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# Low Adult Return of Juvenile Steelhead Treated with 17α-Methyltestosterone to Produce Sterility

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*Abstract.*—Juvenile hatchery summer steelhead *Oncorhynchus mykiss* were treated with the hormone 17α-methyltestosterone by methods developed for rainbow trout *O. mykiss* in an attempt to obtain sterile returning adults. Our objective was to determine if sterile steelhead would return to a target stream at frequencies high enough to provide recreational fisheries while providing fishery managers with a tool for reducing steelhead interactions with wild fish. From three brood years of treated releases, only one sterile adult steelhead returned to the collection hatchery on the South Santiam River, Oregon. Gonads were absent in this fish at the end of spawning in February. Other returning adults from treatment groups were 80% male and 20% female. Adults from control groups were 49% male and 51% female. Males from treatment groups developed secondary sexual characteristics similar to controls but contained deformed gonads at the end of spawning. Gonads of treated females appeared normal, but only one ripened by the end of spawning. Although sperm from treated males was viable, based on crosses with eggs from control females, our inability to hand-strip milt from 81% of the treated males suggest that occluded sperm ducts would prevent many from spawning naturally. The mean return frequency of treatment groups was 0.5%, which was 24% of the mean return frequency of control groups. Treatment groups may have had higher mortality after the juveniles were released, or sterile fish may have survived but not returned to the hatchery. Treating juvenile steelhead with 17α-methyltestosterone by the methods we used was not effective in producing sterile returning adults, although sterile individuals may have remained in the ocean.

Fish culture poses a genetic risk to wild populations because cultured fish are often genetically altered, either intentionally or unintentionally, through such practices as inbreeding, selective breeding, and domestication (Allendorf et al. 1987; Hindar et al. 1991). The potential impact on wild stocks is proportional to the nature and degree of genetic alterations (Donaldson et al. 1993). Hatchery fish are commonly released into natural environments by public resource agencies to supplement fisheries and to mitigate habitat losses. Commercial sea ranching and fish farming also intentionally or accidentally release large numbers of cultured fish into natural habitats. Because these programs will probably continue, the genetic protection of wild populations depends, in part, on reducing interactions with cultured fish.

Sterilization may provide a management option for the biological containment of cultured salmonids (Hindar et al. 1991; Devlin and Donaldson 1992; Donaldson et al. 1993). Early interest in sterilization focused on potential benefits to salmonid aquaculture. These included maximizing growth, producing trophy fish, preventing migration, eliminating precocity in males, and increasing marketability (Donaldson and Hunter 1982). In addition, sterilization may increase recreational and commercial catch of cultured salmonids in some fisheries by increasing longevity (Johnston et al. 1993) and by reducing migrations to spawning streams (Goetz et al. 1979). Recently, more emphasis has been given to the potential of sterilization to reproductively contain cultured salmonids (Bams 1990; Devlin and Donaldson 1992; Donaldson et al. 1993).

Exposure to high doses of androgen, usually 17α-methyltestosterone, is one of several sterilization techniques applicable to large-scale fish culture (Piferrer et al. 1994). Although a few studies have examined the performance of androgen-sterilized salmonids released into natural environments, little is known about their reproductive behavior. Catch rates were much lower for androgen-sterilized kokanee *Oncorhynchus nerka* and coho salmon *O. kisutch* than for control groups sampled with gill nets 1–3 years after release into several lakes (Parkinson and Tsumura 1988). The hormone treatment increased longevity of kokanee but did not affect growth of kokanee or coho salmon. Hormone treatment did not affect survival or migration timing of coho smolts through outlet streams after the fish were released as fingerlings into two small British

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Columbia lakes (Bams 1990). However, the treatment did reduce growth. Fewer androgen-sterilized coho salmon than control fish were recovered in ocean fisheries and at the hatchery for two brood years released from Capilano Hatchery, British Columbia (Solar et al. 1986; Baker et al. 1989). The hormone increased longevity, but reduced growth of adults compared with control fish of the same age.

We evaluated the use of 17α-methyltestosterone to sterilize hatchery steelhead *O. mykiss* in Oregon as a way of reducing interactions between wild and hatchery fish on spawning grounds. Under Oregon's Wild Fish Management Policy (ODFW 1992), hatchery programs are being changed to reduce genetic risks to wild populations. The objective of our study was to determine if sterilized hatchery steelhead would return at frequencies high enough to provide recreational fisheries while providing managers a tool for reducing interactions with wild fish. Although sterilized coho salmon, chinook salmon *O. tshawytscha,* chum salmon *O. keta,* and kokanee have been released in the Pacific Northwest (Donaldson 1986), to our knowledge, sterilized steelhead have not.

## Methods

The study was conducted in the South Santiam River, Oregon, which joins the North Santiam River 19 km above the confluence with the Willamette River at river kilometer 174. South Santiam Hatchery, located at the base of Foster Dam (river kilometer 60), releases 160,000 Skamania stock summer steelhead annually into the South Santiam River. Returning adult steelhead are caught in a recreational fishery below the dam or enter a trap at the base of Foster Dam. The South Santiam River was chosen as an experimental site because no wild summer steelhead are thought to be produced in the system. A small run of wild winter steelhead is transported above the dam to spawn, and most of the larger tributaries below the dam have small runs of winter steelhead. In addition to summer steelhead, spring chinook salmon are also released from South Santiam Hatchery.

Adult summer steelhead return to the South Santiam River mainly from April through September. Adults held for broodstock at South Santiam Hatchery are taken throughout the run. The fish are spawned in January and February. Eyed eggs are transported 274 km to Oak Springs Hatchery on the Deschutes River in March because incubation space is limited at South Santiam Hatchery. The fish are transported back to South Santiam Hatchery in summer for rearing until they are released the following spring.

*Treatment of juveniles.*—We followed procedures developed for rainbow trout (Solar and Donaldson 1985) to sterilize groups of South Santiam steelhead at Oak Springs Hatchery for three brood years (1989–1991). Solar and Donaldson (1985) sterilized rainbow trout by immersing alevins in a solution of 17α-methyltestosterone followed by oral administration of the androgen to fry. Immersion at the alevin stage and dietary administration beginning at first feeding are generally required to obtain a high percentage of sterility in salmonids (Donaldson et al. 1993).

Summer steelhead alevins were treated with 17α-methyltestosterone within 3 d of hatching. Three screened incubation baskets, each containing 10,000 fish, were immersed into separate polyvinyl chloride tubs with 40 L of a 400 μg/L water solution of the androgen. The hormone was dissolved in 5 mL of ethanol and added to each tub just before treatment. Baskets were immersed for 2 h. An oxygen tank and air stone circulated and oxygenated the water. The treatment was repeated 7 d later. Control groups were handled in the same manner, except that the 5-mL solution of hormone and ethanol was not added to the tubs.

Fry were transferred to 1.8-m-diameter circular ponds shortly after they began feeding in April. Treatment groups were then switched to a homogenized mixture of 17α-methyltestosterone and commercial fish feed (Biodiet Grower, Bioproducts Inc., Warrenton, Oregon) at a concentration of 25 mg/kg of feed. The hormone was initially dissolved in herring oil and then mixed with the feed at the factory before being extruded at appropriate sizes for growing fish. The fry were fed treated feed for 90 d at normal hatchery rates and then switched to untreated feed. Control fish were fed untreated feed.

We excised fins and maxillary bones in mid-July at Oak Springs Hatchery to identify treatment and control groups. We used the same clips, but from opposite sides of the fish to differentiate the two groups (Table 1). This eliminated marking as a factor in relative return frequencies of treatment and control groups, assuming there was no survival differential between right and left sides of the fish. Fish were transported back to South Santiam Hatchery in August and reared by standard hatchery practices in a single raceway until they were released at a customary site 8 km below the hatchery in early April (Table 1). We measured fork lengths of samples from treatment and control

TABLE 1.—Treatment and control groups of summer steelhead released into the South Santiam River, 1990–1992. Clip abbreviations are as follows: RP = right pectoral, LP = left pectoral, RV = right ventral, LV = left ventral, RM = right maxillary, LM = left maxillary, AD = adipose.

| Group and clip | Number released | Mean (SE) fork length (cm) | |
|---|---|---|---|
| | | Fall, prior to release | Spring, at release |
| **1990 release** | | | |
| Treatment | | | |
| RP | 6,400 | 14.5 (0.3) | 18.7 (0.3) |
| RM | 8,300 | 13.7 (0.3) | 18.7 (0.2) |
| RVRM | 3,200 | 14.7 (0.3) | 18.8 (0.3) |
| Control | | | |
| LP | 7,800 | 16.1 (0.2) | 19.9 (0.2) |
| LM | 6,000 | 15.1 (0.4) | 20.2 (0.2) |
| RVLM | 3,100 | 15.6 (0.4) | 20.3 (0.4) |
| **1991 release** | | | |
| Treatment | | | |
| ADLP | 8,300 | 12.9 (0.2) | 19.3 (0.2) |
| ADLM | 9,600 | 13.8 (0.3) | 18.9 (0.3) |
| ADRVLM | 10,000 | 13.4 (0.2) | 18.7 (0.3) |
| Control | | | |
| ADRP | 10,000 | 14.2 (0.2) | 20.6 (0.3) |
| ADRM | 12,000 | 13.9 (0.2) | 20.3 (0.3) |
| ADRVRM | 9,400 | 14.6 (0.2) | 19.8 (0.3) |
| **1992 release** | | | |
| Treatment | | | |
| RP | 11,500 | 13.8 (0.3) | 19.6 (0.3) |
| RM | 10,800 | 13.8 (0.3) | 18.8 (0.3) |
| RVRM | 10,400 | 13.6 (0.2) | 20.2 (0.2) |
| Control | | | |
| LP | 9,600 | 15.6 (0.3) | 21.7 (0.2) |
| LM | 10,500 | 15.3 (0.2) | 21.4 (0.2) |
| RVLM | 11,600 | 15.7 (0.2) | 21.2 (0.2) |

groups in October for the 1990 brood and in November for the 1989 and 1991 broods. Each group was measured again in spring just before release. We used a two-way analysis of variance (ANOVA), with marked groups as paired replicates, to test for differences in mean length between treatment and control groups among the three brood years. Treatment juveniles were not histologically examined for sterility; however, Solar and Donaldson (1985) found that rainbow trout were 100% sterile immediately following the same treatment.

*Returning adults.*—Returning adults were trapped in the fish ladder at the base of Foster Dam, the uppermost limit of summer steelhead migration. We used a two-way ANOVA, with marked groups as paired replicates, to test for differences in return frequencies and age composition between treatment and control groups among the three brood years. We applied an arcsine square-root transformation to the proportional data before analysis.

Treatment groups were smaller than control groups when they were released in spring. To understand how small size differentially affected adult returns compared with control fish, we estimated the expected reduction in return frequencies due to size. We accomplished this by using differential return frequencies for small and medium-sized smolts estimated for summer steelhead in the South Santiam River (Wade and Buchanan 1983). Wade and Buchanan (1983) found that the return of small (<18 cm) and medium-sized smolts (18 cm to <20 cm) was 10% and 50%, respectively, that of large smolts (≥20 cm). We used length frequencies of treatment and control groups to partition annual smolt releases of each group into small, medium, and large smolts. From the return differentials above, we derived an equation to estimate the return frequency of large smolts ($x$) from control groups for brood year $i$ by inserting observed values for $a$, $b$, $c$, and $d$, and solving for $x$:

$$0.1x_ia_i + 0.5x_ib_i + x_ic_i = d_i ;$$

$a$ = number of small smolts released, $b$ = number of medium smolts released, $c$ = number of large smolts released, and $d$ = number of adults that returned.

We calculated the return frequencies of small and medium smolts by multiplying $x$ by 0.1 and 0.5, respectively. These return frequencies were then multiplied by the number of small, medium, and large smolts in treatment groups, and the resulting numbers of adults were summed. After adjusting for differences in numbers of smolts released, we estimated the reduction in adult return of treatment groups relative to control groups, had size been the only factor affecting return frequencies.

Adults returning in 1992 and 1993 were measured (fork length) and examined internally for sexual development at the time spawning occurred at the hatchery. We weighed testes, if present, from all treated males and from a sample of control males. The presence of secondary sexual characteristics was also noted. A two-way ANOVA pooled across marked groups was used to test for differences in mean fork lengths and testes weights between treatment and control groups among age-classes returning each year.

Fertility of treatment fish that returned in 1992 and 1993 and could be hand-spawned—the normal hatchery practice—was compared with that of control fish. Treated fish and a like number of controls were each crossed with the same three control fish.

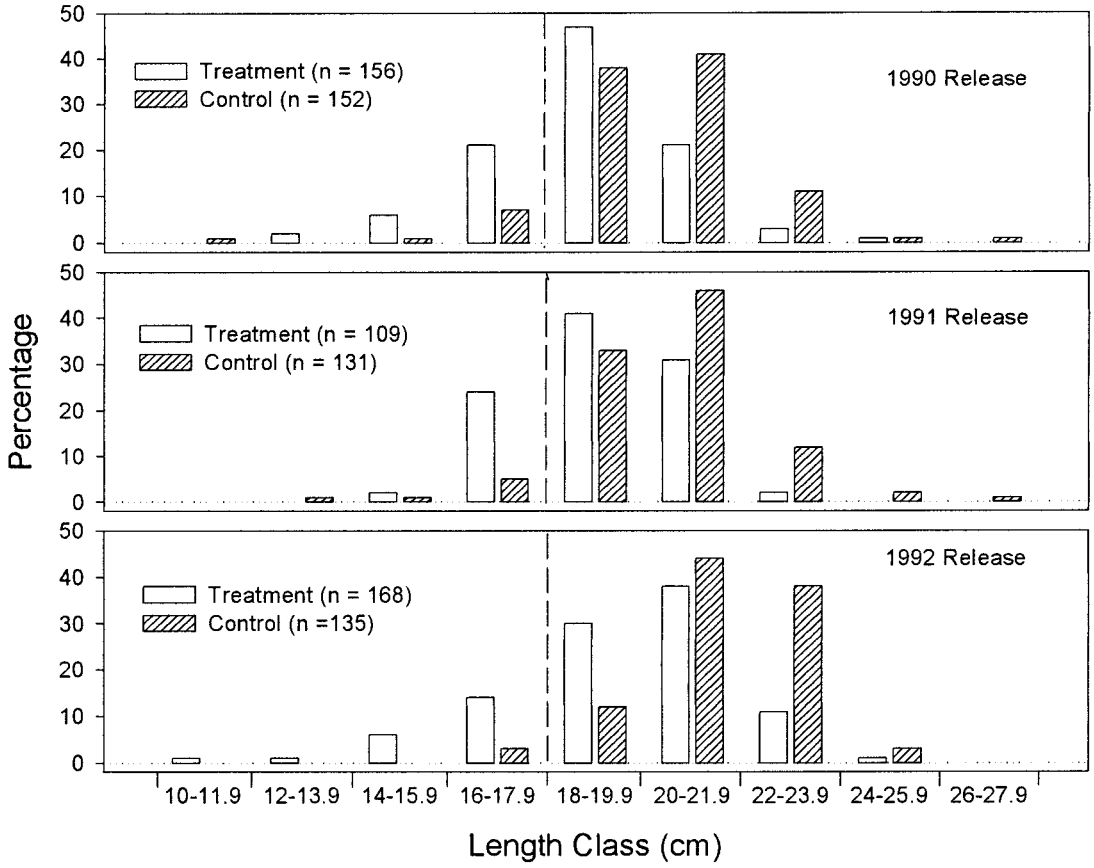


FIGURE 1.—Length frequencies of treatment and control groups of summer steelhead released into South Santiam River, 1990–1992. The vertical dashed line divides the histogram into fish less than 18 cm and 18 cm or longer.

About 300–500 eggs were used in each cross. Survival was estimated to the eyed egg stage. A paired *t*-test was used to compare survival between treatment and control fish. Data were pooled across years because the number of fish that could be hand-spawned in each year was small. We applied an arcsine square root transformation to the data before analysis.

## Results

### *Juvenile Size and Adult Return*

The mean length of treatment groups at the time they were released was consistently smaller ($P < 0.01$) than that of control groups (Table 1). The size of smolts released varied significantly ($P < 0.01$) among years, fish in 1992 being larger than those released in 1990 and 1991. For the 3 years combined, 26% of treated smolts and 6% of control smolts released were small (<18 cm; Figure 1). Medium-sized smolts (≥18 to <20 cm) composed 65% of treated releases and 34% of control releases (Figure 1). Lengths of treated fish measured the previous fall were also significantly smaller ($P < 0.01$) than controls (Table 1) in all years, indicating a divergence in growth early in the rearing cycle.

Mean smolt-to-adult return frequencies for the three brood years combined was 2.2% for control groups and 0.5% for treatment groups, a fourfold difference in returns (Table 2). Return frequencies of treatment groups were consistently less ($P < 0.01$) than for control groups by 75% for the 1989 brood, 72% for 1990, and 80% for 1991. We also found significant differences among years ($P = 0.01$) and among replicate mark groups ($P = 0.03$). Return frequencies of groups marked with a combination ventral fin and maxillary bone clip were significantly lower ($P = 0.01$) than groups marked with only a maxillary bone clip but were not significantly different from groups marked with a pec-

TABLE 2.—Adult returns of treatment and control groups of summer steelhead to South Santiam Hatchery. Clip abbreviations are given in Table 1. ''Ocean'' refers to summers spent in the ocean.

| Group and clip | Number | | Percentage | | |
|---|---|---|---|---|---|
| | 2 ocean | 3 ocean | 2 ocean | 3 ocean | Total |
| **Returns from 1990 releases**[a] | | | | | |
| Treatment | | | | | |
| RP | 12 | 31 | 0.19 | 0.48 | 0.67 |
| RM | 31 | 47 | 0.37 | 0.57 | 0.94 |
| RVRM | 12 | 9 | 0.38 | 0.28 | 0.66 |
| Control | | | | | |
| LP | 143 | 60 | 1.83 | 0.77 | 2.60 |
| LM | 208 | 82 | 3.47 | 1.37 | 4.83 |
| RVLM | 45 | 8 | 1.45 | 0.26 | 1.71 |
| **Returns from 1991 releases** | | | | | |
| Treatment | | | | | |
| ADLP | 18 | 26 | 0.22 | 0.31 | 0.53 |
| ADLM | 27 | 35 | 0.28 | 0.36 | 0.64 |
| ADRVLM | 4 | 20 | 0.04 | 0.20 | 0.24 |
| Control | | | | | |
| ADRP | 118 | 58 | 1.18 | 0.58 | 1.76 |
| ADRM | 164 | 69 | 1.37 | 0.58 | 1.95 |
| ADRVRM | 55 | 58 | 0.59 | 0.62 | 1.21 |
| **Returns from 1992 releases** | | | | | |
| Treatment | | | | | |
| RP | 29 | 15 | 0.25 | 0.13 | 0.38 |
| RM | 23 | 9 | 0.21 | 0.08 | 0.29 |
| RVRM | 29 | 12 | 0.28 | 0.12 | 0.40 |
| Control | | | | | |
| LP | 178 | 21 | 1.85 | 0.22 | 2.07 |
| LM | 195 | 16 | 1.86 | 0.15 | 2.01 |
| RVLM | 127 | 18 | 1.09 | 0.16 | 1.25 |

[a] Four treatment and three control fish returned as 4-ocean adults (not included in return).

toral fin clip. However, the use of opposing clips to differentiate treatment and control groups (Table 1) eliminated marking as a factor in relative return frequencies between the two groups.

The low return of treatment groups could partially be attributed to their small size at release. Small size alone would have reduced return frequencies of treatment groups by 31, 27, and 29% for 1989–1991 broods. The observed reduction in return was 75, 72, and 80% for the same years, respectively. The difference between the observed reduction in return and the estimated reduction due to small size indicates the hormone treatment reduced return frequencies beyond its effect on the size of fish at release.

Fish from treatment groups remained longer in the ocean before returning to freshwater. Adults that spent three summers in the ocean (''3-ocean'') composed 61, 63, and 30% of treatment returns for 1989–1991 broods, respectively, significantly higher ($P < 0.01$) than the 27, 36, and 10% returns of control groups. Most of the remaining returns were 2-ocean. Very few fish from either group that returned to the hatchery had spent more than three summers in the ocean. Age composition differed significantly ($P < 0.01$) among years but not among mark groups ($P = 0.71$).

TABLE 3.—The percentage of adult males in treatment and control groups of summer steelhead that returned to South Santiam Hatchery. ''Ocean'' refers to summers spent in the ocean.

| Release year | Treatment | | Control | |
|---|---|---|---|---|
| | 2 ocean | 3 ocean | 2 ocean | 3 ocean |
| 1990 | 84 | 85 | 46 | 61 |
| 1991 | 57 | 77 | 42 | 59 |
| 1992 | 84 | 94 | 45 | 80 |

*Maturation*

Only one sterile adult steelhead returned from three brood years of treatment releases. Gonads were absent in this fish at the end of spawning in February. Remaining adults from treatment groups averaged 80% male and 20% female. The mean for control groups was 49% male and 51% female. Males predominated in 2-ocean and 3-ocean returns of treatment groups and 3-ocean returns of control groups (Table 3). The proportion of males in treatment groups was consistently higher than that in control groups for all brood years and ocean ages (Table 3).

Externally, treated males appeared similar to control males in the development of secondary sexual characteristics. However, during the normal period of spawning at the hatchery, only a few of the treated males, but most of the control males, could be spawned by hand. Milt was extruded from three of 36 treated males returning in 1992 and nine of 30 treated males returning in 1993.

Upon internal examination, all treated males appeared to have mature, but misshapen testes (Figure 2). Sperm ducts were probably underdeveloped or occluded, based on our inability to hand-strip milt from most of the fish. Testes of 2-ocean and 3-ocean treated males weighed significantly less ($P = 0.02$) than those of controls of the same age (Table 4). However, mean fork length of treated males was not significantly different ($P = 0.22$) from controls of the same age (Table 4).

Of the 43 treated females that returned in 1992 and 1993, only one ripened by the end of spawning in mid-February. This female was hand-spawned with control males to estimate fertility. About 90% of the hatchery females at South Santiam Hatchery normally ripen by the end of spawning (V. T.

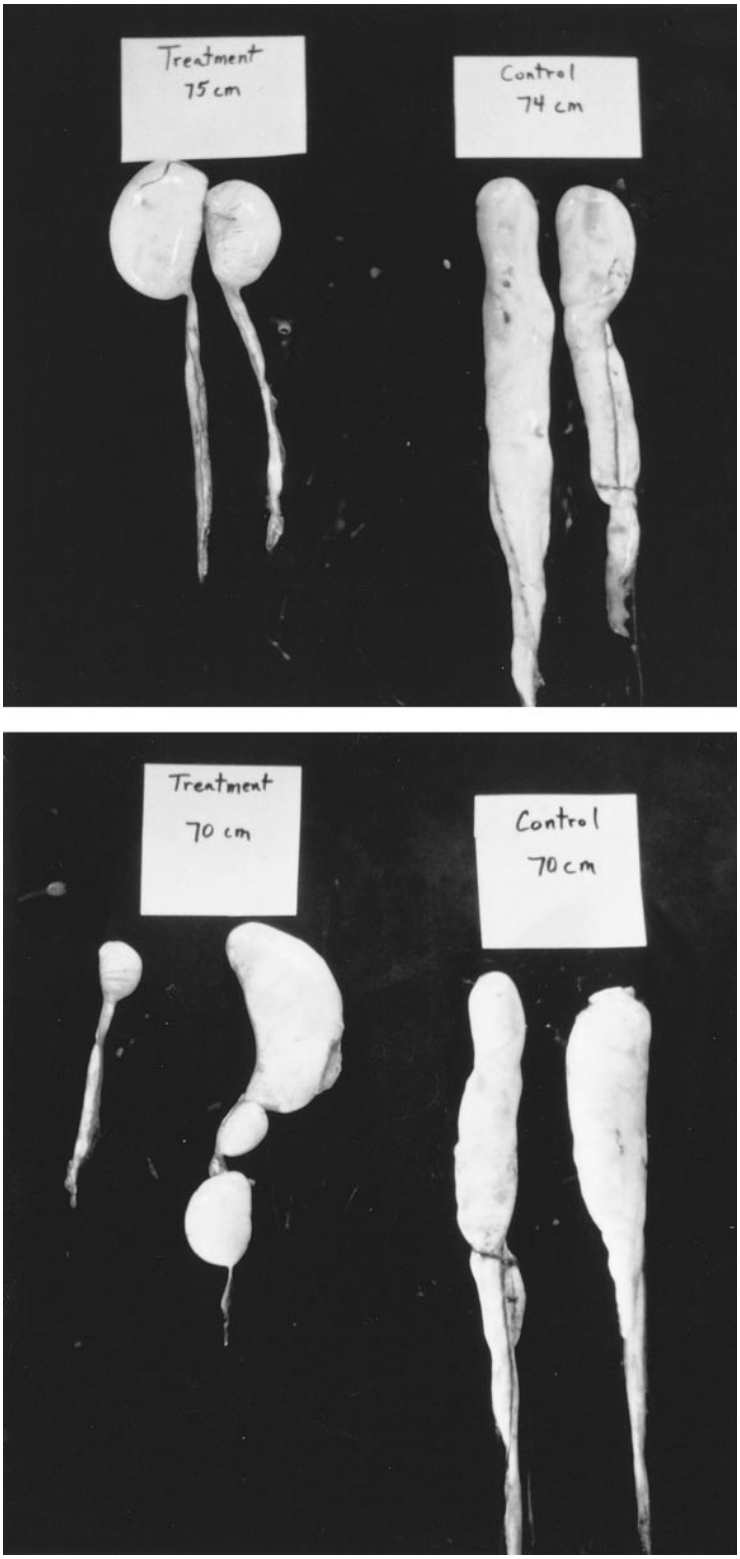


FIGURE 2.—Typical testes removed from treatment and control summer steelhead at time of spawning at South Santiam Hatchery, 1993.

TABLE 4.—Mean (SE) fork length and gonad weight of treatment and control groups of adult male summer steelhead, South Santiam River, 1992 and 1993 return years. ''Ocean'' refers to summers spent in the ocean.

| Ocean age and variable | 1992 | | 1993 | |
|---|---|---|---|---|
| | Treatment | Control | Treatment | Control |
| Two ocean | | | | |
| Fork length (cm) | 70.5 (0.5) | 69.2 (0.5) | 71.0 (1.0) | 69.6 (0.9) |
| Gonad weight (g) | 50.1 (2.8) | 55.4 (2.6) | 59.6 (3.0) | 62.3 (3.5) |
| *N* | 36 | 39 | 10 | 22 |
| Three ocean | | | | |
| Fork length (cm) | | | 81.0 (0.8) | 81.7 (1.3) |
| Gonad weight (g) | | | 72.5 (3.9) | 86.0 (5.1) |
| *N* | | | 20 | 14 |

Shawe, Oregon Department of Fish and Wildlife, personal communication).

*Fertility*

The 12 treated males that could be hand-spawned and 12 control males were crossed with 36 control females. The only treated female that ripened and a control female were crossed with three control males. Mean survival of eggs from crosses of treatment and control males with control females was 87% and 89%, respectively. The difference was not significant ($P = 0.71$). The only treatment female that could be spawned was also fertile, although egg survival was lower (72%) than that of the control female (92%).

## Discussion

Of the treated fish that returned to South Santiam Hatchery, only one appeared truly sterile (i.e., without any evidence of gonadal tissue at the time spawning ended at the hatchery). All other treated fish contained developed gonads, although testes of treatment males were misshapen. Summer steelhead were treated with 17α-methyltestosterone by methods developed to produce sterility in rainbow trout (Solar and Donaldson 1985). Their methods produced 100% sterility when rainbow trout were examined shortly after cessation of the treatment. These procedures were apparently not adequate to completely sterilize steelhead; however, steelhead that were sterile probably lacked the proclivity to return to the South Santiam River and may have remained in the ocean. Hormone-sterilized hatchery coho salmon tended to remain in coastal areas instead of returning to the hatchery (Solar et al. 1986; Baker et al. 1989). Treated coho salmon that did return to the hatchery were mature (Parkinson and Tsumura 1988) similar to our steelhead observations.

Sterility may have been incomplete in our study because of an inadequate dosage of methyltestosterone during oral administration of the hormone. We dissolved methyltestosterone in herring oil at the factory before the feed was extruded at appropriate sizes for fish; the treated fry were fed this treated feed for 90 d. Although herring oil is a component of normal hatchery feed, Johnstone et al. (1978) suspected that steroids degrade as a result of coupled oxidation in the presence of dietary oils. Consequently, they incorporated the hormone into defatted portions of feed (Johnstone et al. 1978). In our study, the use of herring oil as a carrier may have degraded the hormone before feeding and reduced the amount of active steroid ingested during the treatment period.

Treated steelhead in the South Santiam River returned at frequencies ranging from 20% to 28% that of control groups for the three brood years. The treatment either produced sterility in most fish and they remained in the ocean or survival of treatment groups was less than controls.

Because steelhead are rarely caught in ocean fisheries, we could not determine the relative proportions of treated steelhead that remained in the ocean. Of the total returns for two hatchery brood years of sterilized coho salmon, a mean of 93% were caught in ocean fisheries versus 77% for the control salmon (Solar et al. 1986; Baker et al. 1989); 7% and 23% respectively, returned to the hatchery. These data indicate that most of the treated coho salmon were sterile and remained in the ocean until they were harvested or died of natural causes (Donaldson et al. 1993).

Treatment groups of summer steelhead were consistently smaller than control groups at the time they were released as smolts. Small steelhead smolts generally have lower survival to adult than large steelhead smolts (Hallock et al. 1961; Wagner et al. 1963). Based on the relationship between smolt size and adult return frequencies of summer steelhead from earlier studies in the South Santiam River, small size alone would have reduced return

frequencies of treatment groups by a mean of 29%. This would account for 38% of the reduction in return frequencies between treatment and control groups. The hormone either retarded growth directly or the fry did not ingest treated feed as readily as untreated feed. Although, low concentrations of methyltestosterone have been used to increase growth (Fagerlund et al. 1979), high concentrations needed to produce sterility have generally reduced growth (Baker et al. 1989; Bams 1990).

We found no difference in length between treatment and control steelhead of the same age when adults returned to South Santiam Hatchery. The low survival of small steelhead smolts may have equalized sizes by the time both groups returned as adults.

The proportion of 3-ocean adult steelhead in returns of treatment groups was consistently higher than in control groups, although annual variation was high in both groups. Older age at return would reduce survival by subjecting the fish to an additional year of mortality in the ocean. Hormone exposure inadequate to cause sterility may have retarded maturation, thereby increasing the age that treatment adults returned. The smaller gonad size of treated males compared with controls suggests gonad development was inhibited by the hormone. Treating fish with steroids at early stages of development may result in partial sterility or transitory changes in gonads (Goetz et al. 1979). In addition, other studies have shown that small release size can result in older-aged returns of Atlantic salmon *Salmo salar* and sockeye salmon *O. nerka*, although no such relationship was evident in steelhead (Ward and Slaney 1988).

Males composed a mean of 80% of the brood year returns of treatment groups and 49% of control group returns. Either more females than males were sterile and did not return, females did not survive the treatment, or methyltestosterone converted genotypic females to phenotypic males. Differential rates of sterility or mortality of treatment females would have reduced return frequencies by 38%, assuming the sex ratio was the same as that observed in control groups when they returned as adults (i.e., 49% males, 51% females). This would account for 50% of the reduction in mean return frequencies observed in treatment groups. We were unable to determine if the treatment converted females to males because we did not internally examine smolts when they were released and did not evaluate males through test crosses or inspection of chromosomes when they returned. Masculinization of genotypic females through hormonal treatments can produce spermatozoa that would yield mostly female offspring (Donaldson 1986). Several studies have demonstrated sex inversion of genotypic females to phenotypic males at low dosages of methyltestosterone (Johnstone et al. 1978; Donaldson and Hunter 1982; Donaldson 1986; Feist et al. 1995).

Milt could not be hand-stripped from 81% of treatment males, though all had developed, but misshapen, testes. Our inability to hand-spawn most treatment males suggested sperm ducts were occluded. From a group of rainbow trout treated with methyltestosterone, milt could be expressed from only 16% of males that were selected based on spawning coloration (Donaldson and Hunter 1982). Most of the remainder contained mature testes but occluded sperm ducts. In our study, treatment males that could be hand-stripped were fertile based on successful crosses with control females. Although treated males would probably exhibit spawning behaviors, occluded sperm ducts would prevent most from spawning naturally.

Most treatment females did not mature by the time spawning ended at the hatchery. Ovaries appeared normal in size and shape, but eggs were still firmly attached to ovarian membranes at the end of spawning. The hormone treatment apparently delayed maturation of females that returned, but we did not hold them beyond the end of spawning to determine if they would eventually ripen.

The return of treatment groups of hatchery summer steelhead to the South Santiam River was too low to provide for recreational fisheries. In addition, most of the returning fish were males that developed secondary sexual characteristics and were not sterile. In some cases the older age at return, hence increased size, may provide managers with an option for diversifying fisheries by providing large-sized steelhead. However, development of gonads and secondary sexual characteristics indicate returning males would probably be sexually active. Incompletely sterilized males would probably compete with fertile males on spawning grounds, but occluded sperm ducts would prevent most treatment males from spawning successfully. Consequently, treating hatchery steelhead with methyltestosterone by methods we employed for release into natural environments should only be used where there is little chance of interaction with wild stocks.

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