*Redband Trout: Resilience and Challenge in a Changing Landscape*
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# Benchmarks and Patterns of Abundance of Redband Trout in Oregon Streams: a Compilation of Studies

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*Abstract.*—This work summarizes pre-1998 studies of population abundance of stream resident redband trout *Oncorhynchus mykiss* ssp. in Oregon, and compares basin-level surveys of habitat and fish populations in streams of two ecoregions. Interquartile values of density and biomass were used to develop benchmarks of high, moderate, and low abundance. Comparison among Crooked River streams (Blue Mountain ecoregion) showed large differences in population abundance associated with watershed characteristics such as elevation, flow, temperature, land use, and disturbance history. Comparisons among Catlow Valley streams (High Desert ecoregion) found redband trout to be concentrated in discrete reaches associated with high spring flow or in narrow canyon reaches with riparian zones that were not intensively grazed by cattle. These reaches could possibly function as population refugia. Populations of redband trout in Catlow Valley streams were severely depressed during the time of sampling. Degraded stream habitat, drought conditions, and system connectivity appeared to be important factors associated with their status and recovery.

Estimates of fish populations are commonly conducted to monitor population status and trends and to compare treatment effects between populations. Although the rainbow trout *Oncorhynchus mykiss* is one of the most-studied fishes in Oregon streams, very little research has been done on resident populations in central and eastern Oregon, where they are recognized as a distinct subspecies known as redband trout (Currens 1997). Redband trout occur in five major ecoregions in central and eastern Oregon (Figure 1). Their environments are typically arid and range from montane forests to desert shrub and grasslands. Knowledge is particularly lacking about general factors affecting the distribution and abundance of redband trout throughout these widely diverse environments and, at a more basic level, about what constitutes relatively high or low population abundance. In this paper we summarize pre-1998 studies of population abundance of stream resident redband trout in Oregon, from which we develop abundance benchmarks. In addition, comparative surveys of habitat and fish populations in streams in the Crooked River and Catlow Valley basins will be used to demonstrate basin-level effects on the distribution and abundance of redband trout.

## Methods

*Compilation of abundance estimates*.— Abundance estimates (density and biomass) of age-1 and older redband trout (hereafter designated as ≥ age-1) were compiled from pre-1998 published and unpublished studies from central and eastern Oregon (Table 1). Age-class designations were typically putative, being determined by length frequency of sampled fish, but were sometimes more precisely determined by scale analysis. Only studies of stream-resident populations with abundance reported in terms of habitat area were considered. Those with densities reported in lineal terms, such as fish per lineal meter or mile, were excluded. In studies with sample sites that had wetted channel lengths less than 30 times the channel width, multiple sites were averaged to a single estimate at the reach or stream level. Estimates of age-0 fish were omitted to avoid their large variation in between- and within-year abundance. Interquartile values for density and biomass were used to delineate benchmarks for low, moderate, and high levels of abundance.

*Stream surveys*.—Two sets of stream habitat surveys are summarized in this report to provide a comparison of between- and within-stream patterns of redband trout abundance. Stream habitat and fish population surveys were con-

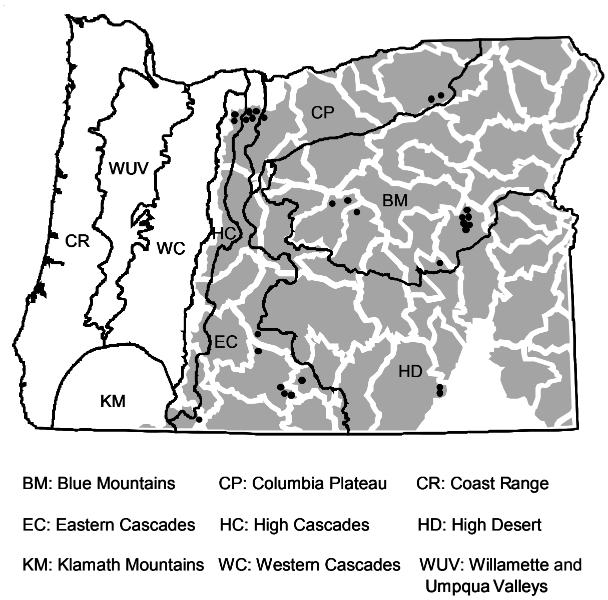


Figure 1.—Major drainages (shaded areas) with historic populations of redband trout and Oregon ecoregions. Ecoregions depicted here are the major ones designated by Clarke et al. (1991), except the High Cascades ecoregion, which is a subregion of the Western Cascades. Filled circles denote location of one or more sites from which abundance data were collected (Table 1).

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TABLE 1.—Data sources for redband trout abundance estimates in streams of central and eastern Oregon.

| Data source | Number of estimates | |
|---|---|---|
| | fish/m² | g/m² |
| Osborn 1968 | 3 | 0 |
| Kunkel 1976 | 5 | 6 |
| ODFW et al. 1985 | 44 | 44 |
| ODFW unpublished data[a] | 30 | 0 |
| Total | 82 | 50 |

[a] Population estimates from 1991 to 1995, Aquatic Inventory Project, Corvallis.

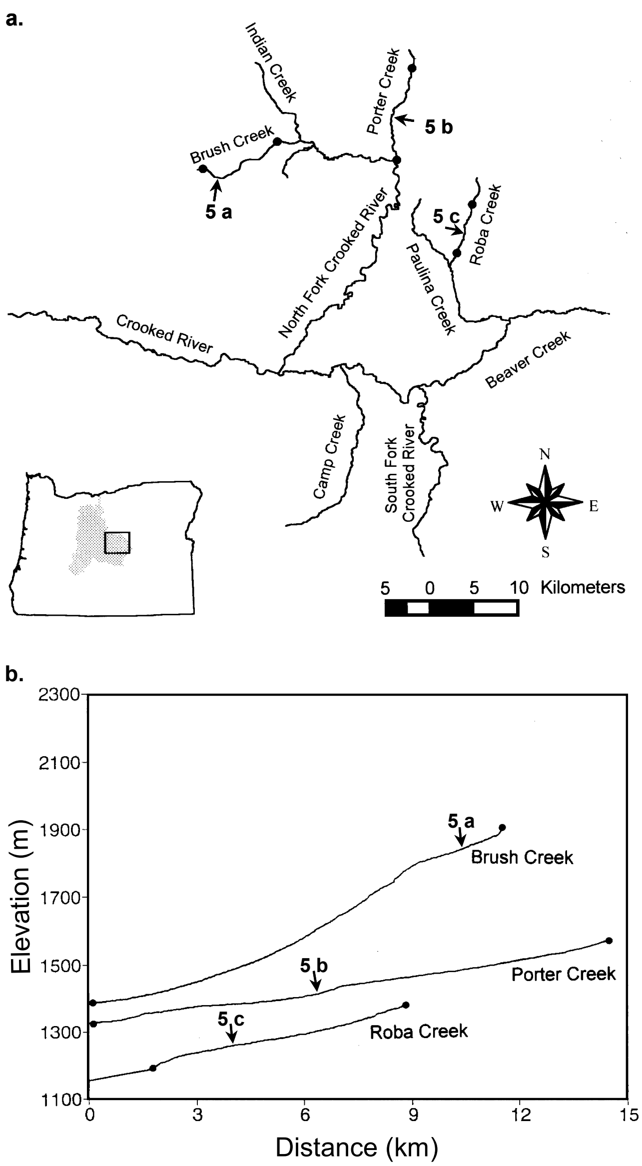


FIGURE 2.—(a) Streams surveyed in the Crooked River basin, Blue Mountain ecoregion, with (b) longitudinal profile. Filled circles denote survey limits; arrows denote location of photographs in Figure 5.

ducted by the Aquatic Inventory Project, Oregon Department of Fish and Wildlife (ODFW), in the Blue Mountain and High Desert ecoregions. Blue Mountain streams were surveyed in the Crooked River basin during the summers of 1991–1993, when there was a drought throughout Oregon (1985–1994). High Desert streams were surveyed in the Catlow Valley basin in 1995, the year following the end of the drought.

Stream habitat was surveyed and fish population abundance was estimated in three streams in the Crooked River basin (Figure 2) deemed to represent high, moderate, and low habitat quality (A. Stuart, ODFW, personal communication). Sampling occurred over three successive years: Porter Creek in 1991 (moderate quality habitat), Brush Creek in 1992 (high quality), and Roba Creek in 1993 (low quality). Stream habitat was quantified with methods of Moore et al. (1997). Estimates of total fish population were made by removal-depletion techniques with backpack electroshockers and blocknets. Streams were stratified into pool and fast-water habitat types and systematically sampled (Hankin and Reeves 1988). Separate estimates of fish abundance were calculated for each habitat type using formulas from Bohlin (1981).

Three streams were inventoried in 1995 (Figure 3) as part of a separate effort to gather information for conservation planning in the Catlow Valley basin (Dambacher and Stevens 1996). In Three Mile Creek, fish population estimates were made with removal-depletion techniques. In Home and Skull creeks only presence-absence sampling was conducted, which consisted of single-pass electroshocking

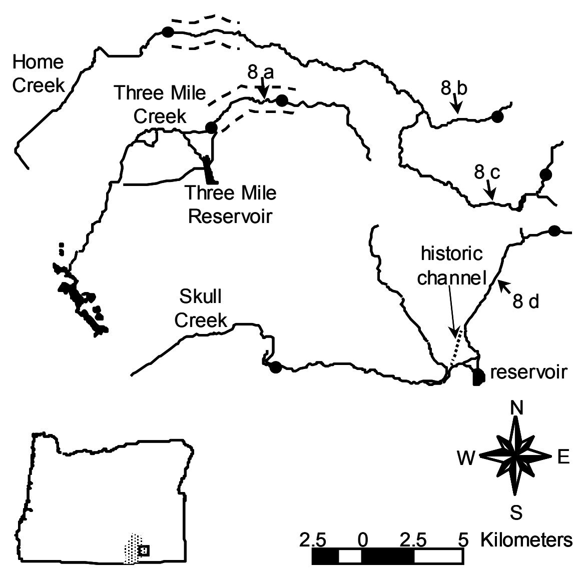


FIGURE 3.—Streams surveyed in Catlow Valley, High Desert ecoregion. Filled circles denote survey limits. Downstream limits of survey are at canyon openings near the east rim of Catlow Valley. Parallel sets of dashed lines denote stream reaches within narrow canyons; arrows denote location of photographs in Figure 8.

without blocknets in three pool and three fast-water habitat types at each sample site. Sample sites were arrayed throughout stream systems to describe the distribution of each fish species. In Home and Skull creeks, capture data from presence-absence sampling were used to infer crude levels of relative abundance, where < 0.01 captured fish/m$^2$ was used to distinguish a low level from higher levels. Presence-absence sampling was conducted in Skull Creek again in 1997.

## Results

*Abundance summary and benchmarks*

A 100-fold difference between the lowest and highest abundances of ≥ age-1 redband trout was reported in the reviewed studies (Figure 4). Density averaged 0.014 fish/m$^2$ and ranged between 0.0069 and 0.65 fish/m$^2$. Biomass averaged 4.2 g/m$^2$ and ranged between 0.14 and 21 g/m$^2$. The overall mean weight of ≥ age-1 fish was 30 g and ranged between 13 and 123 g.

Benchmarks of abundance were developed from interquartile values of fish density and biomass (Table 2). The boundary values for low density and biomass were roughly one-third of those for high levels.

*Crooked River basin*

Watershed characteristics, land-use intensity, and disturbance history differed greatly among the three streams surveyed in the Crooked River basin, which represented a broad spectrum of watershed and stream habitat conditions (Tables 3 and 4). Brush Creek had the highest elevation, the highest flow, the lowest stream temperature, and the lowest level of cattle grazing or timber harvest. Its riparian vegetation appeared to be near its full potential (Figure 5a), with an overstory of large conifers and an understory of small hardwoods and perennial grasses. In contrast, Roba Creek had the lowest elevation and flow, the highest stream temperature, and high levels of cattle grazing and timber harvest. This stream had recently experienced a flash flood, which, after extensive logging of its headwaters, left the channel incised into freshly scoured banks and with degraded riparian conditions (Figure 5c). Conditions in Porter Creek were generally intermediate to Brush and Roba creeks in terms of instream habitat, riparian conditions, and disturbance history. Although Porter Creek historically had a riparian canopy of mature cottonwoods, few remained at the time of the survey; many appeared decadent and many more had fallen (Figure 5b). Recruitment of young cottonwoods was lacking and evidently suppressed as a result of grazing by cattle. Although the three streams differed markedly in watershed characteristics and land use (Table 3), they were similar in measures of instream habitat (Table 4). Brush Creek

TABLE 2.—Benchmarks of abundance for ≥ age-1 redband trout taken from interquartile values of 82 estimates of density and 50 estimates of biomass compiled from pre-1998 studies of central and eastern Oregon streams (Table 1).

| Abundance level | fish/m$^2$ | g/m$^2$ |
|---|---|---|
| Low | ≤ 0.059 | ≤ 2.0 |
| Moderate | 0.060–0.19 | 2.1–4.9 |
| High | ≥ 0.20 | ≥ 5.0 |

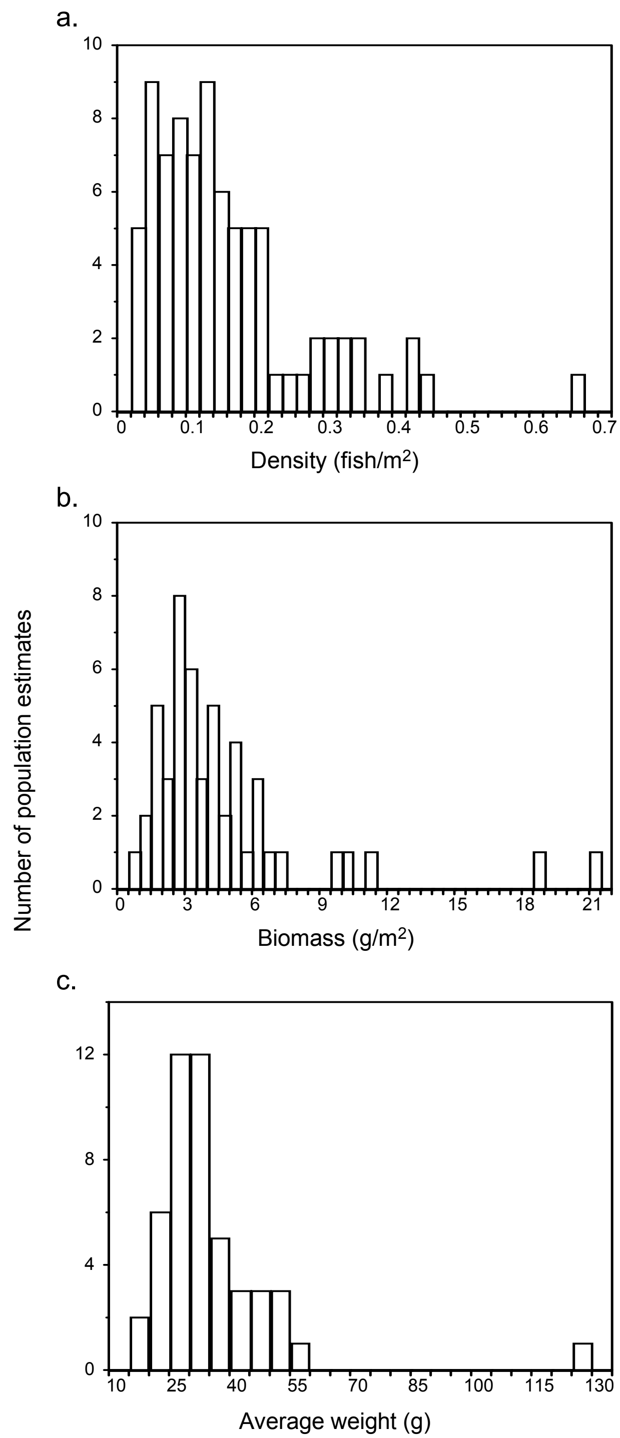


FIGURE 4.—Frequency distribution of ≥ age-1 redband trout (a) density, (b) biomass, and (c) average weight, summarized from published and unpublished estimates (Table 1) of Oregon stream populations.

TABLE 3.—Watershed characteristics of three Blue Mountain streams, Crooked River basin, Oregon.

| Stream | Year surveyed | Basin area | Mid-basin elevation | Stream flow[a] ($m^3/s$) | Maximum water temperature[a] July 1993 | Relative intensity cattle grazing | Relative intensity timber harvest | Disturbance history |
|---|---|---|---|---|---|---|---|---|
| Brush Cr. | 1992 | 20 $km^2$ | 1,600 m | 0.04 | 16°C | low | low | none recently noted |
| Porter Cr. | 1991 | 40 $km^2$ | 1,400 m | 0.01 | 21°C | high | moderate | 1991 channel drying |
| Roba Cr. | 1993 | 30 $km^2$ | 1,200 m | 0.003 | 24°C | high | high | 1991 flood, 1992 channel drying |

[a] Measured at lower limit of stream habitat survey (Figure 3) in July 1993.

had greater bank stability than the other two streams, but also had high levels of fine sediments. Levels of shade, large wood, and pool habitat were mixed among the streams.

Speckled dace *Rhinichthys osculus* occurred with redband trout in all three of the sampled streams. Brook trout *Salvelinus fontinalis* were present in Brush Creek, and the mountain sucker *Catostomus platyrhynchus* in Roba Creek (Figure 6). The upstream distribution of brook trout in Brush Creek was limited by a small falls, as was the distribution of speckled dace in Porter Creek. Dry channel reaches at the time of sampling caused gaps in the distribution of redband trout in Porter Creek. A similar gap in redband trout distribution in Roba Creek occurred in a reach that had been dry the previous summer.

Although available habitat (wetted area) for redband trout in the three streams differed by no more than a factor of 1.6, there was a 20-fold difference in the density of ≥ age-1 fish (Figure 7). Basin area was not correlated with habitat availability or fish population size (Table 3). The smallest basin, Brush Creek, had the greatest amount of available habitat and the largest population of redband trout. Based on the abundance benchmarks in Table 2, densities of ≥ age-1 redband trout were high in Brush Creek, moderate in Porter Creek, and low in Roba Creek. The high density of redband trout in Brush Creek occurred along with many ≥ age-1 brook trout, resulting in a combined density of 0.66 ≥ age-1 salmonids/$m^2$.

### *Catlow Valley basin*

*Habitat overview*.—Habitat surveys in Catlow Valley streams (Figure 3) revealed conditions of moderate habitat quality in Three Mile Creek and in a few reaches of Home Creek, but low habitat quality in all of Skull Creek and in the greater portion of Home Creek. Specific values of habitat conditions are not presented in this report but are summarized in detail by Dambacher and Stevens (1996). Habitat quality, as defined by pool habitat, substrate, bank stability, and riparian conditions (Platts 1991), appeared to be severely reduced in reaches exposed to intensive cattle grazing. Such reaches (e.g., Figure 8b–d) were conspicuously lacking in riparian vegetation, had up to 90% actively eroding stream banks, and were inundated by fine sediments (> 40% in riffle substrates). The best habitat occurred in narrow canyon reaches in the lower portions of Three Mile (Figure 8a) and Home creeks. These reaches were incised into the eastern edge of the Catlow Rim (Figure 9), where remote and difficult access has prevented intensive grazing by cattle. Here dense thickets of alder and chokecherry bordered the streams, boulder substrate and riparian vegetation stabilized stream banks, and large springs maintained cool stream temperatures. The majority of flow in Three Mile Creek comes from a large spring midway through the canyon. Below the canyon reach, streamflow is diverted into Three Mile Reservoir (Figure 3). Skull Creek lacks a narrow canyon (Figure 9), and all channel reaches were severely impacted and degraded from intensive grazing by cattle. Its

TABLE 4.—Habitat characteristics of three Blue Mountain streams in the Crooked River basin, Oregon, from 1991 to 1993, ODFW stream habitat surveys.

| Stream | Percent actively eroding banks | Percent shade | Large wood debris volume ($m^3$/100m) | Percent riffle fines | Percent pool area | Wetted channel width (m) |
|---|---|---|---|---|---|---|
| Brush Cr. | 4 | 57 | 14 | 38 | 15 | 3.5 |
| Porter Cr. | 15 | 49 | not estimated[a] | 13 | 11 | 1.5 |
| Roba Cr. | 38 | 63 | 9 | 33 | 25 | 2.0 |

[a] Generally observed to be lower than levels in Roba Creek.

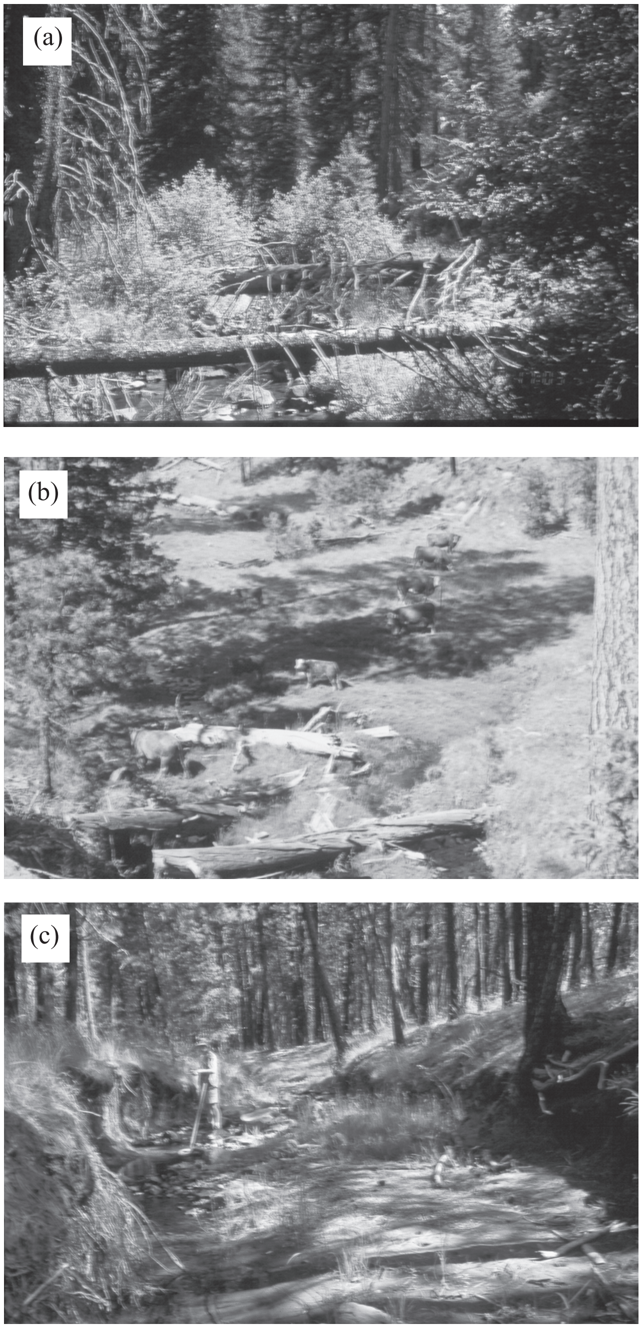


FIGURE 5.—Upstream views of (a) Brush Creek (1992), (b) Porter Creek (1991), and (c) Roba Creek (1993), Crooked River basin. Locations are shown in Figure 2.

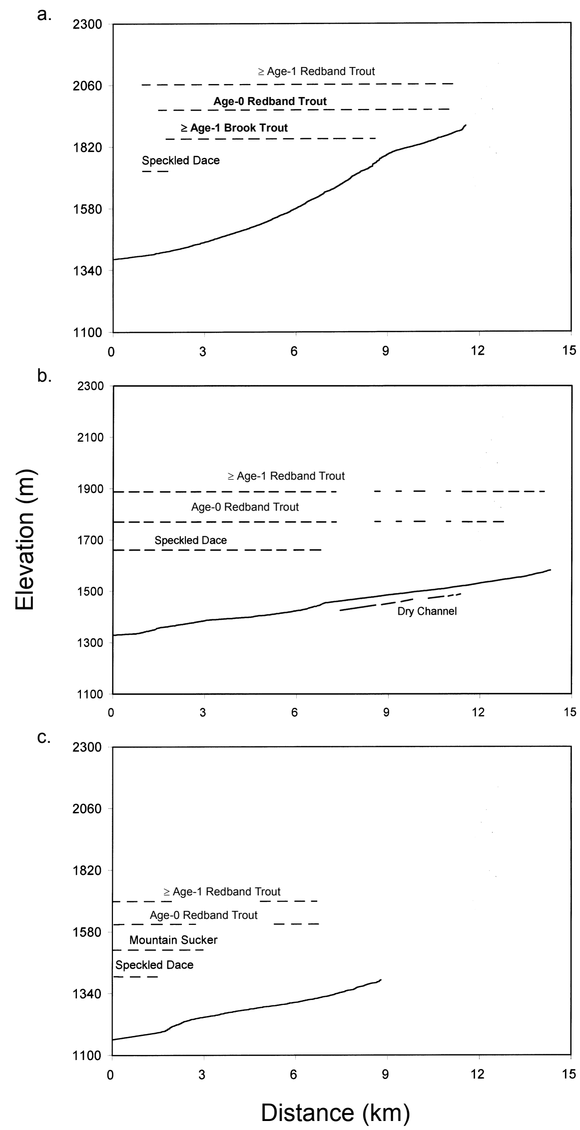


FIGURE 6.—Longitudinal profile and distribution of fishes in (a) Brush Creek, (b) Porter Creek, and (c) Roba Creek. Distribution gaps in Porter Creek are channel segments that were dry during the survey, and in Roba Creek are over a channel section that was wetted during the survey but dry the previous year.

headwaters were bounded by moderately sloped hillsides, and its lower portion had a gentle gradient within an open valley. Below its headwaters, Skull Creek was diverted into a ditch, around a broad meadow, and into a reservoir. From there it flowed back into its natural stream channel below the meadow (Figure 3). The headwaters of Skull Creek had areas of spring inflow, but these were heavily impacted by cattle grazing (Figure 8d).

*Three Mile Creek.*—Redband trout have historically occurred in Three Mile Creek and Three Mile Reservoir, the latter of which has an abundant population of Catlow tui chub *Gila bicolor* ssp. Redband trout commonly enter the reservoir after a year of stream life and become large (> 50 cm) from feeding on tui chub (Kunkel 1976). During the mid-1970s, Kunkel estimated the population of redband trout in Three Mile Reservoir to be as high as 890 fish, with nearly 250 adults spawning, primarily at age 3, in the section of Three Mile Creek between its irrigation diversion and springs. The stream population of ≥ age-1 fish between the diversion and springs was estimated to be as high as 1,700, with a density as high as 1.5 fish/m$^2$. This is an extraordinarily high density (Figure 4) and corresponds with an excep-

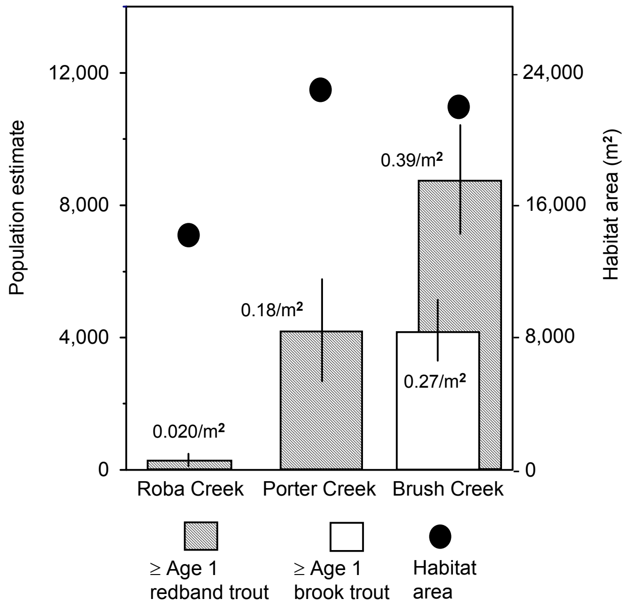


FIGURE 7.—Population estimates (with 95% confidence intervals as vertical lines), habitat area, and density of ≥ age-1 salmonids in three streams of the Crooked River basin, Blue Mountain ecoregion.




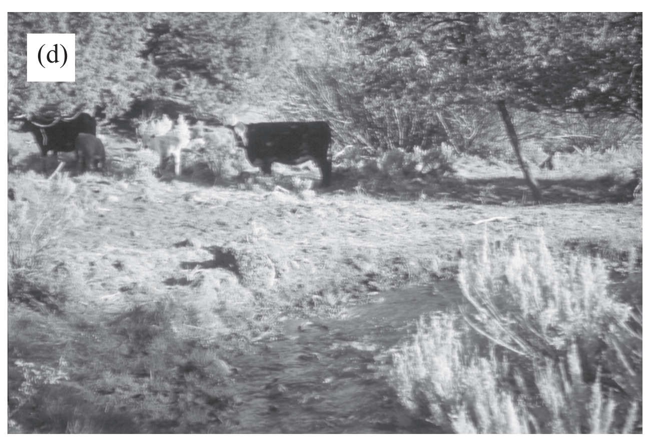


FIGURE 8.—Photographs of Catlow Valley streams, in (a) canyon reach of Three Mile Creek (1994) that has limited access for cattle, (b) area of spring inflow in Home Creek tributary (1995), (c) intensively grazed reach in Home Creek (1995), and (d) intensively grazed reach in Skull Creek where redband trout were found in 1997. Locations are shown in Figure 3; (a) and (b) are upstream views; (c) and (d) are downstream views.

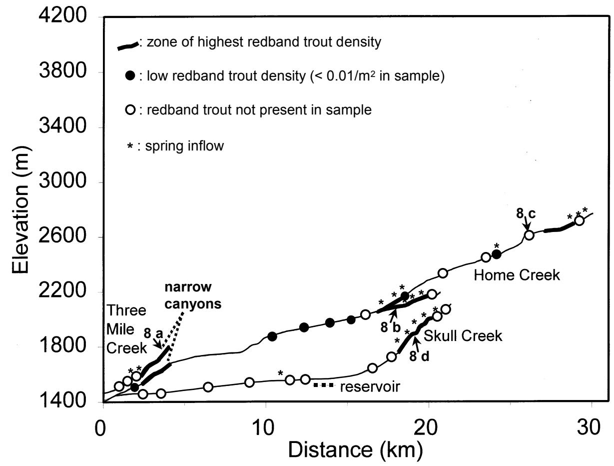


FIGURE 9.—Longitudinal profile of three Catlow Valley streams, High Desert ecoregion, with distribution and relative abundance of redband trout from 1995 and 1997 electrofishing sampling. Arrows denote location of photographs in Figure 8. In general, reaches with the highest densities of redband trout were associated with narrow canyons or with large amounts of spring inflow.

tional level of production (17.2 $g \cdot m^{-2} \cdot yr^{-1}$), which stands as some of the highest ever reported in a small stream (Kunkel 1976).

A change in the schedule of irrigation diversions in the early 1990s is suspected to have interrupted the migration of fish between the reservoir and Three Mile Creek (W. Bowers, ODFW, personal communication). An abundant population of tui chub was found in the reservoir in 1993, but no redband trout were found (unpublished data, W. Bowers, ODFW). In 1995 we found no redband trout in Three Mile Creek between the diversion and the springs, despite intensive population sampling (multiple-pass electroshocking with blocknets), although an estimated 265 ≥ age-1 fish (95% confidence interval ± 41%) were found upstream of the springs. The above-springs reach had only marginal habitat, with puddled flow between pools and dry riffles. Tui chub were abundant in the reservoir in 1997, but again no redband trout were found (Dambacher and Burke 1997).

*Home Creek*.—Redband trout in Home Creek were concentrated in a narrow canyon reach and two reaches associated with heavy spring flow (Figures 8b and 9). Redband trout were absent or in low abundance in all other reaches, especially where intensive cattle grazing caused severe degradation to stream habitat (Figure 8c). Age-0 fish were particularly concentrated near spring inflows in the headwaters and in a tributary.

*Skull Creek*.—We found no redband trout in Skull Creek in 1995 using a presence-absence sampling approach. Tui chub were relatively abundant in a low gradient reach downstream of the reservoir (Dambacher and Stevens 1996). Prior to these surveys, the reservoir had been drawn down for repair, and fish populations in the reservoir were eliminated by repeated episodes of drying. Although it was suspected that redband trout might have been extirpated from Skull Creek (Dambacher and Stevens 1996; Howell 1997), repeat sampling in 1997 found redband trout within a 3.0-km headwater reach (Dambacher and Burke 1997). Sixteen fish were captured in multiple sample sites that covered 6% of the length of this reach.

Presuming no clandestine reintroductions in 1996, redband trout in Skull Creek were likely not extinct in 1995, however their abundance was so low as to be undetected by relatively intensive sampling. Sampling in 1995 had encompassed all of the 3.0-km headwater reach occupied by redband trout in 1997, as well adjacent upstream and downstream reaches. Thirteen percent of the length of the 3.0-km reach was sampled as discrete habitat units of pools and riffles in a series of sample sites. In addition, the majority of pools and pocket-pool habitats between these sites were spot-checked for fish presence by electroshocking.

Evidence suggests that poor survival might be a contributing factor to the status of the Skull Creek population. Based on length-age relationships previously established from Home and Three Mile creeks (Kunkel 1976; Dambacher and Stevens 1996), 15 of the 16 fish captured in Skull Creek in 1997 were either age 0 or not yet hatched at the time of the 1995 sampling. In 1997, one was age 0 (1997 cohort), 14 were age 2 (1995 cohort), and only one was age 4 or 5 (1992 or 1993 cohort).

In 1997, the density of ≥ age-1 fish captured in Skull Creek by presence-absence sampling was 0.06 fish/$m^2$. Assuming that sampling caught no less than half of the actual population (a conservative assumption given that catchability for electrofishing in small streams is typically greater than 0.5, unpublished data JMD), then the density of the 1997 population was likely no higher than 0.12 ≥ age-1 fish/$m^2$. This range in density (0.06–0.12 ≥ age-1 fish/$m^2$) corresponds to a moderate level of abundance (Table 2). Thus, by crude extrapolation of these densities into the wetted area of the 3.0 km reach, the total population of ≥ age-1 redband trout in Skull Creek in 1997 could have been around 250 to 500 fish.

## Discussion

Density and biomass estimates of ≥ age-1 redband trout summarized here are similar to those reported for other rainbow trout populations that are anadromous or resident (Platts and McHenry 1988; Bjornn and Reiser 1991). Our summaries carry the value of not being mixed with age-0 densities (as in Platts and McHenry 1988), and for their being from relatively large sections of stream channel (> 30 channel widths long). As a consequence, they should indicate differences between stream or reach-level abundance, and not merely differences between types of habitat such as pools and riffles.

The three Blue Mountain streams showed wide variation in redband trout abundance that was associated with watershed-level characteristics such as flow and temperature, which in these examples were independent of basin size. Differences in abundance were also likely heightened by a legacy of drought and floods. Although negative impacts to stream habitat from intensive cattle grazing and timber harvest were apparent, it was not possible to determine even relative effects of these two practices on fish populations due to confounding watershed-level factors. Although these comparisons were not intended to rigorously evaluate effects of land use and habitat quality on redband trout, they nonetheless highlight the important context that watershed characteristics can provide to studies of stream fish populations (Dunham and Vinyard 1997). Furthermore, they emphasize the need for an experimental approach, such as a before-after-control-impact (BACI) design, to investigate land-use effects on fish populations.

General patterns of distribution and abundance of redband trout differed greatly between streams in the Crooked River and Catlow Valley basins. In the Crooked River basin the distribution of redband trout was relatively continuous, except for localized channel drying, and major patterns of abundance were more apparent between than within streams. Conversely, populations of redband trout in streams of Catlow Valley were concentrated in relatively discrete reaches that had locally favorable rearing conditions—such as spring inflows or narrow canyons—and were at a low abundance or absent in the majority of habitat elsewhere. Riparian zones are characteristically fragile in arid environments. The degraded condition of habitat in the majority of stream channels in Catlow Valley during these surveys (Figure 8) illustrated the familiar consequence of intensive grazing by cattle in riparian zones (Platts 1991).

Assuming that these patterns of abundance can be generalized to other systems, important considerations for the conservation of redband trout are suggested. In the Blue Mountains, redband trout might be extirpated from streams with the poorest habitat quality and highest disturbance, such as Roba Creek. However, since these stream systems are well connected to one another (Figure 2), at least seasonally, colonization could readily ensue from basins such as Brush Creek, with rearing environments that are more stable and of higher quality and capacity. Conversely, colonization from adjacent basins in the High Desert is often precluded by isolation of streams (Figure 3). Thus identification and protection of local refugia within each stream system are of central importance. High Desert streams represent some of the harshest rearing environments endured by redband trout, and conditions could have approached "worst-case" during the 1985–1994 drought cycle. Narrow canyon and spring inflow reaches (Figure 9) could function as refugia for the stream populations during adverse conditions. These areas may thus represent critical habitat for persistence of redband trout and have the potential to serve as sources of fish to colonize adjacent reaches. As such, they warrant special consideration for protection and restoration.

Based on the size-class distribution of the limited number of fish sampled in Skull Creek in 1997, we speculate that reproduction may have been successful only infrequently. Although a cohort of fish was represented from 1995, limited reproduction apparently occurred in 1994 and 1996, and only a single age-0 fish was found to represent the 1997 cohort. Age-0 fish were apparently difficult to detect in this reach in 1995, but there is less uncertainty about the lack of age-1 and age-3 fish in the 1997 sampling, as electrofishing efficiency is much higher for these larger fish. Moreover, identical sampling gear and effort in other Catlow Valley streams documented a wide range of abundance for both age-0 and ≥ age-1 redband trout (Dambacher and Stevens 1996). Thus it seems unlikely that the observed pattern in Skull Creek was a consequence of sampling bias.

Given the possiblity of episodic reproduction, it is remarkable that ≥ age-1 redband trout in Skull Creek could increase in 2 years from an undetectable level to a moderate level of abundance. However, this example also illustrates an important limitation in the use of fish density alone to rate the status of a population. In Skull Creek a moderate density was exhibited by a population that had a limited distribution (3.0 km), a limited population size (likely < 500 fish), possibly a discontinuous age-class structure, and severely degraded habitat. These factors are of overriding importance in determining the status of a population (Van Horne 1983).

The status of the stream and reservoir populations in Three Mile Creek appears dire. Absence of fish between the diversion and springs is puzzling, as habitat conditions in this reach are some of the most favorable in all of Catlow Valley (Dambacher and Stevens 1996), and this reach has historically supported record levels of abundance and production (Kunkel 1976). Kunkel found this reach of stream to support both stream-resident and adfluvial life histories. It is surprising that a failure of the reservoir population, presumably from a loss of connectivity, would have such a dramatic effect on the stream-resident population. This result raises the question: is the reproductive capacity of the stream-resident life history dependent on the presence of the adfluvial life history?

The adfluvial life history of redband trout is an important component of this species' adaptation to arid inland environments and is in need of basic research. The phenomenon of population collapse and colonization could be ideally studied in the stream and reservoir system of Three Mile Creek, as the scale is small and relatively easy to study. This system is highly productive and therefore likely to respond quickly to recovery efforts. Furthermore, the system could represent a microcosm of larger basins that have experienced collapses of the adfluvial life history, such as the Goose Lake and Warner Valley basins.

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