Exhibit DFG-T-1 (26 pages)

Titus

State of California

Memorandum

To : Mr. Ken Gray, CDPR, Monterey

Date Wed, Aug 3, 1994

From : Department of Fish and Game

Subject Progress on Big Sur River Steelhead Habitat Use Study and Related Work.

The purpose of this memorandum is to present an update on the Environmental Services Division's (ESD) study of steelhead habitat use at the Big Sur River, Monterey County. Included are a preliminary description of the study area and methods, and an overview of the data set compiled thus far.

INTRODUCTION

Populations of native anadromous salmonids all along the Pacific coast of the continental U.S. have declined sharply within the last 150 years. Steelhead (*Oncorhynchus mykiss*) along the central and south coast of California have been especially hard-hit within the last 50 years, primarily because of reductions in the amount and quality of freshwater habitat (Titus et al. 1994). In a partial list of depleted stocks published by the American Fisheries Society (Nehlsen et al. 1991), nine principal steelhead stocks south of San Francisco Bay were included, six of which were rated as having a high risk of extinction. At least 11 other stocks have apparently already become extinct.

The steelhead leads a seemingly tenuous existence under natural conditions in this arid, southern extent of its range. Stream flows are highly stochastic, and vary greatly both seasonally and annually. During the dry summer, stream flow often becomes interrupted, especially in the lower river reaches. Sufficient surficial flow is needed during the winter rainy season to breach a sandbar which closes the mouth of most of these streams. With a connection provided, steelhead and other migratory fishes may migrate between marine and fresh water, where different phases of their life cycles are completed.

In addition to this natural instability in stream flow, a burgeoning human population has put an even greater demand on already limited freshwater resources. During the past 50 years, dams and water diversion systems have been built, and groundwater pumping has increased, to meet the growing human demand for water. Dams block steelhead access to upstream spawning and rearing areas, and regulate stream flow so that below-dam releases may be very low or eliminated altogether. Diversions and pumping also remove water from the stream channel, the effects of which are many from the standpoint of steelhead production. The gross effects include loss of the migratory corridor between the stream and the ocean, and reduction or complete elimination of spawning habitat for adults and rearing habitat for juveniles. Virtually every large coastal river system south of San Francisco Bay has been developed for water extraction, leaving only some of the smaller streams as more-or-less intact, natural steelhead habitats.

The California Department of Fish and Game (CDFG) is currently mandated by the Salmon, Steelhead Trout, and Anadromous Fisheries Program Act of 1988 to significantly increase the natural production of steelhead in the state. The goal set for the CDFG is to double the 1988 level of natural production, estimated at about 150,000 steelhead, by the year 2000 (§6900–6902 of the Fish and Game Code of California 1991). To succeed, management and restoration plans aimed at increasing wild steelhead stocks must be based on a solid ecological understanding of the production requirements for the species.

Yet, little is known about the ontogenetic habitat use and life history of juvenile steelhead in streams of the southern coastal region of California. This information is essential for determining the flow and stream morphology requirements of the species throughout its juvenile freshwater phase in this habitat type. This information should be developed from field studies of wild steelhead in an undeveloped stream system within the region, for extrapolation to altered systems for which appropriate, defensible protection measures may be formulated under the CDFG's mandate.

In addition, contemporary theories regarding developmental variation (e.g. Thorpe 1986) and mating systems (e.g. Hutchings and Myers 1988; Gross 1991) in salmonids, and the genetic consequences of these processes at the population level (e.g. Saunders and Schom 1985), have not been formally applied and tested for *O. mykiss*. This project provides the opportunity to evaluate, for example, the potential development of bimodality in the size-frequency distribution of 0+ steelhead and its relationship to individual life-history pathways (Thorpe 1986). Basic data on steelhead spawning aggregations may also be collected (e.g. as in Titus and Mosegaard 1992) which may help link ideas on individual life-history development to observed polymorphism (rainbows *v.* steelhead) in *O. mykiss* populations.

OBJECTIVE

The objective of this project is two-fold. From a basic research perspective, the long-term goal is to determine the ontogenetic habitat use, associated life history development, and population dynamics of steelhead in a south-central coastal river system. Specifically, the project addresses the following key questions:

1. What are the characteristics of the habitat(s) used for spawning, and for rearing of 0+ parr, ≥1+ parr, and resident rainbow trout? Is there evidence of ontogenetic and/or seasonal habitat shifts? How are the amount and quality of habitat for spawning, rearing, and residency affected by variations in stream flow? By variations in channel characteristics, including substrate and cover?

2. Is there evidence of bimodality in the length-frequency distribution of 0+ trout? If so, do fish in the upper modal group (*sensu* Thorpe 1986) have a higher probability of smolting at age 1 than fish in the lower modal group?

3. Overall, what is the predominant age at smolting, and are larger parr within a cohort more likely

to smolt in any given year than smaller sibling parr? Do parr and pre-smolts also migrate to the ocean?

4. How important is relative location within the stream system for determining whether an individual will smolt and migrate to the ocean in any given year?

5. What is the approximate frequency of mature parr, both males and females, in the population? Do these fish remain in the stream as residents or do they smolt and migrate to the ocean following spawning?

6. What is the composition of spawning aggregations of trout? Is there evidence of interbreeding between mature parr/resident trout and steelhead spawners? What is the life history of migrant spawners?

The primary applied objective is to relate study results from a relatively pristine, unregulated system, to similar systems where water development projects exist or are proposed. The idea behind this approach is that by knowing what the fish do in an unaltered environment, we can better predict and evaluate impacts where alterations are to occur.

STUDY AREA

The Big Sur River was selected as a study site because of its relatively pristine, unregulated condition and good accessibility. Within recent geological history, only the lowermost 12 km or so of the river have been accessible to steelhead. Upstream migration beyond this point in the steep and rugged gorge section of the river has been blocked by a natural bedrock fall. This feature marks the boundary above which the river flows through the Ventana Wilderness within the Los Padres National Forest. Pfeiffer Big Sur State Park is situated immediately downstream from this point along a portion of the lower river where redwoods are a major component of the riparian zone. This far south along the California coast, fog no longer maintains the moisture climate necessary for continuous stands of redwoods, and the steep hillsides that comprise the Big Sur drainage are otherwise dominated by grassland, chaparral, and oak woodland. The lowermost 6.4 km of the river flow through Andrew Molera State Park..

For the purposes of this study, the lower mainstem river was divided into three main study reaches based on visually-assessed differences in stream gradient, channel morphology, substrate composition, riparian vegetation, and retention of detritus of both autochthonous and allochthonous origin.

The upper "gorge reach" extends from the above-mentioned bedrock barrier to the bottom of the gorge section of the river. This reach is characterized by a relatively high gradient in a steep, dry, rocky canyon, a confined channel with no floodplain development, substrate dominated by large cobbles, boulders, and bedrock, and relatively low retention of detritus.

The "campground reach" begins at the bottom of the gorge in the upper campground area of Pfeiffer Big Sur State Park where the stream gradient decreases abruptly, floodplain development is more extensive, average substrate size decreases and is dominated by cobbles, there is a well-developed riparian redwood forest, and detrital retention increases. This reach extends to the upstream boundary of Andrew Molera State Park.

The lower "Molera reach" extends from the upstream boundary of Andrew Molera State Park to the river mouth where the stream gradient is lowest, floodplain development is greatest, substrate is dominated by large gravel and cobbles, the mixed riparian forest gradually diminishes to a dense but narrow willow-dominated riparian border, and detrital retention seems highest. The lowermost 1.6 km of the stream traverses a narrow alluvial plain and terminates at a lagoon during the dry season when a sandbar accumulates and flow to the ocean is minimal.

Two tributaries are also included in the study area. Juan Higuera Creek is the largest perennial tributary to the lower Big Sur River, and enters the river in the lower half of the campground reach. Post Creek is a smaller tributary, with interrupted flow in many summers, which enters the Big Sur River in the upper half of the campground reach. Each tributary has a lower and upper reach, the boundary of which is a barrier that limits steelhead access. Historical steelhead use of these tributaries, as well as of the mainstem river, are summarized by Titus et al. (1994) (excerpt appended).

Quantification of the factors used to discriminate each reach and tributary is thus far limited to measurement of stream width and mean thalweg depth and velocity in several habitat units within each reach (see below). The remaining factors remain to be more precisely characterized or quantified.

METHODS DEVELOPMENT

The spatial component of the study design involves three levels of stratification: (i) main stem or tributary, (ii) reach of main stem or tributary, as described above, and (iii) mesohabitat[1] unit within a reach. Portions of the main stem were habitat-typed in October 1989 (W. M. Snider, CDFG, unpubl. data) following criteria developed by the U.S. Forest Service (after Bisson et al. 1982). The gorge reach consists mostly of a series of step runs and pools. The campground and Molera reaches are dominated proportionately by riffles and runs, both in frequency (66–71%) and by stream length (76–79%). Lateral scour pools (13–15% in frequency, 6–11% by stream length) and main channel pools (4–11% in frequency, 2–10% by stream length) in these reaches were the next most common habitats collectively.

Within each reach, three replicates of each major habitat type amenable to quantitative electrofishing were selected for sampling and habitat measurements. Within the gorge reach, three spatially-segregated step run segments were selected. In the campground reach, three replicates each of riffles and runs were selected, and one fishable lateral scour pool. At least three riffles and runs were selected for study in the Molera reach as well. Most pools were too deep to be sampled efficiently with a battery-powered backpack electrofisher. Pools are therefore underrepresented in the study design.

The temporal component of the study design consists of a series of juvenile steelhead population surveys, and although emphasis is placed on following the dynamics of a given year's

[1] Riffle, run, pool, etc

cohort (age 0+ trout), measurements have also been made of other age-classes (≥age 1+) present. The main idea is that juvenile trout are sampled during late summer in preselected habitat units; their density (no. fish m^{-1} or m^{-2}) is estimated and the habitat in which they are located is quantitatively described (see discussion below); and the trout are batch-marked with subcutaneous injections of Alcian Blue according to their site of capture and within-cohort size class (see Titus and Mosegaard 1989, 1992 for examples). The trout are then released at their respective site of capture. At subsequent intervals over the ensuing nine months (see schedule below), the same units are sampled again to monitor trout movement and changes in age-class specific densities, as functions of their original capture-and-marking site (habitat) and size class.

Separate abundance estimates are made for 0+ and ≥1+ trout using the removal method (Zippin 1958 as in Armour et al. 1983). One to four removal passes are made in each unit, with a pass consisting of a single electrofishing sweep in the upstream direction. In the main stem, two electrofishers are used parallel to one another to increase the sampling efficiency per pass (Kennedy and Strange 1981). When only one removal pass is made, a capture probability is applied from a previous survey in that unit under similar flow and temperature conditions.

Trout are sampled using a pulsed-DC backpack electroshocker at 200–300 V and 90 Hz. The trout are anæsthetized and then measured for total length (TL, 0.5 mm) and wet weight (0.1 g). Each trout is color-classified to qualitatively indicate its degree of smolting. 'Parr' are darkly pigmented trout lacking any external sign of smolting, e.g., body silvering, fin margin blackening, decreasing condition (Folmar and Dickhoff 1980; Wedemeyer et al. 1980). 'Silvery parr' have faded parr marks and a high enough density of silver scales to give them a somewhat silvery, but not fully smolted, appearance. Their scales may be removed fairly easily, even just as a result of normal handling. 'Smolts' have highly faded parr marks, or lack them altogether, a bright silver to white coloration, and highly deciduous scales. Mature parr are identified by extrusion of milt or eggs. Each trout is also checked for infestation with encysted metacercaria of the monogenetic trematode, *Neascus*, a condition commonly referred to as "black spot disease" or here as BSD.

Length data are used to evaluate demographic trends in each cohort, and with weights are used to determine (i) seasonal changes in condition factor (i.e. with respect to smolting and in concert with color classifications); and (ii) length-weight relationships during each season with which to measure biomass dynamics.

Basic measurements are made of the habitat unit in an attempt to reflect its quality for use by young trout that are engaged in a suite of habitat-related activities, e.g. feeding, resting, escaping predators. We believe emphasis should be placed on measuring the central attributes of the habitat that juvenile steelhead are actually utilizing at a given time and location, as opposed to attempting to measure specific habitat characteristics which we feel steelhead may be choosing preferentially. Juvenile trout may often be faced with "making the best of a bad situation" in terms of habitat availability, since their distribution in a stream system appears to be more a function of where they were spawned than one of rearing habitat suitability (Beard and Carline 1991; Titus and Mosegaard 1992). After all, the fish are not able to evaluate the relative habitat quality of their natal stream reach without prior knowledge of other reaches, and, indeed, adopting a strategy of simply wandering the natal stream system to locate the best available rearing habitat would both be energetically costly and increase an individual's predation risk.

Thus, a starting assumption is that during the pre-smolt stage, individuals exhibit a high degree of site fidelity, at least on a scale of tens of meters of stream length, which is the measurement scale in this investigation. This assumption is probably a safe one based on the results of studies on similar species (e.g. Heggenes et al. 1991 and references therein; Titus and Mosegaard 1992). One predictable change is that as an individual grows, it will generally seek deeper water (reviewed by Heggenes 1988). In fact, mean thalweg depth alone can be a good predictor of juvenile trout densities with separation by age-class and thus fish size (e.g. Titus and Mosegaard 1992). Mean thalweg current velocity is also a central habitat attribute from the fish's perspective in terms of swimming costs, and in terms of drift rates of trout food organisms which are directly coupled to current velocity (reviewed by Waters 1972).

Following the fish capture and marking work at each habitat unit, the total length of the unit is measured, and the unit is divided into five equidistant transects, including one each at the very top and bottom of the unit. Total channel width, thalweg depth, and thalweg current velocity (following the convention of the USBR 1984) are measured. The dominant substrate and outstanding cover features adding complexity to the unit (e.g. logs, root wads, overhanging vegetation, boulders) were noted, but no attempt was made to quantify them.

A cohort is typically first sampled in late summer/early fall. Densities of 0+ trout should be relatively stable by this time since this sampling occurs well after the fry emergence period when mortality rates are high (reviewed by Titus 1990). Further, 0+ trout distribution should roughly reflect the distribution of spawning since this sampling occurs before the start of the rainy season, and thus before young trout might migrate from their natal reach in response to increased flow conditions. Densities of ≥1+ trout are also determined at this time.

Age 0+ trout are divided into two size-classes, the division point of which is determined from their observed length range and approximate length-frequency distribution. Individuals are marked with regard to their size-class and stream reach. Age ≥1+ trout are marked following a similar protocol, although they are lumped into only one size-class. Scales are collected from stratified subsamples of trout to confirm their ages and to designate divisions in overlapping length-frequency distributions of adjacent age-classes. Any trout that die from sampling and handling are kept for sex determination and ageing by use of sagittal otoliths.

The second sampling survey occurs in late fall, prior to the period of heaviest precipitation. The sample units are sampled as before to determine: densities of juvenile steelhead; recapture frequencies of marked trout; and the frequencies and sizes of mature parr. Mature parr are given an additional sex-specific mark for identification later in the study. If migrant spawners are captured, then scale samples are taken for life history determination and back calculation of size-at-age.

The final sampling occasion occurs during late spring–early summer, near the end of the predicted period of smolt emigration (Shapovalov and Taft 1954). Again, densities of juvenile trout (including any members of the new year class) are determined in the sample reaches, and recapture frequencies of marked trout are evaluated, including those of previously mature parr.

The downstream movement of fishes in the main stem is monitored continuously by use of pipe traps. Each trap consists of a V-shaped weir made of hardware cloth panels, with the intake to two 15 cm diameter PVC pipes situated at the weir apex. The 12 m long pipes empty into a live box where downstream migrants are captured. The boxes are checked daily. The steelhead are measured for length and weight, color classified, and checked for milt or eggs, BSD, and Alcian Blue marks. Currently, three traps are in operation, one near the downstream end of each major river reach.

The data collected will be used to determine the proportionate reduction of trout as a function of size class within a given cohort, and original location within the stream system (marking site the previous summer). Chi-square analysis is used to accomplish this evaluation (see Titus and Mosegaard 1992). Age and size at smolting is also evaluated based on the separation of smolts and parr by morphological characteristics. Differences in lengths and length-weight relationships among morphs are tested for significance using ANOVA and ANCOVA, respectively. An attempt is being made to determine whether post-spawning parr migrate to the ocean or not. Densities of each age-class will be analyzed as a function of habitat measurements by use of linear regression.

DATA COLLECTED TO DATE

1992–1993

During 17–20 September 1992, a reconnaisance electrofishing survey of the lower Big Sur River revealed the presence of juvenile steelhead/rainbow trout throughout the lower river, and in Juan Higuera Creek. The main river and tributary reaches were also identified at this time.

Fish marking in 1992 did not occur until 13 October–6 November, during which period 881 juvenile steelhead/rainbow trout were marked and released. Trout occurred in all of 19 mainstem habitat units extending from the gorge reach through the Molera reach. They were also found in a unit each of both lower and upper Juan Higuera Creek. Habitat units in the gorge reach and Juan Higuera Creek were actually composite sections of the step-run/pool habitat dominating in the gorge and the cascade habitat dominating in the creek.

The mainstem population structure was clearly dominated by young-of-the-year steelhead although a small proportion of age 1+, 2+, and possibly older trout was also sampled. The population in lower Juan Higuera Creek was also clearly dominated by young-of-the-year, although they were smaller on average than those in the main stem. In contrast, sampling in upper Juan Higuera Creek suggested a resident rainbow trout population where the density was much lower and there was more equal representation by each of possibly four age classes.

Some ripe male parr were found in the main stem during this survey. The smallest observed was 111.5 mm TL and probably age 1+, while the largest was 267.0 mm TL. Mature male parr (202 and 206 mm TL) were also observed in lower Juan Higuera Creek; morphologically these fish looked like resident rainbow trout. There was a relatively large proportion of mature male parr in upper Juan Higuera Creek (32% of all fish sampled). The size and age at first maturity among these males was remarkably small (77.5 mm TL) and low (age 0+), respectively. The largest observed mature male was 212 mm TL.

In addition to the actual riverine and tributary habitats, juvenile steelhead also occurred in the lagoon and river outlet. More than half (56%) of the fish sampled in these habitats were color classified as silvery parr and smolts and none had ripe gonads.

A second survey during fall 1992 was not warranted because of the late date of the marking survey. So, a recapture survey was not conducted until 8 June 1993–9 July 1993. Thirteen of the 19 mainstem habitat units were resampled and only 4 trout were recaptures. All four had been marked as fish in the lower half of the 0+ length-frequency distribution. Three were recovered in the same habitat unit in which they were marked, while one had moved a short distance downstream from a riffle to a run. In Juan Higuera Creek, 3 trout were recaptures, all of which had been marked as age ≥1+ trout in the upper creek. One of these fish was recovered in the lower creek. Few smolts appeared to remain in the stream by this time, and unit-specific abundances of fish from the 1992 year class were greatly reduced.

Because of very high flow conditions during the winter of 1992–1993, the first pipe trap was not installed until 2 April 1993. This trap is located in the lower Molera reach, adjacent to the walk-in campground in Andrew Molera State Park. No distinct smolt emigration was detected through the remainder of the spring and early summer, and although many downstream migrants were captured, very few were marked. Young-of-the-year of the 1993 year class dominated numerically.

The second pipe trap was installed near the downstream boundary of the campground reach (at access gate 10 in Andrew Molera State Park) on 10 August 1993. Situated on a relatively high-gradient riffle, this trap has been especially effective in capturing downstream moving fishes, even under lower flow conditions. The third pipe trap was installed below the downstream boundary of the gorge reach, at the confluence with Post Creek, on 21 September 1993.

Adult steelhead spawned in lower Post Creek during the wet winter of 1992–93, and steelhead fry were seen in the creek, above the upper road crossing in the campground, on 10 June 1993 (R. G. Titus, CDFG, unpubl. memo. of 12 August 1993; copy appended). On 9 July 1993, a 64 m long section, from the upper road crossing to the first foot trail crossing upstream, was sampled by electrofishing to confirm juvenile steelhead presence. Juvenile steelhead abundance was estimated using the two-pass removal method. The estimated abundance of age 0+ steelhead was about 35 fish (54 fish/100 m), and that of age 1+ steelhead was 2 fish (3 fish/100 m). Age 0+ fish comprised about 94% of the steelhead catch. The mean (± SD) length of age 0+ steelhead was 55 ± 12 mm TL (n = 34), and the two age 1+ fish were 101 and 137 mm TL. Age 0+ steelhead also occurred between the upper road crossing and the creek mouth, but no fish were found in the 50+ m of stream spot-checked immediately above the foot trail crossing. Several potential migration barriers for adult steelhead still exist in lower Post Creek, including the support structure for the foot trail crossing mentioned above, and several logjams that have accumulated large volumes of sediment and gravel. Post Creek has probably supported more extensive steelhead spawning and rearing, as current poor conditions for steelhead production appear to be the product of logging effects and water diversion. It is not known if resident rainbow trout persist in the upper creek area.

1993–1994

The 1993 marking survey occurred during 23 August–24 September, during which time 1,068 juvenile steelhead/rainbow trout were marked and released. As in 1992, trout occurred in all of 17 mainstem habitat units from the gorge through the Molera reach. The lagoon and river outlet were dropped from the sampling schedule because these habitat units occur downstream from the lowermost pipe trap, and the seaward movement of these fish would go undetected. Juvenile steelhead were seen in the lagoon, however. Trout were also marked in two units in lower Juan Higuera Creek, and in one in the upper creek. Post Creek was perennial in 1993 and trout were marked in the unit described above.

Again, young-of-the-year dominated the mainstem steelhead population in numbers. Of 1,154 trout that were color classified, none was classified as smolts, and only 116 (10%) were silvery parr; the remainder was parr. No trout had ripe gonads.

Fifteen mainstem trout were recaptures from the 1992 marking survey, of which 13 had identifiable marks. All were found in their original mark-and-release unit or in a contiguous habitat unit. Twelve of the 13 identifiable recaptures were in the upper two reaches of the lower river (gorge and campground) and the remaining one in the Molera reach. Generally, the relative differences among marking size classes persisted such that fish marked as small age 0+ averaged 131 mm TL ($n = 6$), those marked as large 0+ averaged 155 mm TL ($n = 2$), and those marked as age ≥1+ had a mean recapture length of 215 mm TL ($n = 5$).

Four trout in Juan Higuera Creek were recaptures from the 1992 marking survey. Three of these fish were recovered in their original mark-and-release units, while the fourth had moved from above the barrier into the lower creek where it was recaptured. As in the mainstem, these trout maintained their relative size differences during the year following marking.

The late-fall recapture survey was conducted during 8–19 November 1993. Fourteen of the 17 mainstem habitat units in which trout were marked were resampled, and 981 trout were captured. The mean ± SD proportion of recaptures in the mainstem catches was 0.35 ± 0.13 (range, 0.16–0.57). Of 261 recaptues, 242 (93%) were recovered in the same habitat unit in which they were marked. The remaining 19 were found in a unit adjacent to their original units, and of these eight had moved upstream while 11 had moved downstream. Trout occurred in all sampled habitat units, from the gorge through the lower Molera reach.

All four tributary units were resampled during this survey. The mean ± SD proportion of recaptures in the catches from lower Juan Higuera and Post creeks was very high (0.73 ± 0.04; range, 0.70–0.77), and exceptionally high (0.87) in the resident rainbow trout unit in upper Juan Higuera Creek.

Of 961 mainstem trout that were color classified, only one was classed as a smolt, and 99 (10%) as silvery parr; the remainder was parr. Thus, the proportionate breakdown among color classes was the same as when the fish were marked in late summer/early fall. Most trout in the tributaries were also classed as parr.

Ripe males sampled in the main stem ranged from 111.5 mm TL to 305.0 mm TL, which was a very similar pattern to that seen in fall 1992 (see above). Mature male parr were also found in lower Juan Higuera Creek (105.0–225.0 mm TL), and again the larger of these fish appeared to represent the resident type. The proportion of mature male parr in upper Juan Higuera Creek (20% of all fish sampled) was lower than in fall 1992, although their size and age range was similar (83.0 mm TL and age 0+ to 243.0 mm TL). Only immature, young-of-the-year parr occurred in the unit in lower Post Creek.

The lagoon appeared to be heavily used by presmolt steelhead as rearing habitat. Sampling with a 25 ft (7.6 m) seine was completely unsuccessful. A small effort (~1 h) was made by use of electrofishing and flyfishing to sample lagoon-rearing steelhead juveniles. One steelhead was captured by electrofishing and 11 by angling. These fish were 136.0–212.0 mm TL and all were classed as silvery parr. Angling probably selected for larger fish and so smaller steelhead were likely underrepresented in this small sample.

All three pipe traps have fished continuously for downstream moving fishes since September 1993, except during storms when they were rendered dysfunctional by high stream flow and sediment transport. Downstream movement of juvenile steelhead was generally light during fall 1993, which was also reflected in the relatively high recapture rates of marked fish during the November 1993 electrofishing survey (see above).

The pipe traps were successful in capturing pre- and post-spawning adult steelhead as well. Adults were captured from the second week of January 1994 through at least April 1994. The earliest observed adults were all males. Adults were captured in all three traps which demonstrates that the 2 ft high weirs used at the traps did not impede upstream migration of adult steelhead. Nonetheless, personnel at the Ventana Wilderness Sanctuary at Big Sur, who are hired to operate and maintain the traps, were instructed to remove a single weir panel at each trap to ensure free upstream passage. These weir panels were reinstalled to maximize trap efficiency for steelhead juveniles once it was judged that the adult upstream migration was completed. The onset of a distinct smolt emigration was coincident with the vernal equinox and continued into at least May 1994.

No formal recapture survey was conducted during late spring–early summer 1994 due to time and budgetary constraints. However, single electrofishing passes were made through several habitat units on two occasions to determine the proportion of marked fish remaining in each unit. During 13–15 April 1994, five mainstem units in the campground and Molera reaches were sampled, and one unit each in lower and upper Juan Higuera Creek. The mean ± SD proportion of recaptures among ≥age 1 trout in the mainstem catches was 0.12 ± 0.10 (range, 0.00–0.22) and thus much lower than in November 1993 (see above). One fish had an unreadable mark, but the remaining seven recaptures were recovered in the same habitat unit in which they were marked, or from an adjacent unit. Trout color classified as smolts were only seen in the lowermost unit in the Molera reach. Only one ripe male parr (192.0 mm TL) was observed. Recently emerged fry of the 1994 year class were present in all mainstem units sampled.

The recapture rate of marked ≥age 1 trout was higher in the lower Juan Higuera Creek unit (0.40), and again exceptionally high in the upper creek unit (0.92). One fish in the lower creek was color classed as a smolt and four others as silvery parr, whereas all trout in the upper creek were parr. Ripe male parr were present in both the lower (114.0–230.0 mm TL) and upper (92.5–216.0 mm TL) creek. A ripe female parr (166.0 mm TL) was also seen in the upper creek. Newly-emerged fry were present in the lower creek unit but not in the upper creek unit.

During 23–24 June 1994, one unit each in the gorge, campground, and Molera reaches was sampled in a similar fashion. The primary objective of this sampling effort was to collect tissue samples for mitochondrial DNA analysis, to be conducted by Ms. Cindy Carpanzano at Hopkins Marine Station under the direction of Dr. Jennifer Nielsen. In the gorge reach unit, seven of 19 ≥age 1+ trout (37%) were recaptures, while only one of eight (13%) and none, respectively, in the campground and Molera reach units were recaptures. Most trout were color classified as parr; no smolts and few silvery parr were seen. No ripe parr were seen, either.

The other unit in lower Juan Higuera Creek was also sampled, and the upper creek unit resampled, at this time. In the lower creek unit, 30 of 35 trout were young-of-the-year, but all five age 1+ trout were recaptures from 1993 that were marked in that unit. All trout were parr and none had ripe gonads, although ripe male parr (213.0–273.0 mm TL) were sampled elsewhere in the lower creek. In the upper creek unit, the recapture rate among ≥age 1+ trout remained high (0.73). Both ripe males (110.0–222.0 mm TL) and a ripe female (158.0 mmTL) were sampled in the upper creek area. Fry of the 1994 year class had also emerged by this time.

COMPLEMENTARY AND UPCOMING WORK

The plan for 1994–1995 is to continue marking and trapping juvenile steelhead and rainbow trout as in previous years, with the marking survey tentatively scheduled for 12–23 September 1994. We hope to switch from marking with Alcian Blue to PIT (passive integrated transponder) tags, both to speed up the marking process as well as obtain growth and migration information on an individual fish basis. An attempt was made with visible implant (V.I.) tags in November 1993 but the tag retention rate so far has been low, and only trout ≥140 mm TL can be marked with this method. We would like to expand the scope of trapping by installing a 5 ft rotary screw trap at the head of the lagoon in an attempt to better capture marked emigrants during storms, and an upstream migrant trap in the lower Molera reach. In the meantime, there is still a great deal of information to be processed from the data collected so far and their analysis will continue.

During 18-27 July 1994, our program initiated a validation study of the physical habitat simulation (PHABSIM) model of the instream flow incremental methodology (IFIM). Transect work was conducted primarily in habitat units in both the main stem and Juan Higuera Creek where we also measure juvenile steelhead/rainbow trout abundance. We are also planning on habitat typing the entire lower Big Sur River in connection with developing a geomorphologically based typing method..

If you have any questions regarding the Big Sur River steelhead study or the information presented herein, please feel free to contact me at (916) 654-9865.

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Exhibit DFG-T-1 (26 pages)

STEELHEAD IN MONTEREY CO.

EXCERPT FROM

HISTORY AND STATUS OF STEELHEAD IN CALIFORNIA COASTAL DRAINAGES SOUTH OF SAN FRANCISCO BAY

~~ROBERT G. TITUS, AND~~ DON C. ERMAN, AND
WILLIAM M. SNIDER

BIG SUR RIVER DRAINAGE

The Big Sur River drainage is currently among the largest of those systems south of San Francisco Bay that remain mostly pristine. Within recent geological history, only the lowermost 12 km or so of the river have been accessible to steelhead. Upstream migration beyond this point in the steep and rugged gorge section of the river has been blocked by a natural bedrock fall. This feature marks the boundary above which the river flows through the Ventana Wilderness within the Los Padres National Forest. Pfeiffer Big Sur State Park is situated immediately downstream from this point along a portion of the lower river where redwoods are a major component of the riparian zone. This far south along the California coast, fog no longer maintains the moisture climate necessary for continuous stands of redwoods, and the steep hillsides that comprise the Big Sur drainage are otherwise dominated by grassland, chaparral, and oak woodland. The lowermost 6.4 km of the river flow through Andrew Molera State Park.

The following is a chronological rundown of available information on Big Sur River steelhead and resident rainbow trout. On 9 April 1940, six adult steelhead were seen in the large pool immediately below the barrier falls, and many more were reportedly seen there a few weeks earlier attempting to ascend the falls (Shapovalov 1940). On 27 March 1946, the CDFG observed a fresh run of adult steelhead in the river, again as far upstream as the barrier falls. Recently emerged steelhead fry were also seen downstream from the falls. In 1953, the CDFG began stocking catchable rainbow trout annually during May–September to support a lower river sport fishery. Prior to that time, rainbow trout fingerlings had

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been planted for several years. The stocking area was a 5 km reach, mostly within Pfeiffer Big Sur State Park. Resident rainbow trout have not been planted in the Big Sur River since 1975, following adoption of the steelhead rainbow trout policy which prohibits the planting of resident fish in steelhead drainages.

About 19 km of the Big Sur River, from the bottom of the gorge upstream to Sykes Camp in the Ventana Wilderness, were surveyed by the CDFG during July–August 1957. Most of the survey area was upstream from the impassable steelhead barrier, and thus represented the stream portion inhabited primarily by wild resident rainbow trout. river canyon was narrow and steep-sided, and contained many migration barriers. quality spawning areas were limited. Rearing habitat was adequate for both juvenile and adult rainbow trout. Rainbow trout, 7.5–25 cm long, were observed throughout the survey area. However, recruitment to the 1957 year-class was regarded as poor since few young-of-the-year (fish ≤5 cm long) were seen.

On 4 January 1961, stream flow just above the lagoon was about 0.6 m^3/s, and few adult steelhead had been reported in the river. Two steelhead, about 0.9 and 4.5 kg, were caught in the surf outside the lagoon. Other steelhead were also seen outside the river mouth. A 1.4 kg steelhead was captured on 31 January 1961.

Fisher (1961) captured 338 juvenile steelhead in a downstream-migrant trap in the lower Big Sur River, during 30 April–2 June 1959. The number of downstream migrants captured per day was greatest during the first 3 days of the trapping period, and then decreased sharply and fluctuated around a much lower level through the remainder of the period. Most (87%) movement occurred during the night or early morning. Most downstream migrants were believed to be 1-year-olds. Some 0+ steelhead apparently also entered the trap, although their relative abundance was probably underestimated due to a low trapping efficiency for fish that size. Stream flow in the lower Big Sur averaged 0.7 m^3/s during the study period, which was uncharacteristically low for the month of May. Thus, these steelhead migration data may not be representative for normal or wet water years.

On 19 April 1961, young-of-the-year steelhead/rainbow trout were seen throughout the stream reach within Pfeiffer Big Sur State Park, and 12.5–15 cm long juveniles were common. An adult steelhead was caught in the lower river on 31 January 1962. On 28 April 1962, juvenile steelhead captured on hook-and-line in the lower river at a rate of 1.08 trout/angler hour ranged in fork length from 10 to 18 cm, and averaged about 14 cm (R. N. Hinton, CDFG, intraoffice corr. of 31 May 1962). On 15 May 1962, four steelhead estimated at 61 cm and 1.8–2.7 kg, and one at about 36 cm, were seen in a pool in the lower river area. On 22 May 1962, juvenile steelhead, 5–10 cm long, were common in abundance in pools up to the base of the barrier falls. In 1965, the CDFG estimated the annual steelhead spawning run in the Big Sur River at about 300 fish, based on the observations of local field personnel (California Department of Fish and Game 1965).

The CDFG surveyed the north and south forks of the Big Sur River in August 1978, following the Marble Cone fire of 1977 (P. Chappell, CDFG, unpubl. memo. of 11 June 1979). These headwaters were somewhat degraded due to the fire, yet resident rainbow trout were common in abundance, as determined by hook-and-line sampling.

Following several attempts and much discussion over the years regarding removal of the bedrock barrier in the lower gorge, the Big Sur drainage above the barrier was surveyed by the CDFG and USFS during 14 July–4 August 1981 to determine the quantity and quality of stream habitat that would become available to steelhead for spawning and rearing (USFS stream survey reports, and summary by R. C. Benthin, CDFG, unpubl. memo. of 26 August 1981). High quality steelhead spawning and rearing habitats were observed throughout the survey area, including: the entire 21.7 km of the main stem; the lowermost 1.6 km each of the mainstem tributaries, Ventana and Lion creeks, and the lowermost 160 m of the Ventana Creek tributary, Doolans Hole Creek; the lowermost 7.2 km of the North Fork Big Sur River; and the lowermost 4.0 km of the South Fork Big Sur River up to an 3.7 m high bedrock migration barrier. So, with removal of the bedrock barrier in the lower gorge, at least 36 km of habitat would become accessible to steelhead; an unknown proportion of another 19 km of unsurveyed stream sections would also become available. The mainstem tributaries, Logwood and Terrace creeks, and the North Fork tributary, Cienega Creek, all had an impassable bedrock waterfall at their mouths. The North Fork tributary, Redwood Creek, was full of debris, apparently as a result of the Marble Cone fire. Resident rainbow trout, including young-of-the-year, were abundant in all stream sections surveyed, and occurred in section specific visually-estimated average densities of 40–100 trout/30 m. A subsample of 50 hook-and-line captured rainbow trout averaged about 15 cm FL (overall range, 10.0–35.0 cm FL). The USFS stream survey report indicated that the CDFG had planted rainbow trout at Barlow Flat in 1948, but none since that time in the stream area above the gorge.

Beginning in the fall of 1981 and through the fall of 1984, a series of modifications was carried out on the barrier to enhance steelhead passage. Six adult steelhead were observed by the CDFG on 18 March 1985 between Barlow Camp and the gorge. Adult steelhead have also been reportedly seen by anglers in upstream areas in subsequent years (K. R. Anderson, CDFG, pers. comm. of 9 July 1992).

On 7 November 1988, abundance estimates of juvenile steelhead were made by the CDFG in two sections of the lower river, each about 46 m long. Fish were sampled by electrofishing, marked, released, and resampled to make Lincoln-Peterson abundance estimates. In a section just below the confluence with Post Creek, the calculated abundance was 109 trout/30 m. These fish averaged 84 mm FL (range, 55–247 mm FL). The second section, located in Andrew Molera State Park, contained an estimated 128 trout/30 m. Average fish length was 82 mm FL (range, 55–140 mm FL). A sample of juvenile steelhead was also collected in Molera Park by electrofishing on 17 July 1990 (D. C. Rischbieter, California Department of Parks and Recreation, unpubl. data); these fish averaged 86 mm SL (SD = 32 mm SL; range, 50–175 mm SL).

The largest adult steelhead reported from the Big Sur River was an illegal catch that measured 90 cm and weighed about 7 kg (Rischbieter 1990a). During the 1992-93 season, the reported angler catch of adult steelhead in the Big Sur included one 79 cm female and several 56 cm fish (M. Fitzsimmons, CDFG, pers. comm. of 13 March 1993).

Recent study of juvenile steelhead habitat use in the lower Big Sur River shows that the entire area, from the lagoon to the gorge, remains highly functional for steelhead production (R. G. Titus, CDFG, unpubl. data of 1992–1994). Preliminary analysis suggests that most juveniles leave the stream after only 1 yr of rearing, and that there is a relatively small proportion of mainstem fish that appears to be resident rainbow trout. Most mainstem trout are infested with encysted metacercaria of the monogenetic trematode, *Neascus*, a condition commonly referred to as "black spot disease".

Resident rainbows are still abundant above the barrier falls in the gorge, and these fish too have black spot disease (C. Carpanzano, U.S. Forest Service, unpubl. letter of 24 September 1993). Some of these trout may be juvenile steelhead, but it is not clear if adult steelhead are still able to negotiate the barrier falls.

Overall, the Big Sur River continues to support a healthy steelhead population, one that Nehlsen et al. (1991) classified as a stock of special concern.

Juan Higuera Creek. Juan Higuera Creek is the largest perennial tributary to the lower Big Sur River. The CDFG surveyed the creek on 8 August 1961. Steelhead spawning areas were lacking as stream substrate materials were cemented by calcium carbonate precipitates. Rearing habitat in the form of pools and cover also appeared limited. Several potential barriers to upstream movement of adult steelhead were identified. Two small pipe diversions removed water from the stream. No fish were seen during the survey although local residents reported that each small pool in the stream supported one catchable size (15–20 cm long) juvenile steelhead/rainbow trout. Adult steelhead reportedly migrated into Juan Higuera Creek during high flow periods in winter (R. L. Moore, CDFG, unpubl. draft memo. of August 1960).

Another long-time streamside resident and landowner corroborated historical presence of adult steelhead in Juan Higuera Creek (K. Wright for D. Fee, Big Sur, CA, pers. comm. of 4 February 1994). Steelhead were seen and captured in the creek until 1972, when the combined effects of an upslope fire and heavy flooding washed out the road crossing near the creek mouth. A culvert was subsequently installed which then created at least a partial barrier to upstream migrating adult steelhead.

Exhibit DFG-T-1 (26 pages)

Recent study of juvenile steelhead habitat use in the lower Big Sur River reveals that Juan Higuera Creek is still well-populated with juvenile steelhead/rainbow trout (R. G. Titus, CDFG, unpubl. data of 1992–94). Preliminary analysis of population structure suggests that lower Juan Higuera Creek is populated by a mixture of juvenile steelhead and resident rainbow trout, as evidenced by a relatively high proportion of age 0+ fish. What is not clear is whether steelhead actually spawn in the creek and their progeny rear there, or if juvenile steelhead migrate into the creek from the Big Sur River. The population in upper Juan Higuera Creek is much more sparse in comparison, and clearly characterized by a higher proportion of larger, older individuals, including mature adults, suggesting a resident rainbow trout population segment.

Post Creek. Post Creek enters the lower Big Sur River within Pfeiffer Big Sur State Park. Shapovalov (1940a) described the creek as "an inconsequential stream that is reported to go completely or nearly dry each summer", in his consideration of potential hatchery sites in the park and vicinity. In contrast, Rischbieter (1990d) noted the creek as an historically perennial stream, and when surveyed by the CDFG in 1980, the creek was identified as an important spawning and rearing area for steelhead. At that time, only the lowermost 275 m of the creek were accessible to steelhead because of an impassable logjam. The stream habitat consisted primarily of small pools and low gradient riffles. The calculated juvenile steelhead abundance for this area was >1,000 fish, or >365 trout/100 m of stream.

The stream habitat at Post Creek has degraded significantly in recent years (Rischbieter 1990d). In 1986, a landslide occurred about 335 m above the creek mouth which introduced a large amount of sediment into the lower creek. The sediment filled in pools and covered spawning gravels. The lower creek went dry during the summer–fall period of the drought years 1988 and 1989. Apparently, drought effects were exacerbated by water withdrawal by the Ventana Inn and other upstream water users. Rischbieter (1990d) concluded that these conditions precluded steelhead use of the creek, and no fish were seen during a brief survey of the lower creek on 18 September 1992 (R. G. Titus, Univ. Calif.

Berkeley, unpubl. field notes).

Adult steelhead spawned in lower Post Creek during the wet winter of 1992–93, and steelhead fry were seen in the creek, above the upper road crossing in the campground, on 10 June 1993 (R. G. Titus, CDFG, unpubl. memo. of 12 August 1993). On 9 July 1993, a 64 m long section, from the upper road crossing to the first foot trail crossing upstream, was sampled by electrofishing. Juvenile steelhead abundance was estimated using the two-pass removal method. The estimated abundance of age 0+ steelhead was about 35 fish (54 fish/100 m), and that of age 1+ steelhead was 2 fish (3 fish/100 m). Age 0+ fish comprised about 94% of the steelhead catch. The mean (± SD) length of age 0+ steelhead was 55 ± 12 mm TL ($n = 34$), and the two age 1+ fish were 101 and 137 mm TL. Age 0+ steelhead also occurred between the upper road crossing and the creek mouth, but no fish were found in the 50+ m of stream spot-checked immediately above the foot trail crossing. Several potential migration barriers for adult steelhead still exist in lower Post Creek, including the support structure for the foot trail crossing mentioned above, and several logjams that have accumulated large volumes of sediment and gravel. Post Creek has probably supported more extensive steelhead spawning and rearing, as current poor conditions for steelhead production appear to be the product of logging effects and water diversion. It is not known if resident rainbow trout persist in the upper creek area.

MANUSCRIPT AS OF Mon, Jul 11, 1994

Exhibit DFG-T-1 (26 pages)

State of California

Memorandum

To Jennifer Nelson, DFG, Monterey

Date Aug. 12, 1993

From : Department of Fish and Game, ESD, Sacramento

Subject: Steelhead use of Post Creek, tributary to Big Sur River, Monterey County, as a spawning and nursery area

Objective: Post Creek, in Pfeiffer Big Sur State Park, was observed and electrofished during June-July 1993 to determine the presence/absence and approximate distribution of juvenile steelhead in the lower creek area.

Methods: On June 10, 1993, a very brief survey was conducted which consisted of streamside observations made near the upper road crossing in the campground.

On July 9, 1993, a 64.2 m long section of the creek was sampled using a Smith-Root Type 12 backpack electroshocker at 200-300 V and 60-90 hz. The sample section was located between the upper road crossing and the first foot trail crossing upstream. Separate abundance estimates were made for age 0+ and 1+ steelhead using the removal method (Zippin 1958). Two removal passes were made, with a pass consisting of a single electrofishing sweep in the upstream direction. Several other locations also were spot-checked for steelhead using the electroshocker, both upstream from the trail crossing, and downstream from the upper road crossing to the mouth of Post Creek at its confluence with the Big Sur River.

All captured fish were anaesthetized with MS-222, and measured for total length (TL, nearest 0.5 mm) and wet weight (nearest 0.1 g). Following recovery in fresh water, the fish were released near their site of capture.

Fulton's condition factor, *K*, was calculated with the formula, 10^5(wet weight, g)/(total length, mm)^3; *K* was calculated only for steelhead >40 mm TL to eliminate the inconsistency in condition due to the morphological change that occurs in young trout at about 40 mm, and because of imprecision in weighing fish <1 g with the balance used. Abundance and biomass estimates, and associated parameters and variances, were calculated by use of Pop/Pro Software (Kwak 1992).

Results: Observations made on June 10, 1993 revealed the presence of steelhead fry in Post Creek, above the upper road crossing in the campground.

On July 9, 1993, steelhead were designated age 0+ if TL was <100 mm, and age 1+ if TL was ≥100 mm, based on the length frequency distribution of the catch (Fig. 1; attached copy of raw data) and expected growth. The estimated abundance (± S.E.) of age 0+ steelhead in the sample section was 34.62 ± 1.03 fish, at a linear density (± S.E.) of 0.54 ± 0.02 fish/m. The abundance of age 1+ steelhead was estimated at 2 ± 0 fish, at a density of 0.03 ± 0 fish/m. Age 0+ fish comprised about 94% of the steelhead catch.

Age 0+ fish had a mean (± S.D.) TL of 55.3 ± 12.0 mm (*n* = 34), and averaged 1.8 ± 1.4 g. The two age 1+ fish observed were 101.0 and 137.0 mm TL, and 10.3 and 24.6 g, respectively. The mean (± S.D.) *K* of steelhead >40 mm TL was 0.92 ± 0.12. The total biomass of age 0+ steelhead in the sample section was about 61 g, or 0.95 g/m, while that of age 1+ fish was about 35 g, or 0.54 g/m.

Fish were absent in the 50+ m of stream spot-checked upstream from the foot trail crossing. In contrast, five age 0+ steelhead and one threespine stickleback were sampled by spot-checking between the upper road crossing and the creek mouth.

Discussion: These surveys confirmed the use of Post Creek as a steelhead spawning and nursery tributary to the Big Sur River. Juvenile steelhead distribution appeared to be restricted to the lowermost portion of the creek, although sampling farther upstream may have shown otherwise. Several potential migration barriers for adult steelhead occur in lower Post Creek, including the support structure for the abovementioned foot trail crossing, and several logjams that have accumulated large volumes of sediment and gravel. The creek may have previously supported more extensive steelhead spawning and rearing, and possibly resident rainbow trout, assuming the current poor condition of the watershed is the product of logging effects and water diversion, and is not the natural state of the system.

From a steelhead production perspective, Post Creek functions primarily as a nursery for age 0+ fish, as reflected in the composition of the catch in this survey (Fig. 1). A lack of depth/cover in the stream, at least within the sample section, precluded greater inhabitation by age 1+ and older steelhead or resident rainbow trout. Deeper cascade pools may exist farther upstream which might provide more suitable habitat for larger/older fish.

The various descriptive statistics presented above merely provide a snapshot characterization of the juvenile steelhead population in lower Post Creek, and in particular a portion of the 1993 cohort. These data can be given greater meaning by making comparisons with results from an ongoing juvenile steelhead study in the Big Sur River (R.G. Titus, unpubl. data), and by conducting follow-up surveys in Post Creek to document the abundance, growth, and distribution of the juvenile steelhead through this growing season.

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Robert G. Titus
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RGT:rgt

Fig. 1 Juvenile steelhead total lengths (mm), Post Creek, 7/9/93