelhead. Progressive Fish Culturist 59:4, 310-311.

Tschaplinski, P.J. 1988. The use of estuaries as rearing habitats by juvenile coho salmon. In T.W. Chamberlain (ed.), Proceedings of a workshop: Applying 15 years of Carnation Creek results. (pp. 123-142). Nanaimo, BC: British Columbia Ministry of Environment, Lands, and Parks.

Tschaplinski, P. J., and G. F. Hartman. 1983. Winter distribution of juvenile coho salmon (*Oncorhynchus kisutch*) before and after logging in Carnation Creek, British Columbia, and some implications for overwinter survival. Canadian Journal of Fisheries and Aquatic Sciences 40: 452–461.

Turley, C. 2008. Impacts of changing ocean chemistry in a high-CO2 world. Mineralogical Magazine 72(1):359-362.

USEPA (U.S. Environmental Protection Agency). 1997. The incidence and severity of sediment contamination in surface waters of the United States. Volume 1: National Sediment Quality Survey. EPA Report No. EPA 823-R-97-006. Washington, D.C.: Office of Science and Technology.

Vasemagi, A., R. Gross, T. Paaver, M.-L. Koljonen, and J. Nilsson. 2005. Extensive immigration from compensatory hatchery releases into wild Atlantic salmon population in the Baltic sea: spatio-temporal analysis over 18 years. Heredity. 95: 76-83.

Waples, R.S. 1991. Definition of "species" under the Endangered Species Act: Application to Pacific salmon. U.S. Department of Commerce. Technical Memorandum NMFS F/NWC-194. 29 p.

Waples, R.S. 1999. Dispelling some myths about hatcheries. Fisheries 23(2):12-21.

Waples, R.S. 2002. Effective size of fluctuating salmon populations. Genetics 161: 783-791.

Waples, R. S., and C. Do. 1994. Genetic risk associated with supplementation of Pacific salmonids: Captive broodstock programs. Canadian Journal of Fisheries and Aquatic Sciences. 51 (Supplement 1): 310-329.

Waples, R., T. Beechie, and G. Pess. 2009. Evolutionary history, habitat disturbance regimes, and anthropogenic changes: What do these mean for resilience of Pacific salmon populations? Ecology and Society 14(1): 3. [online] URL: http:// www.ecologyandsociety.org/vol14/iss1/art3.

Waples, R.S., G.R. Pess, and T. Beechie. 2008. Evolutionary history of Pacific salmon in dynamic environments. Evolutionary Applications 1(2):189-206.

Ward, D.M., K.H. Nislow, J.D. Armstrong, S. Einum, C.L. Folt. 2007. Is the shape of the density–growth relationship for stream salmonids evidence for exploitative rather than interference competition? Journal of Animal Ecology, 76:135–138.

Ward, B. R., and P. A. Slaney. 1988. Life history and smolt-to-adult survival of Keogh River steelhead trout (*Salmo gairdneri*) and the relationship to smolt size. Canadian Journal Fisheries and Aquatic Sciences. 45: 1110-1122.

Wells, B.K., C.B. Grimes, J.C. Field and C.S. Reiss. 2006. Covariation between the average lengths of mature coho (*Oncorhynchus kisutch*) and Chinook salmon (*0. tshawytscha*) and the ocean environment. Fisheries Oceanography 15(1):167-79.

Westerling, A.L., B.P. Bryant, H.K. Preisler, T.P. Holmes, H.G. Hidalgo, T.Das, and S.R. Shrestha. 2011. Climate change and growth scenarios for California wildfire. Climate Change 109(1):445-463.

Westley, P. A. H., T. P. Quinn, and A. H. Dittman. 2013. Rates of straying by hatchery-produced Pacific salmon (*Oncorhynchus spp*.) and steelhead (*Oncorhynchus mykiss*) differ among species, life history types, and populations. Canadian Journal Fisheries and Aquatic Sciences. 70: 735-746.

Whitlock, M. C. 2000. Fixation of new alleles and the extinction of small populations: Drift, load, beneficial alleles, and sexual selection. Evolution. 54(6): 1855-1861.

Willi, Y., J. V. Buskirk, and A. A. Hoffmann. 2006. Limits to the adaptive potential of small populations. Annual Review of Ecology, Evolution, and Systematics. 37: 433-458.

Williamson, K. S., A. R. Murdoch, T. N. Pearsons, E. J. Ward, and M. J. Ford. 2010. Factors influencing the relative fitness of hatchery and wild spring Chinook salmon (*Oncorhynchus tshawytscha*) in the Wenatchee River, Washington, USA. Canadian Journal of Fisheries and Aquatic Sciences. 67: 1840-1851.

Williams, T.H., B. Spence, W. Duffy, D. Hillemeier, G. Kautsky, T.E. Lisle, M. McCain, T. Nickelson, E. Mora, and T. Pearson. 2008. Framework for assessing viability of threatened coho salmon in the Southern Oregon/Northern California Coasts evolutionarily significant unit. NOAA Technical Memorandum NMFS-SWFSC-432. U.S. Department of Commerce, NOAA, NMFS, Southwest Fisheries Science Center Santa Cruz, California. 113 pp.

Williams, T.H., D.A. Boughton, S.T. Lindley, and B.C. Spence. 2011a. Southern Oregon/Northern California Coast Recovery Domain 5-Year Review: Summary and Evaluation of Southern Oregon/Northern California Coast Coho Salmon ESU. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Fisheries Ecological Division, Southwest Fisheries Science Center, Santa Cruz, CA.

Williams, T.H., D.A. Boughton, S.T. Lindley, and B.C. Spence. 2011b. North-Central California Coast Recovery Domain 5-Year Review: Summary and Evaluation of California Coastal Chinook Salmon ESU and Central California Coast Coho Salmon ESU. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Fisheries Ecological Division, Southwest Fisheries Science Center, Santa Cruz, CA.

Williams, T.H., B.C. Spence, S.T. Lindley, and D.A. Boughton. 2011c. North-Central California Coast Recovery Domain 5-Year Review: Summary and Evaluation of Central California Coastal Steelhead DPS and Northern California Steelhead DPS. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Fisheries Ecological Division, Southwest Fisheries Science Center, Santa Cruz, CA.

Williams, T.H., B.C. Spence, D.A. Boughton, R.C. Johnson, L. Crozier, N. Mantua, M. O'Farrell, and S.T. Lindley. 2016. Viability assessment for Pacific salmon and steelhead listed under the Endangered Species Act: Southwest. 2 February 2016 Report to National Marine Fisheries Service – West Coast Region from Southwest Fisheries Science Center, Fisheries Ecology Division 110 Shaffer Road, Santa Cruz, California 95060. 182 p.

Wipfli, M. S., J. P. Hudson, J. P. Caouette, and D. T. Chaloner. 2003. Marine subsidies in freshwater ecosystems: salmon carcasses increase growth rates of stream-resident salmonids. Transactions of the American Fisheries Society. 132: 371-381.

Withler, I. L. 1966. Variability in life history characteristics of steelhead trout (*Salmo gairdneri*) along the Pacific coast of North America. Journal of the Fisheries Research Board of Canada. 23(3): 365-393.

Withler, R. E. 1988. Genetic consequences of fertilizing Chinook salmon (*Oncorhynchus tshawytscha*) eggs with pooled milt. Aquaculture. 68: 15-25.

YKFP (Yakima/Klickitat Fisheries Project). 2008. Klickitat River Anadromous Fisheries Master Plan. Yakima/Klickitat Fisheries Project 1988-115-35. 188p.

5.2 Federal Register Notices Cited

60 FR 38011. 1995. National Marine Fisheries Service. Endangered and Threatened Species; Proposed Threatened Status for Three Contiguous ESUs of Coho Salmon Ranging from Oregon through Central California. Federal Register 60(142). July 25, 1995.

62 FR 24588. 1997. National Marine Fisheries Service. Final Rule. Endangered and Threatened Species; Threatened Status for Southern Oregon/Northern California Coast Evolutionarily Significant Unit (ESU) of Coho Salmon. Federal Register 62(87). May 6, 1997.

62 FR 43937: National Marine Fisheries Service. Final Rule: Listing of Several Evolutionary Significant Units of West Coast Steelhead. Federal Register, Volume 62 p. 43937-43954. August 18, 1997. Federal Register.

64 FR 24049. National Marine Fisheries Service. Final Rule and Correction. Designated Critical Habitat; Central California Coast and Southern Oregon/Northern California Coasts Coho Salmon. May 5, 1999. Federal Register.

65 FR 36074. National Marine Fisheries Service. Endangered and Threatened Species: Threatened Status for One Steelhead Evolutionarily Significant Unit (ESU) in California. June 7, 2000. Federal Register.

70 FR 37160. National Marine Fisheries Service. Final Rule. Endangered and Threatened Species: Final Listing Determinations for 16 ESUs of West Coast Salmon, and Final 4(d) Protective Regulations for Threatened Salmonid ESUs. June 28, 2005. Federal Register.

70 FR 52488. National Marine Fisheries Service. Final Rule. Endangered and Threatened Species: Designation of Critical Habitat for Seven Evolutionarily Significant Units of Pacific Salmon and Steelhead in California. September 2, 2005. Federal Register.

71 FR 834. National Marine Fisheries Service. Final Rule. Endangered and Threatened Species: Final Listing Determinations for 10 Distinct Population Segments of West Coast Steelhead. January 5, 2006. Federal Register.

79 FR 20802. 2014. National Marine Fisheries Service. Final Rule. Endangered and Threatened Wildlife; Final Rule To Revise the Code of Federal Regulations for Species Under the Jurisdiction of the National Marine Fisheries Service. Federal Register79(71):20802-20817. April 14, 2014.

81 FR 7214. Fish and Wildlife Service and the National Oceanographic and Atmospheric Administration. Final Rule. Interagency Cooperation-Endangered Species Act of 1973, as Amended. Definition of destruction or adverse modification of critical habitat. February 11, 2016. Federal Register.

5.3 Personal Communications

Michael Sparkmann. May 9, 2016. Email communication with Dan Free, NMFS, regarding recent salmon and steelhead monitoring in the Mad River. California Department of Fish and Wildlife, Arcata, California.

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