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Title: Ecology and Decline of a Rare Western Minnow: the Oregon Chub (Oregonichthys crameri)

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Once historically widespread thoughout the Willamette and Umpqua River drainages, the Willamette Oregon chub is now restricted to scattered populations along 15 miles of the Middle Fork of the Willamette River whereas the Umpqua Oregon chub is still widely distributed. The decline in the Willamette drainage was more severe because changes in the physical and biological habitat were more severe when compared to the Umpqua drainage. The Willamette Oregon chub may be more sensitive to environmental degradations than the Umpqua Oregon chub. The difference in sensitivity to degradation is a result of ecological differences between Willamette and Umpqua Oregon chub. Willamette Oregon chub inhabited areas with primarily very little if any current, fed in the water column, and spawned in aquatic vegetation. Umpqua Oregon chub inhabited areas with primarily slow water velocities, fed on benthic prey, and spawned over gravel

substrate. Because Willamette Oregon chub inhabit slackwater habitats they may be more sensitive to water velocity increases and exotic species, whereas Umpqua Oregon chub have a habitat refuge in relatively faster water velocity habitats.

Willamette Oregon chub larval stages are described and illustrated. The following combination of characters distinguish Willamette Oregon chub larvae from other cyprinid larvae found in the Willamette drainage: 33-37 myomeres, preanal length of 52-61%, and absence of snout pigment. Willamette Oregon chub larvae generally congregated in nearshore areas, in the upper layers of the water column, in shallow water. They fed primarily in the water column, and ate primarily rotifers and cladocerans.

Ecology and Decline of a Rare Western Minnow: the Oregon Chub (Oregonichthys crameri)

by

Todd N. Pearsons

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Ecology and Decline of a Rare Western Minnow: the Oregon Chub (*Oregonichthys crameri*)

GENERAL INTRODUCTION

The Oregon chub (*Oregonichthys crameri*, Snyder) is found in only the Willamette and Umpqua River drainages of western Oregon (Bond 1966, 1974; Long, 1980), and appears to be quite rare (Long and Bond, unpublished data). Long and Bond (unpublished data) found that only 19% of the known Oregon chub historical locations had Oregon chub populations in 1983. A distributional survey was needed to determine the status of Oregon chub in the two drainages.

Since little was known about the biology (Long, 1980) and development of the Oregon chub in the two drainages, a study was designed to characterize the life history of the species. The goals were to determine age structure, reproductive biology, and food and habitat requirements across life history stages, so reasons for the decline of the Oregon chub could be proposed. Before studying larval feeding behavior, diet, and habitat it was first necessary to know how to identify them. Consequently, a further goal was to describe and illustrate the larvae and provide methods to distinguish Oregon chub larvae from other larvae in the two drainages. It was hoped that the information gathered would enable managers to stop the decline of the Oregon chub and to repopulate areas that historically contained Oregon chub. During the study a minimum number of individuals were sacrificed so existing populations of Oregon chub would not be harmed.

Ecology and Decline of a Rare Western Minnow: the Oregon Chub (Oregonichthys crameri)

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ABSTRACT

Once historically widespread thoughout the Willamette and Umpqua River drainages, the Willamette Oregon chub is now restricted to scattered populations along 15 miles of the Middle Fork of the Willamette River whereas the Umpqua Oregon chub is still widely distributed. The decline in the Willamette drainage was more severe because changes in the physical and biological habitat were more severe when compared to the Umpqua drainage. The Willamette Oregon chub may be more sensitive to environmental degradation than the Umpqua Oregon chub. The difference in sensitivity to degradation is a result of ecological differences between Willamette and Umpqua Oregon chub. Willamette Oregon chub inhabited areas with primarily very little if any current, fed in the water column, and spawned in aquatic vegetation. Umpqua Oregon chub inhabited areas with primarily slow water velocities, fed on benthic prey, and spawned over gravel substrate. Because Willamette Oregon chub inhabit slackwater habitats they may be more sensitive to water velocity increases and exotic fish species, whereas Umpqua Oregon chub have a habitat refuge in relatively faster water velocity habitats.

INTRODUCTION

The Oregon chub (Fig. 1) was described in 1908 by J. O. Snyder (Snyder, 1908) who placed it in Hybopsis, an eastern cyprinid genus. It is currently treated as a monotypic genus, Oregonichthys by Mayden (1988). The Oregon chub is only found in the Willamette and Umpqua river drainages of western Oregon (Bond, 1966, 1974; Long, 1980). Habitat differences between Oregon chub from each drainage have been noted (Bond, 1966, 1974; Long, 1980). Long and Bond (upublished data), sampled all known (n=26) historical locations of Oregon chub, found that only 19% had populations in 1983, and suggested that the decline of the Willamette Oregon chub was largely a result of "habitat loss and alteration".

Very little is known about the biology of this species (Long, 1980). By examining brain and gustatory structures Davis and Miller (1967) suggested that the Oregon chub must be considered "an obligatory sight feeder." Long (1980), stated that field observations supported Davis and Miller's hypothesis and Long and Bond (unpublished data) stated that feeding appeared to be "opportunistic and varied including aquatic insects, plant material, and organic debris." Long and Bond, (unpublished data) reported that sexually mature Oregon chub were greater than 35-40 mm TL and Long, (1980) suggested that the Oregon chub "appears to spawn in early spring in still water."

The objectives of this study were to 1) characterize the life history of the species in the Willamette and Umpqua drainages, 2) determine the present status and the reasons for the decline of the species in the two drainages, and 3) provide information necessary for recovery of the species.

METHODS

A detailed description of the habitat of the two known permanent Willamette Oregon chub populations was conducted from May 1986 to September 1987 at Shady Dell Pond and Buckhead Creek Slough (Fig. 2). Visual estimates of substrate compostition were based on a modified Wentworth scale (Hynes, 1970). Substrate was classed on a percent basis as silt, small detritus (<1 cm), large detritus (>1 cm), sand, gravel, small cobble (5-10 cm), large cobble (10-20 cm), small boulder (20-40 cm), or large boulder (>40 cm). Thermographs were used to obtain water temperature data. Dissolved oxygen and pH were measured using a Hach kit and a pH meter. Water samples were taken on July 30, 1986 and January 9, 1987 and were analyzed by Water Analysis and Consulting, Inc. Taxa lists were made of the fish, amphibians, aquatic invertebrates, and aquatic vegetation present at the two sites. Small numbers of potential predators (bullfrog _Rana catesbeiana_, garter snake _Thamnophis sp_., cutthroat trout _Oncorhynchus clarki_, and prickly sculpin _Cottus asper_) of the Willamette Oregon chub were captured, dissected or stomach flushed (Legler, 1977; Robertson, 1945) in the field, fixed in 10% formalin and analyzed in the laboratory.

The daily and seasonal activity patterns of different size classes of Willamette Oregon chub were recorded using underwater and above water observation techniques. Sizes were estimated _in situ_ by placing rulers on the substrate below fish and occasionally verified with captured fish.

The microhabitat of Willamette Oregon chub larvae in Shady Dell Pond was described in terms of distance to shore, water depth, and distance below the water surface. Because larvae were often in groups, measurements were frequently made on individuals in the center of the group and then applied to describe the microhabitat of the number of individuals in the group.

During the summer of 1986, Shady Dell Pond lost water at an alarming rate. By the beginning of August there was an estimated 6 days of water remaining in the pond. The low water conditions prompted the Willamette National Forest to pump water from the Middle Fork of the Willamette River into Shady Dell Pond. Following weekly pumpings, a gravity line without a fish screen was placed in Dell Creek to maintain adequate water levels in Shady Dell Pond. Changes noted after pumping are pointed out below.

Habitat, swimming performance, and length frequency were calculated for Umpqua Oregon chub from May 29, 1986 to August 30, 1987 in Elk Creek near the town of Elkton. Water temperature and pH were taken on various days throughout the year. Visual estimation of substrate composition was based on a modified Wentworth scale (Hynes, 1970). Qualitative observations of habitat changes through the year were recorded.

The swimming performance of ten Umpqua Oregon chub from Elk Creek was compared to five Elk Creek redside shiners (Richardsonius balteatus) to determine if there might be a physiological correlation with the Oregon chub's slow water habitat (Beamish, 1978). Both species were kept in aquaria for a minimum of three months so that recent prior exercise would not be a factor during the tests. Fish were placed in a modified Blazka respirometer (Barton, 1987), allowed to equilibrate, and forced to swim at a slow speed (approximately 2 cm/s) for 15 minutes. After 15 minutes the water velocity was increased by 5 tranformer units every 5 minutes (corresponding to water velocities at each transformer setting of 9, 22, 31, 39, 46, 51, 55, and 60 cm/s). When a fish was totally fatigued, (specimen unable to swim off the rear area of the swim tube) the time at a particular setting, and the total length of the fish were recorded.

As has been noted by (Carlander, 1969) and others, scales can be difficult if not impossible structures to use in aging cyprinids. Many of the scales on the Oregon chub are regenerated and aging is difficult. Length frequency analysis was therefore chosen as the aging method. On August 24, 1987, 339 Umpqua Oregon chub were captured and measured to the nearest mm total length (TL) and their modal lengths used to estimate year class groups.

reproduction

The spawning behavior of the Oregon chub was observed in the field and in the lab. Field observations of spawning behavior were conducted above the water, and under the water from June 1986 through July 1986, and from April 1987 through July 1987 at Shady Dell pond, and in August 1987 at "the Pit" (Fig 2). On June 13, 1986 and June 3, 1987 qualitative observations of spawning frequency throughout the day and night were recorded at Shady Dell pond. Spawning activity of Umpqua Oregon chub was never seen in the field.

To observe spawning behavior of Oregon chub under controlled conditions, Willamette and Umpqua Oregon chubs were collected in the summer of 1986 and the spring of 1987 and placed in 20 gallon aquaria. Aquaria containing Willamette and Umpqua Oregon chubs were similar, having similar amounts of gravel, cobble, and aquatic vegetation. The water temperature (Bullough, 1939) and the photoperiod (Harrington, 1957) were increased gradually simulating the transition from winter to spring in order to induce spawning. Oregon chub were also soaked in a solution of luteinizing hormone - releasing hormone ethylamide (LH-RHa) to induce spawning (Sherwood and Harvey, 1986). Oregon chub were videotaped in the field and in the lab for comparative behavioral analysis, and slow motion observations.

Material for fecundity estimates and ovarian egg size was obtained from museum specimens and recent field collections. Seventeen Willamette Oregon chub were found to contain visible eggs while only 2 Umpqua Oregon chub had visible eggs. Fecundity estimates were made by counting yolked eggs larger than 0.50 mm. Each fish that contained visible eggs was measured (TL) and twenty diameters of yolk laden eggs were measured using an ocular micrometer.

feeding

In situ feeding behavior of Willamette Oregon chub was observed at Shady Dell pond during the springs and summers of 1986 and 1987. *In situ* feeding behavior was observed in summer of 1987 throughout the Willamette and Umpqua river drainages and qualitatively compared to the Shady Dell population. Aquarium observations of feeding behavior of Willamette Oregon chub and Umpqua Oregon chub were recorded when fed a floating food.

Specimens for dietary analysis were taken from Shady Dell Pond, Calapooya Creek, Elk Creek, and the OSU museum. Willamette Oregon chub collected at Shady Dell Pond and Umpqua Oregon chub collected at Calapooya Creek were used in quantitative analysis, whereas Oregon chub from other sites were used in qualitative analysis. Twenty juvenile to adult Willamette Oregon chub (27-58 mm) were collected on May 20, 1987 at 1430 at Shady Dell pond. Willamette Oregon chub larvae were collected throughout the spring and summer of 1986 and 1987. Twenty juvenile to adult Umpqua Oregon chub (38-49 mm) were collected on June 6, 1987 at 1200 at Calapooya Creek. All juvenile to adult specimens were immediately fixed in 10% formalin and later transferred to 45% isopropanol. Larval specimens were fixed in 5% buffered formalin.

Intestines from juveniles and adults were removed and measured to the nearest mm. The anterior section of the intestine (up to the first bend) was removed from the posterior section and analyzed separately (Hellawell, 1971). Separate analysis of the anterior section of the intestine should reduce the effect of differential digestion. Intestine contents were quantified by means of the frequency of occurrence, and percentage composition by number methods (Windell and Bowen 1978; Berg, 1979; Hyslop, 1980; Bowen, 1983). Prey items were identified to the lowest practical taxon. The shortest and longest prey items from the anterior section of the intestine were measured using an ocular micrometer. The above techniques were used for larval Willamette Oregon chub except that the whole intestine was analyzed at once. Museum and Elk Creek specimens were qualitively examined with respect to frequency of occurrence and relative abundances.

Feeding microhabitat of Willamette and Umpqua Oregon chubs was analyzed with respect to prey microhabitat. Each prey taxon was categorized as being primarily found in the substrate, on the substrate, in the water column, or on the surface of the water. Prey taxa were categorized based on surveys of the habitat for the various prey items in Shady Dell pond, and on published information on the given taxon (Merritt and Cummins, 1984).

distributional survey

A distributional survey was conducted from July 20, 1987 to September 1, 1987. Sites to be sampled were selected by their presumed probabilities of containing Oregon chub as determined by studies at Shady Dell Pond, Buckhead Creek, Calapooya Creek and Elk Creek. Priority was given to historical sites and sampling effort was distributed such that most potential sites were visited in each drainage. Historical records of the Oregon chub were taken from OSU freshwater fish data base (Rexstad, 1987), and Long and Bond (unpublished data).

Many physical and biological variables were measured but only mesohabitat, water velocity, substrate, temperature, and associated fish species abundance will be discussed in this paper. Mesohabitats were classed as one of the following: riffle, run, pool, slough, oxbow, pond, lake, or reservoir. Water velocity was visually classed as none (0 cm/s), slow to none (0-2 cm/s), slow (2-5 cm/s), slow to moderate (5-10 cm/s), or moderate (>10 cm/s). Visual estimates of substrate composition were based on a modified Wentworth scale (Hynes, 1970). If a site had greater than 50% of sand or smaller material it was classed as depositional. If a site had greater than 50% of gravel or larger material it was classed as erosional. Sites with equal depositional and erosional material were classed as mixed. All fish taxa caught/observed were identified and qualitatively ranked as rare, scattered, common, or abundant.

Habitat suitability ratings were constructed so that possible reasons for the decline of the species could be proposed. Suitability ratings were based on preliminary study of the physical habitat (Fig. 3). As Umpqua Oregon chub inhabited somewhat different habitat than Willamette Oregon chub, the suitability ratings differed. Prior to sampling a site a suitability ranking of excellent, very good, marginal, or poor was recorded. Table 1 shows criteria used in determining Oregon chub habitat suitability for the two drainages.

The absence of Oregon chub was ascribed to one of five causes (Fig. 3):

1) low habitat suitability - a suitability rating of marginal or below;

2) physical and/or chemical degradation - obvious habitat alteration by man such as channelization, or chemical dumping;

3) biological degradation - presence of exotic fishes at an abundance ranking above scattered;

4) physical and biological degradation - both physical and biological degradation as described above;

5) none of the above - habitat appeared to be suitable and none of the above categories were appropriate; if a site was classified as physically, chemically, or biologically degraded, the absence of Oregon chub from the site was attributed to man's interference with the habitat.

RESULTS

Willamette Oregon chub habitat characteristics

Shady Dell Pond is a 550 m^2 body of water that appears to have been a side channel or backwater of the Middle Fork of the Willamette River prior to the construction of state highway 58. After the highway was completed the pond became isolated. The pond is bordered by a rocky bank (remains from highway construction) on the north side, a bedrock cap on the west side, and sediment elsewhere. Willow, alder, cottonwood, and ceder surround the pond. Sunlight reaches the pond from about 0900 to 1500 hr during the summer months. In May 1986, and the winter of 1987 the maximum depth of the pond was about 2 m which was approximately the maximum depth under bank full conditions. In August of 1986, the maximum depth of the pond was about 0.5 m.

With the exception of pH, the water chemistry did not appear to be unusual (Table 9, and Wetzel, 1983). Water visibility was about 1 m. On July 30, 1986 pH ranged from 7.6 to 10.0 in different locations of the pond. Dissolved oxygen was close to saturation throughout the year.

The composition of the substrate in June of 1986, was 80% floculent detritus, 15% small boulders, and 5% bedrock. The percent cover by aquatic vegetation ranged from 30% in June 1986, to 70% in August 1986 (mostly from the increase of Spirogyra). Woody debris covered about 10% of the surface area of the pond.

Temperature ranges in Shady Dell Pond were large between seasons and within a day. On July 30, 1986 temperatures ranged from 14 C to 29.5 C. A high of 31 C was recorded on August 12, 1986. On January 9, 1987 the water temperature was 3 C and a layer of ice from 5 to 25 mm thick covered the entire surface of Shady Dell Pond.

Aquatic vegetation in and around the pond was quite diverse (Table 10). During the colder months Fontinalis antipyretica was the most common aquatic plant in the pond. As temperatures went above about 23 C Spirogyra increased in abundance while F. antipyretica decreased in abundance. *Alisma* and *Sparganium* were the most abundant marginal aquatic plants.

The zooplankton abundance and species richness in Shady Dell Pond was very poor (as compared to Buckhead Creek Slough), and was dominated by smaller individuals of species present especially *Bosmina longirostris*. Among the zooplankters present were *Bosmina*, *Chydorus*, cyclopoid copepods, Hydracarinas, baetid mayfly larvae, and Ostracoda.

The aquatic insects found in Shady Dell Pond were characteristic of slow water species (Table 11, and Merritt and Cummins, 1984). Ephemeroptera (mostly *Callibaetis*), Hemiptera (mostly corixids and notonectids), and Odonata (mostly lestids and coenagrionids) were the most dominant orders above substrate, whereas Diptera (mostly chironomidae) was the most dominant order within the substrate.

The most abundant herpetile in the pond was the exotic bullfrog *Rana catesbeiana*. Large numbers of all life history stages of this frog were present. Egg masses of the native red-legged frog *R. aurora* were found, but no other life history stage of this frog were found. Occasionally the number of rough-skinned newts *Taricha granulosa* exceeded the number of bullfrogs. Garter snakes frequented the pond on occasion.

Stomach contents of 11 bullfrogs and 1 garter snake were examined. Bullfrogs ranged in size from 54 to 160 mm snout to vent length. Juvenile bullfrogs fed primarily on aquatic and terrestrial insects, whereas adults fed on crayfish, bullfrog tadpoles, juvenile bullfrogs, and aquatic and terrestrial insects. One garter snake 66 cm in length contained unidentifiable insect parts. Stomach contents of cutthroat trout and prickly sculpin also revealed no Oregon chub.

Before water pumping began in the summer of 1986, the fish species present were the Willamette Oregon chub (O. crameri), cutthroat trout (Oncorhynchus clarki), largescale sucker (Catostomus macrocheilus) and prickly sculpin (Cottus asper). Following the water pumping, redside shiners (R. balteatus) were collected in addition to the above mentioned species.

Besides the species mentioned above there were many other species that were associated with the pond. Crayfish were quite abundant. There was evidence to suggest that beaver were in the area (such as beaver gnawings and wood piles) although none were observed. Many bird species also made use of the pond.

Buckhead Creek (Fig. 2) is a second order stream that undergoes an abrupt change in gradient where it meets North shore road. No Willamette Oregon chub have been caught above North shore road. Below North shore road the creek has a low gradient and flows slowly for about 1-2 km and then empties into the Middle Fork of the Willamette River across from Shady Dell Pond.

Most study was conducted at a slough of Buckhead Creek adjacent to North shore road. The slough is relatively long and narrow, somewhat V-shaped in cross section, and bordered by sediment banks. The maximum depth in June 1986 was about 2 m and maximum area about 1,100 m^2. There was a decrease in water depth from June to September but the derease was not as great as at Shady Dell Pond. Because of a semi-closed canopy (approximately 60% closed), most sunlight impinging on the slough is filtered. The substrate composition consisted of about 100% silt/detritus, about 20% of which is covered by woody debris, and about 30% by aquatic vegetation.

Buckhead Creek Slough appears to be much less variable in water chemistry and temperature than Shady Dell Pond. The water visibility was poor, ranging from 0.5 to 0.8 m. The pH was always close to 7.6, and the dissolved oxygen was always close to saturation. Other components of water chemistry were fairly constant (Table 9). The maximum variation in temperature recorded for 48 hours was 9 C (13 C to 22 C on July, 30 1986). On January 9, 1987 the water temperature was 3 C and the slough was completely covered by a sheet of ice from 5 to 25 mm thick.

The aquatic vegetation at Buckhead Creek was primarily Elodea densa (Table 10). When ice covered the pond Azolla grew profusely causing the ice to look pink. Juncus and Alisma were the most abundant marginal plant species.

The zooplankton community in the slough was dense but not species rich. Bosmina longirostris was by far the most numerous zooplankter present. Cyclopoid copepods and Hydracarinas were present but found in very low numbers. Compared to Shady Dell Pond the zooplankters in Buckhead Creek Slough were larger, being of average size for the species.

Bullfrogs were present but in much smaller numbers than at Shady Dell Pond. Rough-skinned newts were present in large numbers. Crayfish were present but their abundance was unknown. Evidence of beaver activity was great although no beaver were observed. With the exception of speckled dace Rhinichthys osculus, the fish species present at Buckhead Creek Slough were the same as those found at Shady Dell Pond following water pumping.

Willamette Oregon chub biology

Willamette Oregon chub larvae in Shady Dell Pond generally congregated in nearshore areas (Fig. 4), in the upper layers of the water column in shallow water (Fig. 5). As the transition from larvae to juvenile occurred, at about 16-20 mm TL, their habitat changed. Juveniles started to venture farther from shore and ventured into deeper areas of the water column.

Juvenile and adult Willamette Oregon chub in Shady Dell Pond occuppied quite different habitats seasonally. On January 9, 1987 a snorkeling survey of Shady Dell Pond was conducted. No Willamette Oregon chub were seen in the water column or above the substrate. In February of 1987 two size classes of Willamette Oregon chub were collected by electroshocking in Shady Dell Pond. Although Willamette Oregon chub were taken from many locations throughout the pond, most fish were taken from shallow areas less than 0.75 m deep. These shallow areas were dry in the summer. Willamette Oregon chub were found buried in soft floculent detritus, or buried or concealed in the bottom portions of aquatic plants (mostly F. antipyretica). Although most of the F. antipyretica was suspended from logs, Willamette Oregon chub were never taken in F. antipyretica unless it was associated with the bottom.

In March of 1987, Willamette Oregon chub began coming out of cover, and were seen hovering over mounds of F. antipyretica. Although the Willamette Oregon chub were now in the open, they were still inactive. In April of 1987, Willamette Oregon chub started to behave much as they do during the summer months: fish of the same size classes were schooling and feeding together; but fish were still using the shallow margins of the pond and had not ventured into the deeper central portions of the pond.

From May through September Willamette Oregon chub were observed feeding, reproducing, resting, and "sleeping". Reproduction and feeding will be discussed in later sections. During the day juvenile and adult fish were observed in aggregations throughout the whole pond. Throughout the day there did not appear to be any strong preference for depth or for distance to shore, but during midday large aggregations of Willamette Oregon chub were seen resting very close to the surface. At night Willamette Oregon chub were scattered on the bottom of the pond or in aquatic vegetation.

There appeared to be 3 size classes of Willamette Oregon chub in August. Young of the year were approximately 7-32 mm, presumed 1+ fish were approximately 33-46 mm, and presumed 2+ fish were approximately 47-64 mm. Most of the presumed 2+ fish present in May and June were absent by August. Most Willamette Oregon chub that were placed in aquaria at a presumed age of 1+ died after living for 1 additional year. Willamette Oregon chub populations in different locations (Buckhead Creek Slough and the "Pit") had similar length frequency distributions. The largest Willamette Oregon chub ever captured (69 mm TL) was captured in the "Pit" (Fig. 2) on August 7, 1987.

As has been reported for other cyprinids (Scott and Crossman, 1973) fecundity increased directly with Willamette Oregon chub length. Fecundity ranged from 147 eggs (41 mm TL) to 671 eggs (64 mm TL) [Table 2]. When fecundity was plotted against fish TL an intercept of 2.7 and a slope of 0.06 resulted using an exponential regression model $Y=e^{(2.7+0.06x)}$ (overall F-test $p<0.0001$; df=1, 15)

Linear regression analysis suggested that there was no significant relationship between average egg diameter and total length of ripe females (overall F-test $p<0.38$; df=1, 15). In general, three size classes of eggs were seen in most individuals: Yolky eggs were largest (0.5-1.3 mm); the next size class of eggs were colorless and about 0.3-0.6 mm, and the smallest size class were colorless and about 0.2 mm.

Umpqua Oregon chub habitat characteristics

The Elk Creek site was somewhat typical of the low gradient tributaries of the Umpqua River. Substrate composition was 65% bedrock, 10% small boulder, 5% cobble, 5% silt, and 15% sand. Aquatic vegetation covered about 30% of the site. In August of 1986, the maximum water depth at the site was about 1 m and the average depth was about 30 cm. Water velocity in the site ranged from none to moderate. Water temperature recorded on February 6, 1987 was 6 C, and on June 6, 1987 23 C. Dissolved oxygen was saturated on February 6, 1987 and the pH was 8.4. During the winter months the water velocity, turbidity, and the depth increased.

In Elk Creek, Umpqua Oregon chub inhabited areas of none to moderate water velocities, with most fish inhabiting areas of slow water velocities. They were generally associated with aquatic vegetation. Smaller Umpqua Oregon chub inhabited shallower, slower water velocity areas that were closer to shore than the larger Umpqua Oregon chub. Fish taxa caught in the site were *O. crameri*, *Ptychocheilus umpquae*, *R. balteatus*, *R. osculus*, *Cottus* sp., and *Ictalurus natalis*.

Umpqua Oregon chub biology

On August 24, 1987 there were three size classes of Umpqua Oregon chub in Elk creek (Fig. 6). Only 2 fecund Umpqua chub were discovered. Both of these fecund fish were collected on June 3, 1987 (Table 2).

The swimming performance of the redside shiner was far superior to that of the Umpqua Oregon chub. Five redside shiners ranging from 37 to 47 mm TL had a mean swimming performance of 11.5 body lengths per second (se=2.8). Ten Umpqua Oregon chub ranging from 55 to 67 mm TL had a mean swimming peformance of 5.2 body lengths per second (se=1.5).

reproduction

Although gametes were never collected in the field or in the lab there were five reasons to believe that spawning behavior was observed. Before and after the spawning season, all age classes of Oregon chub were very social and non-aggressive, whereas during "spawning" Oregon chub over about 35 mm became territorial, aggressive, and generally performed behaviors not observed at other times. Second, spawning behavior as described herein, could be induced following hormone treatment. Third, larvae were observed shortly after spawning behavior began, and ripe females were only found during the months that spawning behavior was observed. Fourth, secondary sexual characteristics were noted during the months that spawning behavior was observed. The spawning colors of Oregon chub consist of a faint yellow at fin bases in both sexes, relatively drab compared to sympatric minnows such as <u>Richardsonius</u> <u>balteatus</u> and <u>Rhinichthys</u> <u>osculus</u> (see description in Wiesel and Newman, 1951; Moyle, 1976). As well, breeding tubercles were developed on the head, pectoral, and pelvic fins during spawning season. Finally, the literature also shows that other cyprinids have somewhat similar reproductive behavior and timing (Breder and Rosen, 1966).

Willamette Oregon chub were observed spawning in Shady Dell Pond from the end of April (water temperature = 18 C) in 1987, to mid July, 1986 and the end of July, 1987 (water temperature = 16-28 C). At "the Pit" chub were observed spawning into August, 1987 (water temperature = 23 C). During the spawning season of 1987, there were peaks in the spawning activity of Willamette Oregon chub in early May and June of 1987 in Shady Dell Pond. Following the spawning peak in June 1987, spawning activity remained high for the rest of June and most of July 1987. Between the spawning peaks (during the rest of May) there was very little spawning activity observed. Additionally, there were peaks in larval abundance following the spawning peaks. Observations during all day light hours on June 13, 1986 and June 3, 1987, were made to determine if there was a peak spawning time. The intensity of reproductive behavior was greatest from about 1200 to 1400 hours (similar to Hybognathus nuchalis; Raney, 1939). Willamette Oregon chub did not spawn after dark.

Spawning behavior of the Oregon chub in Shady Dell Pond was observed as follows:

Establishment of a territory - large male Willamette Oregon chub (generally greater than 45 mm) set up territories, in or just outside a natural depression in a mound or expanse of aquatic vegetation. At Shady Dell Pond the aquatic vegetation chosen was almost exclusively Fontinalis antipyretica. The territory size varied with the complexity of the habitat. If an expanse of F. antipyretica with numerous natural pockets and high numbers of female Willamette Oregon chub was present, a territory size could be as small as 10 cm^2, whereas if there was a small clump (ca 15 cm^2) of F. antipyretica with relatively few female Willamette Oregon chub passing by, the territory size could be as large as 1 m^2. The territory seemed to be used as a place to start the courting of a female. There did not appear to be any preparation of the spawning site by either sex. Often the territorial male did not spawn in his territory, and sometimes he did not return to his territory after a skirmish with another Willamette Oregon chub or after a spawning bout. The "non-attachment" of male Willamette Oregon chub towards spawning territories is similar to that described for Rhinichthys atratulatus atratulatus (Raney, 1940).

Skirmishes between male Willamette Oregon chub were quite common. Generally a territorial male would ignore male intruders less than 35 mm TL. Intruders greater than 35 mm were often chased out of the territory by the territorial male swimming rapidly towards the intruder. Occasionally an intruder would not swim away and a series of side to side head butts would be exchanged until one gave up or until a female entered the territory. The densest accumulation of breeding tubercles seemed to be on the opercular region, which may aid males in side to side head butting.

Courtship and spawning - Many full spawning sequences were observed during the summers of 1986 and 1987. The start of a spawning sequence started when a female entered a male's territory and ended when the presumably spent female emerged from the aquatic vegetation. Three sequential units of behavior were detected in the male.

Head rubbing - Males would swim under females and try to position themselves so that the top of the head rubbed the ventral region of the female between the pectoral and anal fins (similar to behavior reported in Ptychocheilus oregonensis; Patten and Rodman, 1969; and Hybognathus nuchalis; Raney, 1939).

Directing - A head rubbing male would try to direct the female into aquatic vegetation by slight changes in the angle and pressure of the head upon the lateral undersides of the females.

Twirling - When both sexes were in aquatic vegetation, a spawning twirl, lasting from 1-5 seconds began. Both individuals were head to head and tail to tail. Because of the rapidity of the twirling, and the covering of aquatic vegetation, it was difficult to determine if eggs were released or to see any other details of twirling.

Sequence of spawning behavior - A generalized account of reproductive behavior observed in Shady Dell Pond from the summers of 1986 and 1987 follows. If a female swims into a male's territory, he will swim towards her and she will either try to leave by swimming quickly away or allow courtship by swimming somewhat slowly (see description for Notropis longirostris; Hubbs and Walker, 1942). The male generally approaches from the ventral side of the female to begin head rubbing, which lasts for 2-60+ seconds. If head rubbing is successful, the male directs the pair into the vegetation where twirling takes place.

Multiple males may be involved in courting, head rubbing, directing, and twirling. This can happen when two males are fighting over a territory and a female swims by, when a courting pair swim through another male's territory, or when satelite males try to interfere. During head rubbing as many as four males were observed battling for the primary position (ventral region between pectoral and anal fins) of the female. The other males take up positions behind and to the side of the male in the primary position (similar to Hybognathus nuchalis; Raney 1939) and may be successful at taking the primary position when the female changes direction. Often males that are not in the primary position give up and resume courting elsewhere.

In aquaria, Willamette Oregon chub soaked in a solution of LH-RHa and reserpine, began spawning whereas those given only an increase in photoperiod and temperature did not. Approximately 40 complete spawning bouts were observed for both the Willamette and Umpqua Oregon chubs. Willamette Oregon chub spawned in aquatic vegetation and all behavior was the same as that observed in situ. In contrast, Umpqua Oregon chub treated with the same hormones and having the same availability of substrates spawned over rocks and in corners of the aquaria. Umpqua Oregon chub were also much more territorial and aggressive, a situation similar to the differences in spawning behavior noted by Raney (1940) for Rhinichthys atratulatus atratulatus and R. a. meleagris).

feeding

Willamette Oregon chub in Shady Dell Pond fed throughout the day but stopped feeding shortly after dusk. Their feeding behavior could be broken into five categories:

Slash-fish approaches a substrate then rapidly turns it's body as if to rub against the substrate (this is not to be confused with "itching" where no prey items are visually taken).

Pick-fish approaches a prey item on the substrate, on aquatic vegetation, or in the water column; the fish being very close to the prey item moves slightly forward and picks the prey item from the given microhabitat.

Surface - fish swims rapidly to the surface and grabs a prey item from the surface (infrequently, this act is initiated from the water's surface).

Chase-fish chases a prey item along the bottom or in the water column until captured or unsuccessful.

Dig-predator generally orients itself at 45 degrees to the substrate (always soft substrate such as floculent detritus) and then dives into the substrate covering up to 2/3 of the body length of the predator.

Slashes and picks are by far the most common feeding behaviors in Shady Dell Pond. Slashes appear to be more common during the morning and evening hours, whereas picks appear to be the most common during midday. Digging was rarely seen until about 1700 hours at which time it increased in frequency until dark. Chasing and surface feeding were the feeding behaviors observed least frequently. Willamette Oregon chub larvae seemed to use the picking and chasing behaviors exclusively. The distances from prey items to larvae were generally much smaller than from adults and juveniles to prey. The Umpqua Oregon chub was never observed using the digging behavior, seldom observed surface feeding, but like the Willamette Oregon chub used the pick, and slash behavior most frequently. Feeding of larval Umpqua Oregon chub was never observed.

When fed a floating food (Tetramin) in aquaria, Willamette Oregon chub fed at the surface and remained there until satiated or no food remained. In contrast, the Umpqua Oregon chub darted to the surface, fed, and returned to the bottom of the tank.

The diet of the Oregon chub is summarized in Tables 3 and 4. The Willamette Oregon chub fed mostly on water column fauna whereas the Umpqua Oregon chub fed mostly on infauna.

The sample size analyzed was appropriate to describe local diets based on the methods by Hurtubia (1973). An asymptote of prey richness was reached by the sixteenth Willamette Oregon chub and the fourteenth Umpqua Oregon chub. Qualitative examination of museum specimens indicated that diets described for the two populations seemed to be fairly representative of other Oregon chub populations throughout the drainage. For example, various zooplankters along with some chironomid larvae made up the bulk (occurrence and numbers) of the prey items found in Willamette Oregon chub museum specimens. Chironomid larvae and occasional ephemeropteran larvae made up the bulk of prey items found in Umpqua Oregon chub museum specimens, and other field specimens.

Significant positive relationships were found between Willamette Oregon chub length and largest and median prey items found in the gut (Table 5, 6). No significant relationships were found when largest ($p<0.47$; df=1,14), smallest ($p<0.82$; df=1,14), or median ($p<0.47$; df=1,14), prey items were regressed against Willamette Oregon chub larvae length (6.2-16.0 mm TL). When larval, juvenile and adult Willamette Oregon chub were combined a significant positive relationship between Willamette Oregon chub length and largest, smallest, and median prey items was found (Table 5). Oregon chub length regressed against intestine length also produced a significant positive relationship (Table 5).

distributional survey

Sixty-nine sites were sampled in the Willamette drainage basin and only one had Willamette Oregon chub. Seventy-five percent of the sites sampled were rated as excellent or very good. The single positive site, the "Pit" was rated excellent. Figure 7 shows the sampling sites and distribution in the Willamette drainage. Four of the Willamette Oregon chub sites illustrated in Fig. 2 were known before the survey and two of those (Hazel Creek Slough and Rolling Riffle Slough) apparently have transient populations which are dependent on Lookout Point Reservoir. The other Willamette Oregon chub sites are Shady Dell Pond, and Buckhead Creek. It appears that the Willamette Oregon chub is now confined to about 15 miles of the Middle Fork of the Willamette River. Twenty-two of 29 historical Willamette Oregon chub sites were sampled. Willamette Oregon chub were present at 4 of the sampled historical sites. Of the 29 known historical sites, 24 had dates recorded at which Willamette Oregon were last captured. Willamette Oregon chub were last captured from 6 (25%) of the historical sites between 1890-1899, 0 (0%) sites between 1900 and 1939, 2 (8%) sites between 1940 and 1949, 5 (21%) sites between 1950 and 1959, 3 (13%) sites between 1960 and 1969, 2 (8%) between 1970 and 1979, and 2 (8%) sites between 1980 and 1988. Four (17%) of the 24 dated historical sites contained Willamette Oregon chub in 1988. Sampling effort did influence when and where Willamette Oregon chub were captured (sampling effort was high between 1890 and 1899, low between 1900 and 1939, and high between 1940 and 1988).

Thirty-eight sites were sampled in the Umpqua drainage basin and 13 had Umpqua Oregon chub (Fig. 7). Sixty percent of the 38 sites were rated as excellent or very good. Umpqua Oregon chub were found about equally at excellent and very good sites. Umpqua Oregon chub are found throughout the Umpqua drainage from near its mouth in the Smith River to just inside the Umpqua National Forest in the South Umpqua (Fig. 8). They appear to be absent only in the North Umpqua River although they were there historically. Ten of 11 historical Umpqua Oregon chub sites were sampled (one of the historical sites could not be located). Umpqua Oregon chub were present at 7 of the sampled historical sites. Of the 3 historical sites Umpqua Oregon chub were eliminated from, the last dates they were collected were 1899, 1926, and 1971 respectively.

Sites containing Oregon chub in the two drainages were compared with respect to mesohabitat, water velocity, substrate size, and temperature. Thirteen Umpqua sites and all five known Willamette sites were used for analysis. The number of sites recorded in each mesohabitat for Umpqua Oregon chub were as follows: run 6, pool 1, and slough 6. The mesohabitats recorded for Willamette Oregon chub were as follows: run 1, and pond 4. The number of sites recorded for water velocity categories showed similar trends - for the Umpqua, none 2, none to slow 8, slow 2, and slow to moderate 1; for the Willamette, none 4, and none to slow 1. In the Umpqua drainage 38% (n=5) of the sites had depositional substrate, 38% (n=5) had erosional substrate, and 23% (n=3) had mixed depositional and erosional substrate. The Willamette Oregon chub inhabited only depositional substrate sites (n=5). In summary, the Umpqua Oregon chub were found in habitats with relatively faster water, containing more erosional substrates than the Willamette Oregon chub.

Water temperatures were averaged according to the rated Oregon chub habitat suitability. In the Umpqua, poor sites averaged 17.5 C (n=2), marginal sites averaged 18.3 C (n=13), very good sites averaged 21.0 C (n=14), and excellent sites averaged 22.4 C (n=9). In the Willamette, poor sites averaged 20.0 C (n=3), marginal sites averaged 16.5 C (n=14), very good sites averaged 18.0 C (n=22), and excellent sites averaged 17.4 C (n=30). Although there appears to be a positive relationship between temperature and suitability for Umpqua Oregon chub there does not appear to be any such relationship for sites in the Willamette drainage.

Eight out of 30, or 27% of the sites rated as excellent in the Willamette drainage were less than 14 C. Many of these sites were near extant Willamette Oregon chub sites. Since spawning was never observed at temperatures below 16 C, these sites should probably be reclassified as marginal or poor. If very good and excellent sites with water temperatures less than 16 C are reclassified as poor, a positive relationship between average temperature and site suitability exists in the Willamette (poor = 14.4 C, marginal = 16.4 C, very good = 19.2 C, and excellent = 20.6 C).

The fish taxa associated with the Oregon chub in the two drainages were very similar (Table 7). All native fish species collected or observed with Oregon chub were also caught in faster velocity areas. All Umpqua or Northern squawfish collected or observed in association with the Oregon chub were smaller than about 150 mm with most averaging 60-70 mm TL. The majority of fish associated with Oregon chub were young of the year or juveniles. With the exception of the yellow bullhead, exotic fishes were rarely associated with Oregon chub. Exotic fishes were found in many areas that appeared suitable and historically had Oregon chub.

The characterization of sites that did not contain Oregon chub was analyzed for the Umpqua (n=25) and Willamette (n=68) drainages separately. For the Umpqua drainage 48% of the sites were deemed to be low habitat suitability, 4% physically and/or chemically degraded habitat, 12% biologically degraded habitat, 4% physically and biologically degraded habitat, and 32% were classified as none of the above. For the Willamette drainage 19% (46% when reclassified with respect to temperature) of the sites were deemed to be low habitat suitability, 13% physically and/or chemically degraded habitat, 22% biologically degraded habitat, 9% physically and biologically degraded habitat, and 37% (10% when reclassified with respect to temperature) were classified as none of the above. Overall, a minimum of 20% of the sites sampled on the Umpqua were degraded by man, whereas 44% of the sites sampled on the Willamette were degraded by man.

DISCUSSION

One result of the extensive survey was a dramatic difference in status of Willamette Oregon chub and Umpqua Oregon chub (Fig. 8). Historically the Willamette Oregon chub was collected from 29 sites and the Umpqua Oregon chub from 11 sites. Willamette Oregon chub ranged from near the mouth of the Willamette River near Oregon City to tributaries of the Middle Fork of the Willamette River near Oakridge. Umpqua Oregon chub ranged from near the mouth of the Smith River to upper reaches of the South Fork of the Umpqua River (Fig. 8). During the summer of 1987 Willamette Oregon chub were found in only 18% of historical sites sampled (N=22) whereas Umpqua Oregon chub were found in 70% of historical sites sampled (N=10). Willamette Oregon chub have steadily been eliminated from sites from 1940 to the present, except for the years from 1950 to 1959 when a greater proportion of Willamette Oregon chub were eliminated from historical sites. The years between 1950 and 1959 accounted for 36% of sites that Willamette Oregon chub were eliminated from, during the time period of 1940 to the present. The possible hypotheses explaining the differential status of Oregon chub in the two drainages are: 1) Willamette and Umpqua drainages have been differentially degraded with respect to Oregon chub habitat; 2) Willamette Oregon chub are biologically different from Umpqua Oregon chub; or 3) a combination of the above.

Oregon chub habitat in the Willamette drainage has been physically, chemically, and biologically degraded to a greater extent than in the Umpqua drainage. Potential biological degradation includes the introduction of exotic animals that may prey on, compete with, spread diseases to, or hybridize with Oregon chub. Physical and chemical degradation includes: channelization, hydro-project construction, and chemical dumping. Two effects of channelization are elimination of Oregon chub habitat by land filling and the degradation of habitat by increasing water velocity.

Although Willamette Oregon chub and Umpqua Oregon chub inhabit somewhat different habitats they both occupy areas that have relatively slow to no water velocities. The redside shiner, which was associated with Oregon chub in 100% of the sites (Table 7), has a swimming performance twice that of the Umpqua Oregon chub. The relatively poor swimming performance of Umpqua Oregon chub may explain why it is restricted to slow water habitats. It is interesting to note that Willamette Oregon chub are found in habitats with relatively slower water velocities than Umpqua Oregon chub. Since it appears that Oregon chub require habitats with slow to no water velocities, practices that increase water velocities above that tolerable for Oregon chub, will eliminate Oregon chub.

Extensive channelization of the Willamette River has occurred since the late 1800's (Sedell and Froggatt, 1984; Hjort et al., 1984; Li et al., 1987) (Fig. 9), while channelization of the Umpqua River appears to be minimal. For various socioeconomic reasons the Willamette River has essentially been reduced to a single channel. Backwaters were filled for agriculture, revetment was installed over 11 percent of the shoreline to prevent erosion (Hjort et al., 1984; Hughes and Gammon, 1987), large woody debris was removed for "habitat enhancement" and for river navigation, and side channels were closed for river navigation (Sedell and Froggatt, 1984). Historically, the shoreline in a 25 km reach between Harrisburg and the McKenzie River confluence decreased over four-fold (Sedell and Froggatt, 1984). Although data are lacking I believe that the Umpqua River has been impacted less severely. The following reasons support this view: the Umpqua River area is less populated (70% of the population and the three largest cities of Oregon are located on the Willamette River) the Umpqua River was not used extensively for river navigation, and the Umpqua River is less revetted.

The purpose of many of the channelization practices was to increase land available to farming (land filling), to reduce land erosion (revetting), and to facilitate river navigation (revetting). The construction of hydro-projects for flood control and power generation, was another practice used to protect land from erosion. Negative effects that hydro-projects might have on the Oregon chub are:

the reduction of spring and summer temperatures immediately below the dam (Petts, 1984; Hughes and Gammon, 1987), and the reduction of periodic floods (Petts, 1984; Pflieger and Grace, 1987). The reduction of spring and summer water temperatures below 16 C may inhibit Oregon chub spawning. Willamette Oregon chub began spawning when water temperatures were about 16 C, and Willamette Oregon chub were absent from areas rated as excellent and very good (27% of negative sites) yet were less than 16 C during the summer. Twenty-eight percent of those sites not containing Willamette Oregon chub due to temperature were below dams. Flooding may have been one way that the Oregon chub used to colonize new habitats such as flood plain ponds, and maintain gene flow. If flooding was a method by which Oregon chub were dispersed, the fragmentation of the river system (Sheldon, 1988) may have reduced the potential colonization of areas that no longer experience floods.

The magnitude of flooding has decreased more in the Willamette basin than in the Umpqua basin. Flood control structures reduce the magnitude of floods and distribute waters during normal low flow time periods (Petts, 1984; Pflieger and Grace, 1987). There are 11 flood control structures, 3 began operation from 1940-1949, 2 from 1950-1959, and 6 from 1960-1968, in the Willamette basin. This corresponds to 2,649 km^2 of drainage area/flood control structure and 2,000,000,000 m^3 mean annual discharge for basin/flood control structure. Between 1950 and 1970, the rate of Willamette Oregon chub elimination from historical sites was probably the greatest. Although correlational, Willamette Oregon chub had their highest rate of elimination from historical sites during the time period that most of the dams were in operation. The two flood control structures in the Umpqua basin began operation in the late 1970's to mid 1980's. This corresponds to 6,125 km^2 of drainage area/flood control structure and 3,600,000,000 m^3 mean annual discharge/flood control structure.

The tolerance of Oregon chub to chemical pollutants is largely unknown, although the Willamette basin has probably been degraded more with respect to chemical pollution than the Umpqua basin (Dimick and Merryfield, 1945; Hughes and Gammon, 1987). The Willamette Oregon chub was classed by Ziebell (1954) as faculative ("being neither a strictly clean-water or polluted water fish"), although he based his findings on only one sample. Thirteen percent of the sites that did not contain Willamette Oregon chub and 4% that did not contain Umpqua Oregon chub were attributed to physical and chemical degradation. Although the tolerance of Oregon chub to chemical pollution is unclear, it appears that the Willamette drainage has been more chemically degraded than the Umpqua drainage suggesting that the Willamette Oregon chub has suffered greater losses.

Willamette Oregon chub also may have declined to a greater extent than Umpqua Oregon chub due to introduction of exotic species into the Willamette and Umpqua basins. Preliminary lab experiments demonstrated that largemouth bass had little difficulty catching and swallowing Umpqua Oregon chub. Oregon chub's slow swimming speed, and short, plump bodies make them ideal prey for fishes of the family Centrarchidae (Howick and O'Brien, 1983).

Willamette and Umpqua Oregon chubs have not adapted in systems where predation is a major threat to survival. The only large piscivores that might have been historically present with Oregon chubs are the Umpqua and Northern squawfish (Table 7). Most exotic species in the Willamette and Umpqua river systems inhabit areas of slow to no water velocities, such as backwaters and ponds, throughout their whole life cycle (Li _et al_., 1987). Many of the exotic centrarchids in the Willamette valley such as largemouth bass are piscivorous at a small size (Carlander, 1977). At a length of 10-44 mm largemouth bass begin feeding on fish, and feed mainly on fish, and fish and large invertebrates when over 80-100 mm (Carlander, 1977). Squawfish are not piscivorous until they reach about 100 mm, but fish are not a major component of the diet until about 300 mm (Carlander, 1969). All of the squawfish captured or observed with the Oregon chub were quite a bit smaller than 300 mm, and most were less than 100 mm. By the time squawfish become piscivorous they have already left the areas that Oregon chub inhabit and so do not prey on Oregon chub.

Observations of declines of native fish with corresponding introduction of exotic fish are common (Moyle 1976; Sigler and Sigler, 1987; Taylor _et al_., 1984; Meffe, 1985). Some accounts of declines of native fishes "due to" exotic fishes may be from degradation of habitat during or prior to the time of exotic fish introduction. Although habitat degradation may have occurred in some of the sites from which Oregon chub were extirpated, it does not appear to account for all losses. Many sites (12% in the Umpqua drainage, and 22% in the Willamette drainage) had very good or excellent habitat but did not contain Oregon chub presumably because of competition or predation by exotic fishes. Oregon chub were rarely associated with exotic fishes although exotic fishes appeared to prefer the same habitat. Li et al. (1987) show that many exotic fishes in the Columbia River drainage inhabit slow water velocity areas. Bond (unpublished report) suggested that competition and predation by exotic fish species, notably centrarchids, might explain the disappearance of Willamette Oregon chub from Lookout Point Reservoir.

The Willamette basin has been biologically more degraded than the Umpqua basin. Collection records from the OSU museum freshwater fish database (Rexstad, 1987) indicate that 17 exotic fish species were captured from the Willamette drainage and only 9 from the Umpqua drainage. Although the mechanism is unknown it seems likely that the Willamette Oregon chub has suffered greater losses from the introduction of exotic fishes than the Umpqua Oregon chub.

Willamette Oregon chub and Umpqua Oregon chub differ in their spawning and feeding behaviors, diets, and habitat requirements. Reproductive behavior of Umpqua Oregon chub was more aggressive; they defended spawning territories and spawned on hard substrate. Willamette Oregon chub were less aggressive; they defended spawning territories and spawned in aquatic vegetation. I believe the observed differences in reproductive behavior are not an artifact of the experiment. Availability of spawning substrates in the aquaria were similar and field observations of Willamette Oregon chub were very similar to laboratory observations so that lab set-up and artifact are unlikely explanations.

Differences in prey type, prey size, feeding behavior and feeding microhabitat were observed between Willamette Oregon chub and Umpqua Oregon chub in the field and in the laboratory. Without information on the availability of prey items and size of prey items present it is difficult to know if Willamette and Umpqua Oregon chubs are selecting for different prey taxa or prey sizes. As Willamette Oregon chub and

Umpqua Oregon chub occupy different habitats and feed in different microhabitats (Table 3) it might be expected that the prey items available to the Willamette Oregon chub and Umpqua Oregon chub were different. Feeding microhabitat and laboratory feeding behavior observed for Willamette Oregon chub and Umpqua Oregon chub are probably a result of the difference in habitat occupied. Fishes that occupy faster water velocities and feed on surface prey, generally dart to the surface, engulf the prey and then return to the bottom or to slower water velocity area. This strategy reduces the time spent in fast water and thus saves energy. In areas of slow to no water velocity, it is favorable energetically to stay at the surface while feeding and energetically unfavorable to dart to the surface, obtain a prey item, and return to the bottom for there is little to no chance of being displaced downstream because of water velocity. An alternative strategy to surface feeding in fast water velocity areas is to feed off the bottom.

Based on the microhabitat of prey items found in the intestine of Oregon chub the primary feeding microhabitat of Umpqua Oregon chub at midday on June 6, 1987 was on the bottom (Table 3). The primary feeding microhabitat of Willamette Oregon chub at midday on May 20, 1987 was in the water column (Table 3). From an energetic standpoint if prey caloric intake and handling time is favorable on the bottom (slower water velocity) that is where the Umpqua Oregon chub should feed. Because Willamette Oregon chub generally inhabit areas of no water velocity they should feed wherever caloric intake is highest and handling time is low. Since water velocity is not a factor in determining where Willamette Oregon chub feed the diet may be more variable for Willamette Oregon chub than for Umpqua Oregon chub. The higher diversity of prey taxa taken by Willamette Oregon chub (Table 3) is consistent with this interpretation.

The mesohabitats occupied by the Willamette and Umpqua Oregon chubs had different water velocities and substrates. The differences observed could be a result of habitat availability, species interactions, biological preference, or a combination of the above. Quantitative habitat availability data are lacking, however qualitatively we observed more extensive slow to no water velocity habitats in the Willamette drainage than in the Umpqua drainage. Although the swimming performance of the Umpqua Oregon chub was poor compared to the redside shiner, the swimming performance of the Willamette Oregon chub may be even poorer because it has adapted to and inhabits slower water velocity habitats than the Umpqua Oregon chub. In short, it is unclear why Willamette Oregon chub and Umpqua Oregon chub inhabit different habitats.

Probable life history requirements of the Willamette Oregon chub makes them more susceptible to historical and present physical and biological degradation than the Umpqua Oregon chub. Life history stages of Willamette Oregon chub may require slow to no water velocities while Umpqua Oregon chub can tolerate faster water velocities. As slow water velocity habitats are eliminated or degraded, Willamette Oregon chub should decline at a faster rate than Umpqua Oregon chub. Umpqua Oregon chub can survive in faster water habitats and are not dependent on slackwater habitats. In conclusion, it appears that the reason for the differential decline of the Oregon chub in the two drainages has been from differential degradation of the two drainages, and differential tolerances of the Willamette Oregon chub and Umpqua Oregon chub to physical and biological degradation of habitat.

Persistence of the Willamette Oregon chub will require careful, longterm, management strategies that might include transplants within the native range (Williams et al., 1988), and curtailment of activities that might be harmful to the Willamette Oregon chub. Although the reasons proposed for the decline of the Willamette Oregon chub are speculative, management activities (such as introducing exotic species, and dam construction) should be carefully evaluated before implemented.

TABLE 1. Habitat suitability ratings for Willamette and Umpqua Oregon chubs.

Habitat element	Habitat Rating			
	Excellent	Very good	Marginal	Poor
WILLAMETTE				
Water velocity	none	none	slow - none	> moderate
Substrate	depositional	depositional or erosional	depositional or erosional	erosional
Depth	shallow < 1.5 m	shallow < 2.0 m	medium > 2.0 m	____
Aquatic vegetation	common	sparse - present	absent - sparse	____
Bank slope	gradual	gradual - moderate	moderate	____
Geomorphology	protected	semi - protected	unprotected	____
UMPQUA				
Water velocity	slow - none	slow - none	slow - moderate	moderate - fast
substrate	depositional or erosional	depositional or erosional	erosional	erosional
Depth	shallow < 1.5 m	shallow < 2.0 m	medium > 2.0 m	____
Aquatic vegetation	common	absent - sparse	sparse	absent - sparse
Bank slope	gradual	moderate	moderate	____

TABLE 2. Average (N=20) egg diameter (mm), and fecundity for the Oregon chub.

	Willamette		Umpqua	
TL	Fecundity	Mean Egg Diameter	Fecundity	Mean Egg Diameter
41	147	0.9		
43	156	0.8		
45	189	0.8		
45	255	0.9		
47	164	0.8		
48	212	0.8		
48	246	0.9		
49	192	0.7		
49	226	0.8		
50	291	0.9		
54	255	0.8		
56	544	0.8	332	1.1
58	184	0.8		
59			231	0.9
61	562	0.8		
62	447	0.9		
63	531	1.0		
64	671	0.8		

TABLE 3. Intestine contents (N=20) of Willamette Oregon chub caught on May 20, 1987 at 1430 at Shady Dell Pond (27-58 mm TL), and Umpqua Oregon chub caught on June 6, 1987 at 1200 at Calapooya Creek (38-49 mm TL). Analysis by percent numeric and percent occurrence methods.

	Willamette		Umpqua	
	Percent Numeric	Percent Occurrence	Percent Numeric	Percent Occurrence
Infauna	8	75	93	90
Chironomidae	7.1	70	89.1	85
Ceratopogonidae	0.1	5	0.6	15
Muscidae	0.1	5		
Hirudinea	0.1	5		
Nematoda	0.4	15	3.1	50
Epifauna	4	35	3	55
Dytiscidae	2.5	30		
Ostracoda	1.2	15		
Isopoda	0.1	5		
Trichoptera			0.4	10
Hydroptilidae			0.2	5
Hydropsychidae			0.8	15
Limnephilidae			1.2	20
Plecoptera			0.2	5
Water Column Fauna	86	100	3	55
Ephemeroptera	1.1	30	2.5	55
Callibaetis	2.8	35		
Siphlonurus	0.6	15		
Corixidae	4.2	50		
Notonectidae	0.2	10	0.2	5
Chydorus	65.8	70		
Ceriodaphnia	0.1	5		
Bosmina	2.1	25		
Daphnia	0.2	10		
Copepoda	8.9	60	0.2	5
Surface Fauna	1	25	1	20
Hydracarinid	0.2	10		
Collembola	0.1	5		
Haliplidae adult	0.3	15	0.2	5
Diptera adult	0.3	15	0.6	15
Lepidoptera adult			0.4	10
Terrestrial insects	0.2	10		
Miscellaneous				
Diptera pupa	0.1	5		
Unknown insects	0.1	5	0.4	10
Eggs	0.8	40		
Spirogyra		15		
Cladophora				15
Sand grains				70

TABLE 4. Intestine contents (N=18) of Willamette Oregon chub larvae caught throughout the spring and summer of 1986 and 1987 at Shady Dell Pond (6.2-16.0 mm TL). Analysis is by percent numeric and percent occurrence methods.

	Percent Numeric	Percent Occurrence
Rotifers		
Colurella	1.2	6
Filinia	23.5	19
Keratella	62.9	88
Lepadella	2.0	13
Trichocerca	0.6	6
Bosmina	2.8	25
Chydorus	3.4	19
Copepoda	0.6	19
Ostracoda	0.6	13
Chironomidae	1.6	44
Ephemeroptera	0.2	6
Diatoms	0.2	6
Unidentifiable	0.4	6

TABLE 5. Linear regression equations for Oregon chub length versus prey size, and intestine length. All measurements are in mm, and standard errors are beneath equations. Large=largest prey item found in the intestine, Small=smallest prey item found in the intestine, Median=median size prey item found in the intestine.

Prey Size and Intestine Length	*P*	d.f.
Willamette Oregon chub (27-58 mm TL)		
Large = -1.58 + 0.109 (TL) (2.06) (0.048)	<0.033	1,18
Median = -0.69 + 0.064 (TL) (1.50) (0.035)	<0.08	1,18
Intestine = 5.07 + 0.50 (TL) (2.92) (0.07)	<<0.0001	1,17
Willamette Oregon chub combined (6.2-58 mm TL)		
Log (large) = -1.56 + 0.058 (TL) (0.27) (0.008)	<<0.0001	1,34
Log (small) = -3.25 + 0.065 (TL) (0.25) (0.008)	<<0.0001	1,34
Log (median) = -1.99 + 0.058 (TL) (0.24) (0.007)	<<0.0001	1,34
Umpqua Oregon chub (38-49 mm TL)		
Intestine = -8.92 + 0.82 (11.76) (0.26)	<0.007	1,16

TABLE 6. Summary statistics for food size and intestine length of the Oregon chub. All measurements are in mm.

	TL	Largest Prey	Smallest Prey	Median Prey	Intestine Length
Willamette - Adults and Juveniles					
Sample size	20	20	20	20	19
Average	43	3.08	0.98	2.03	26
Mode	44	3.04	1.04	1.64	25
Stan. error	1.8	0.42	0.21	0.29	1.1
Minimum	27	0.26	0.14	0.22	16
Maximum	58	6.72	3.95	5.23	35
Willamette - Larvae					
Sample size	16	16	16	16	
Average	10.4	0.61	0.07	0.34	
Mode	10.7	0.14	0.06	0.10	
Stan. error	0.6	0.13	0.01	0.06	
Minimum	6.2	0.06	0.04	0.06	
Maximum	16.0	1.4	0.14	0.72	
Umpqua - Adults and Juveniles					
Sample size	20	17	17	17	18
Average	45	4.05	1.81	2.93	28
Mode	45	2.90	2.95	2.74	28
Stan. error	0.6	0.45	0.17	0.23	0.8
Minimum	38	1.86	0.58	1.78	20
Maximum	49	8.32	2.95	5.02	33

TABLE 7. Species associated with the Oregon chub in the Willamette and Umpqua drainages.

Species	Percent of sites	
	Umpqua (N=13)	Willamette (N=5)
Richardsonius balteatus	100	100
Ptychocheilus umpquae	92	---
Rhinichthys osculus	54	80
Catostomus sp.	54	100
Cottus sp.	46	100
Ptychocheilus oregonensis	---	40
Gasterosteus aculeatus	38	0
Ictalurus natalis	31	40
Micropterus dolomieui	23	0
Gambusia affinis	8	0
Lepomis sp.	8	0
Oncorhynchus kisutch	8	0
Percopsis transmontana	8	20
Oncorhynchus clarki	0	40
Lamprey ammocoete	0	20

Figure 1. Willamette Oregon chub (50.6 mm SL) collected from Buckhead Creek Slough, (OS 9620).

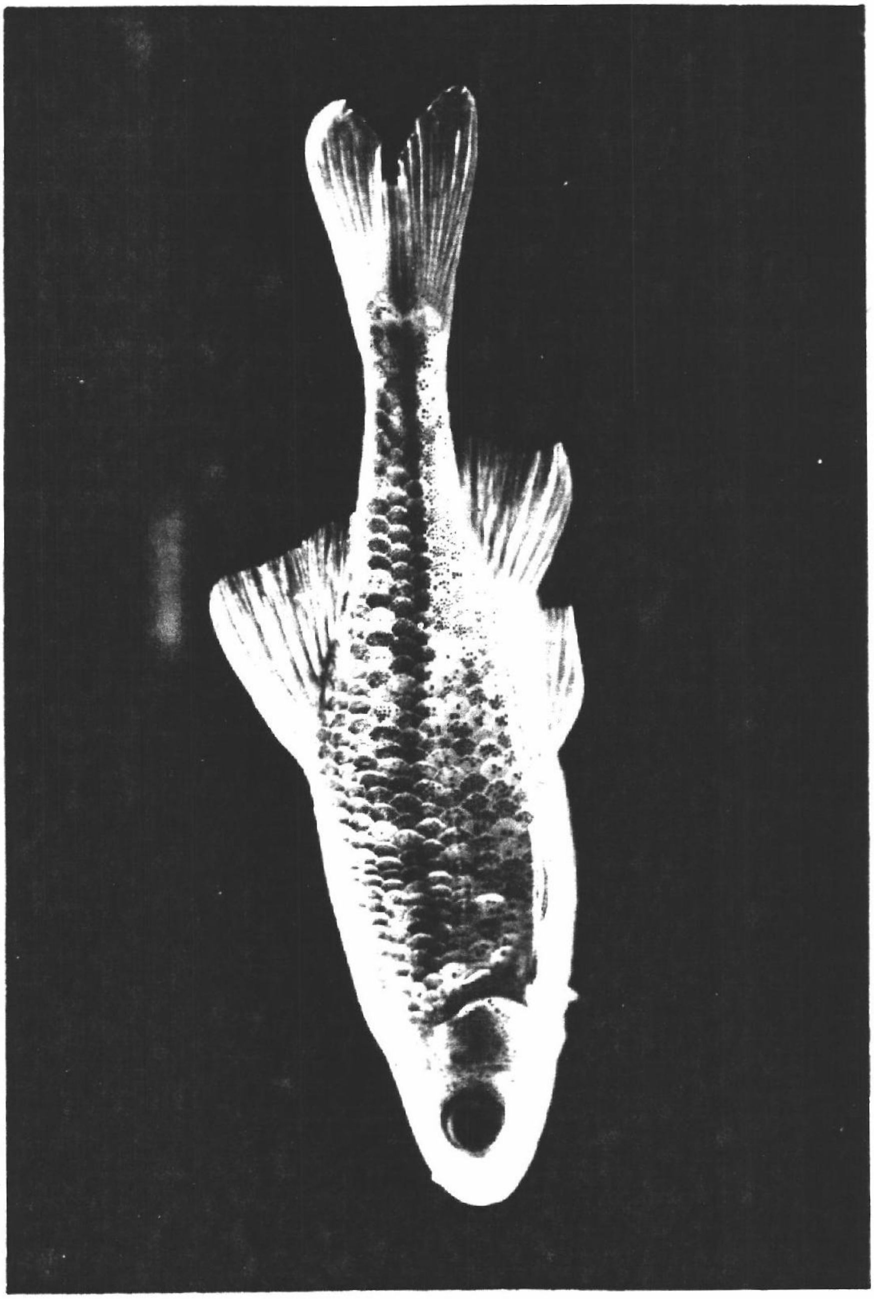


Figure 1.

Figure 2. Distribution of the Willamette Oregon chub. Point 1 to 5 is about 15-miles of the Middle Fork of the Willamette River. Point 1 - Buckhead Creek, 2 - Shady Dell Pond, 3 - Hazel Creek Slough, 4 - Rolling Riffle Slough, and 5 - the "Pit".

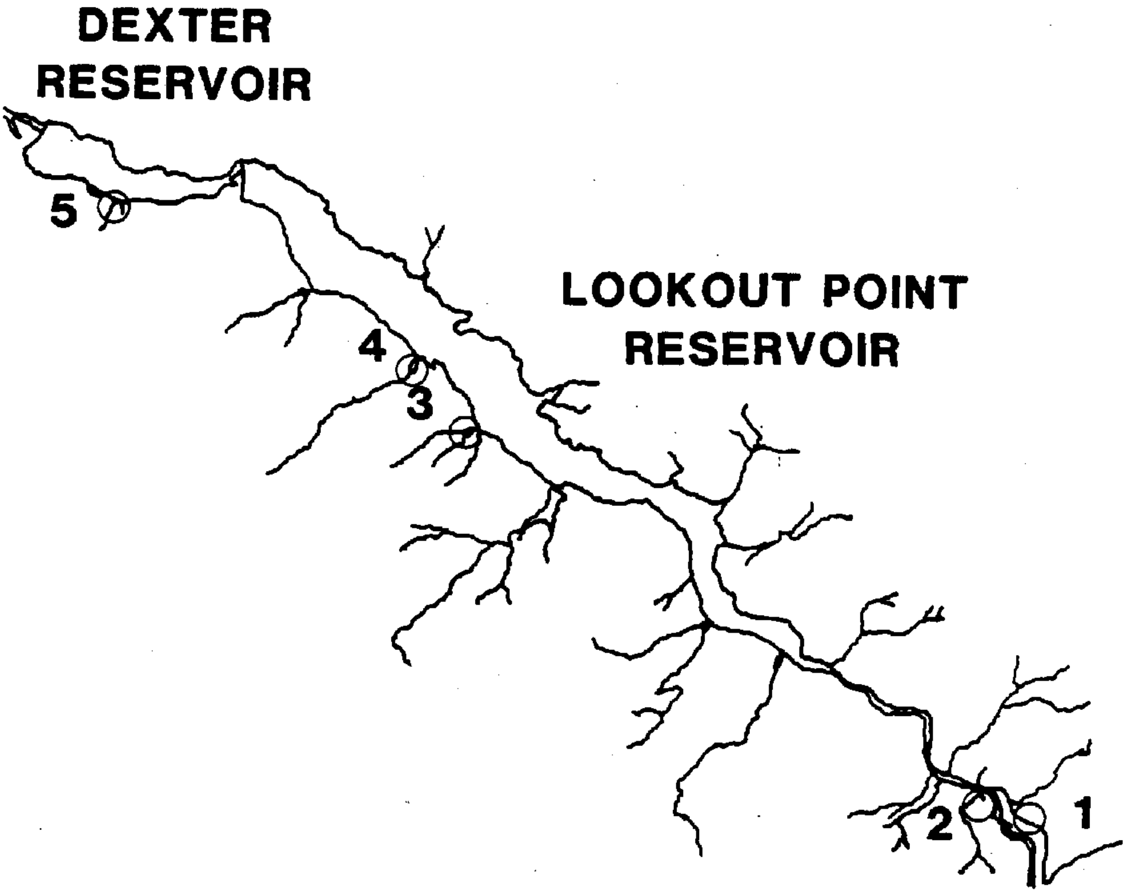


Figure 2.

Figure 3. Flow chart illustrating how habitat suitability ratings for Oregon chub were derived and used. (+) = Oregon chub present, (-) = Oregon chub absent.

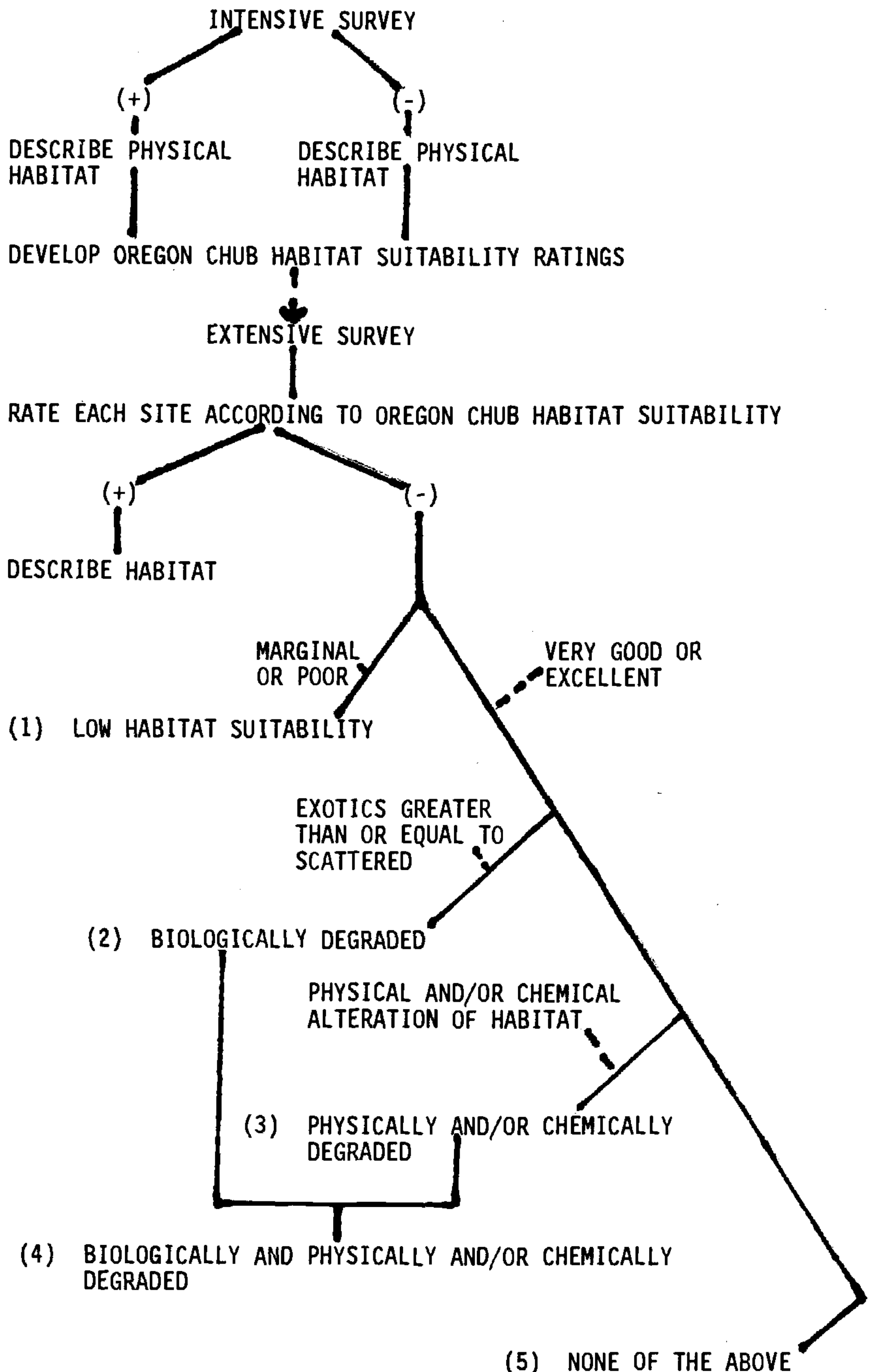

INTENSIVE SURVEY
(+)
(-)
DESCRIBE PHYSICAL HABITAT
DESCRIBE PHYSICAL HABITAT
DEVELOP OREGON CHUB HABITAT SUITABILITY RATINGS
EXTENSIVE SURVEY
RATE EACH SITE ACCORDING TO OREGON CHUB HABITAT SUITABILITY
(+)
(-)
DESCRIBE HABITAT
MARGINAL OR POOR
VERY GOOD OR EXCELLENT
(1) LOW HABITAT SUITABILITY
EXOTICS GREATER THAN OR EQUAL TO SCATTERED
(2) BIOLOGICALLY DEGRADED
PHYSICAL AND/OR CHEMICAL ALTERATION OF HABITAT
(3) PHYSICALLY AND/OR CHEMICALLY DEGRADED
(4) BIOLOGICALLY AND PHYSICALLY AND/OR CHEMICALLY DEGRADED
(5) NONE OF THE ABOVE

Figure 3.

Figure 4. Distance from shore and number of sightings for larvae of the Willamette Oregon chub in Shady Dell Pond. The x-axis is the available distance from shore.

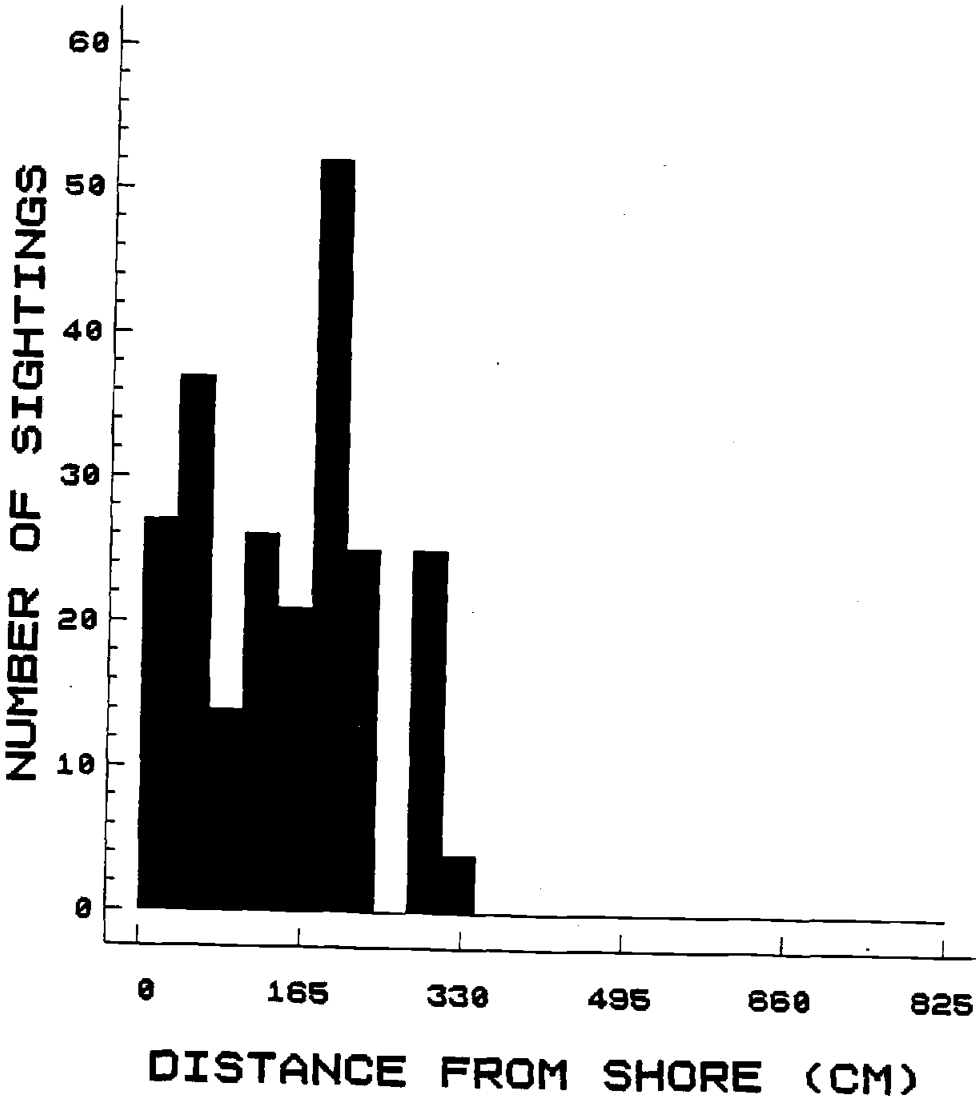
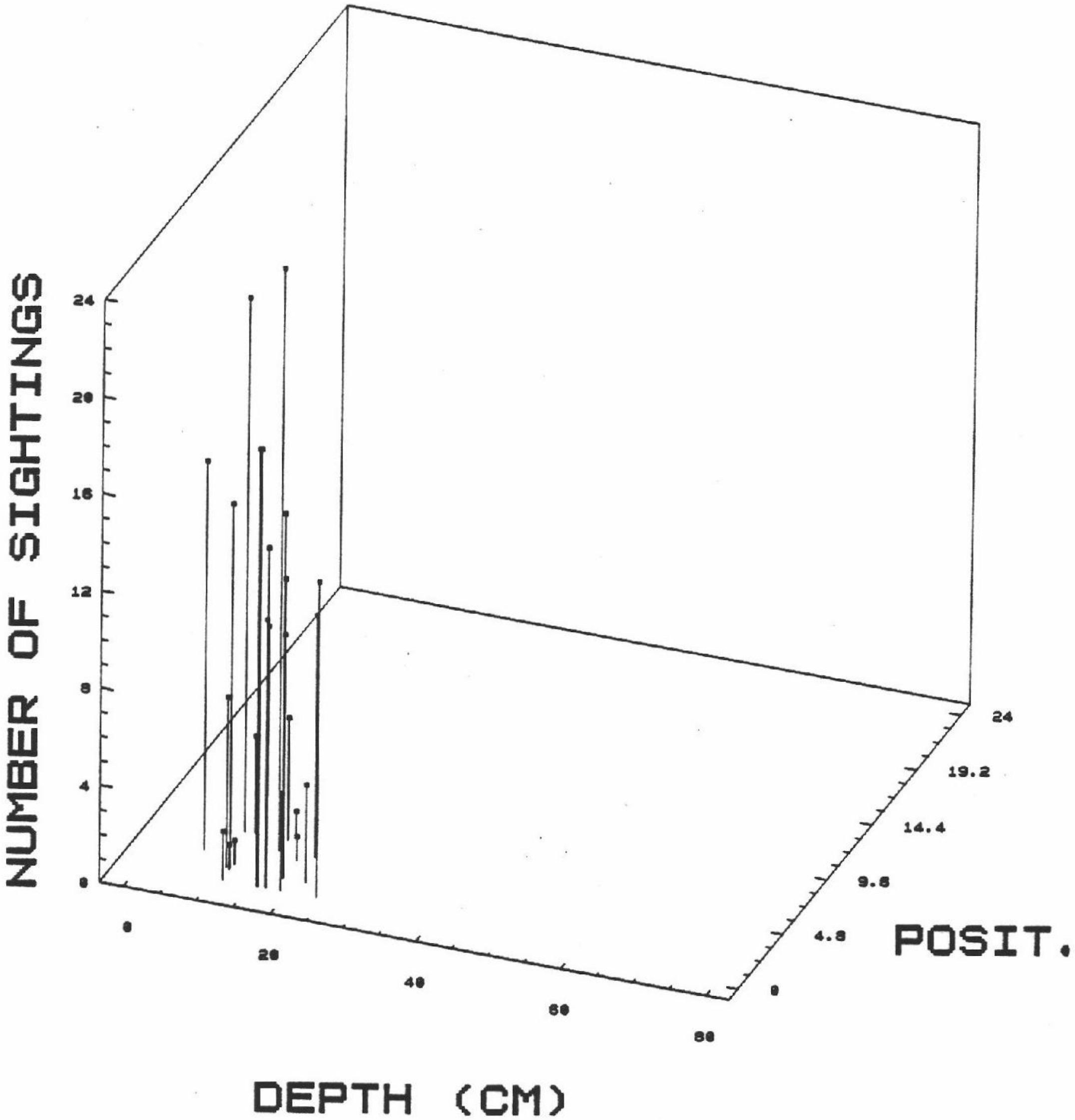

NUMBER OF SIGHTINGS
60
50
40
30
20
10
0
0
165
330
495
660
825
DISTANCE FROM SHORE (CM)

Figure 4.

Figure 5. Number of sightings in relation to depth of the water column and position (posit. = distance below the surface in cm) of larvae of the Willamette Oregon chub.



NUMBER OF SIGHTINGS
24
20
16
12
8
4
0
0
20
40
60
80
DEPTH (CM)
0
4.8
9.6
14.4
19.2
24
POSIT.

Figure 5.

Figure 6. Length frequency graph for 339 specimens of the Umpqua Oregon chub captured on August 24, 1987 at Elk Creek.

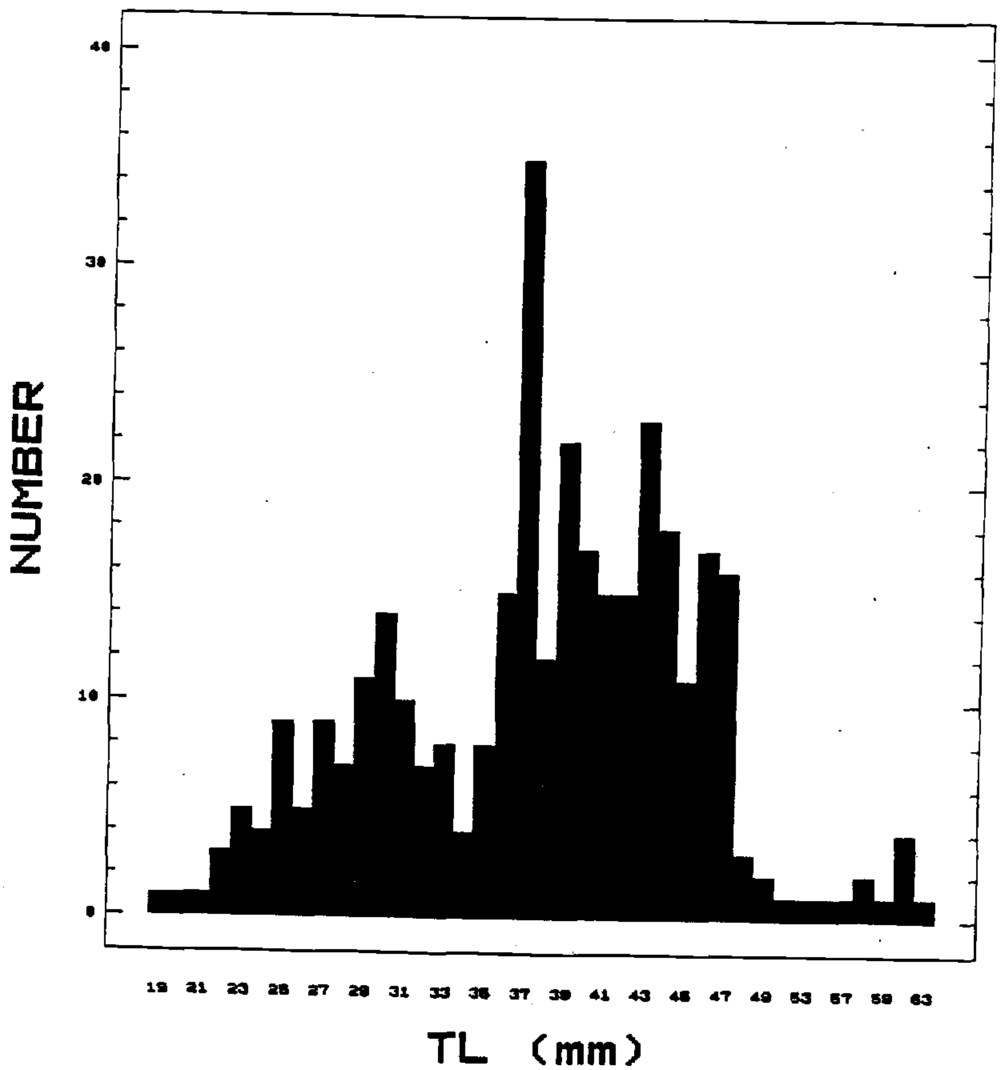

40
30
20
10
0
NUMBER
19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 53 57 59 63
TL (mm)

Figure 6.

Figure 7. Sampling sites and distribution (closed figures and arrow) of the Oregon chub in the Willamette and Umpqua river drainages. Open figures (circles and squares) represent sites sampled at which no Oregon chub were captured or observed.

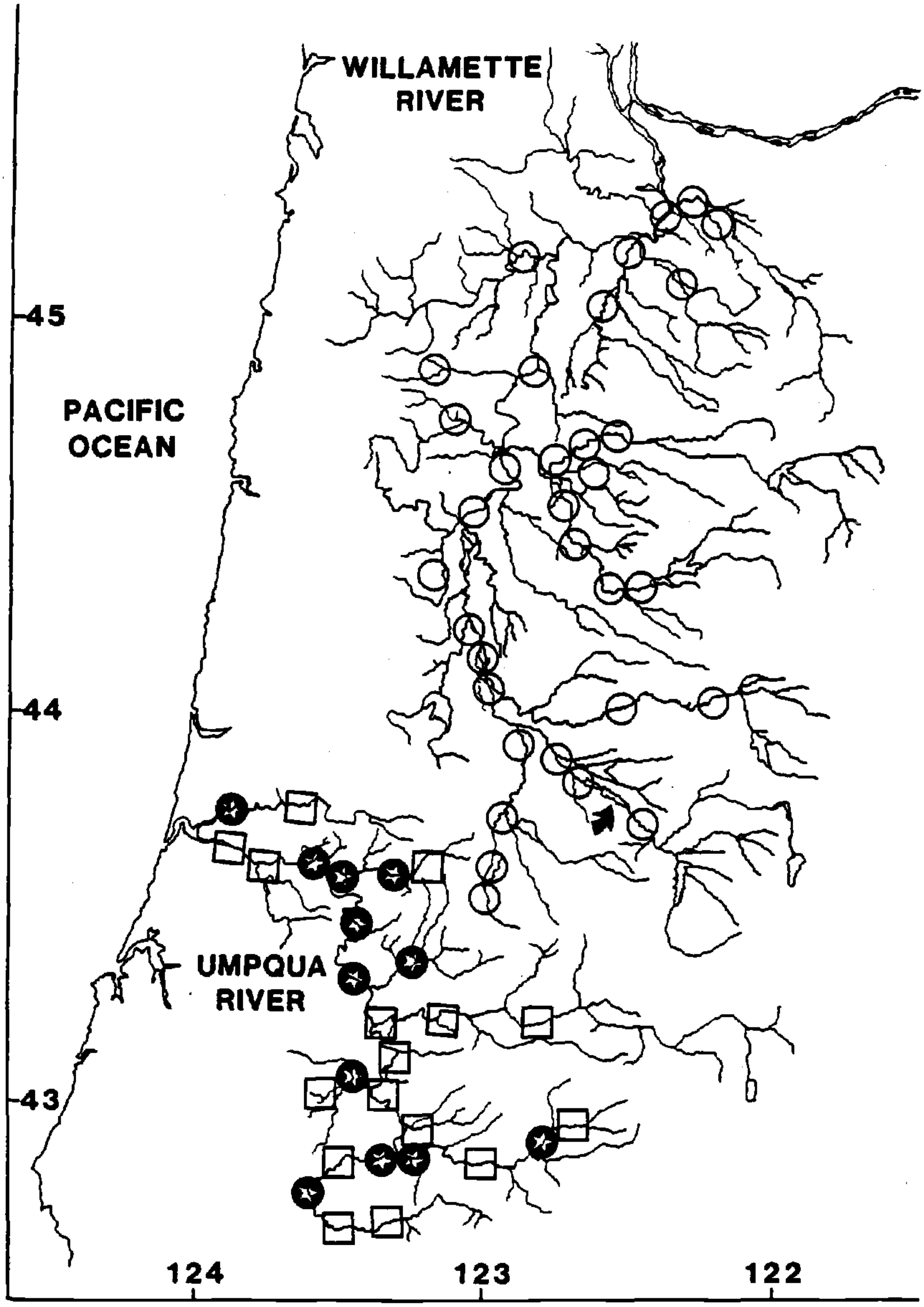

WILLAMETTE
RIVER
PACIFIC
OCEAN
UMPQUA
RIVER
45
44
43
124
123
122

Figure 7.

Figure 8. Distribution of the Oregon chub in the Willamette and Umpqua river drainages.

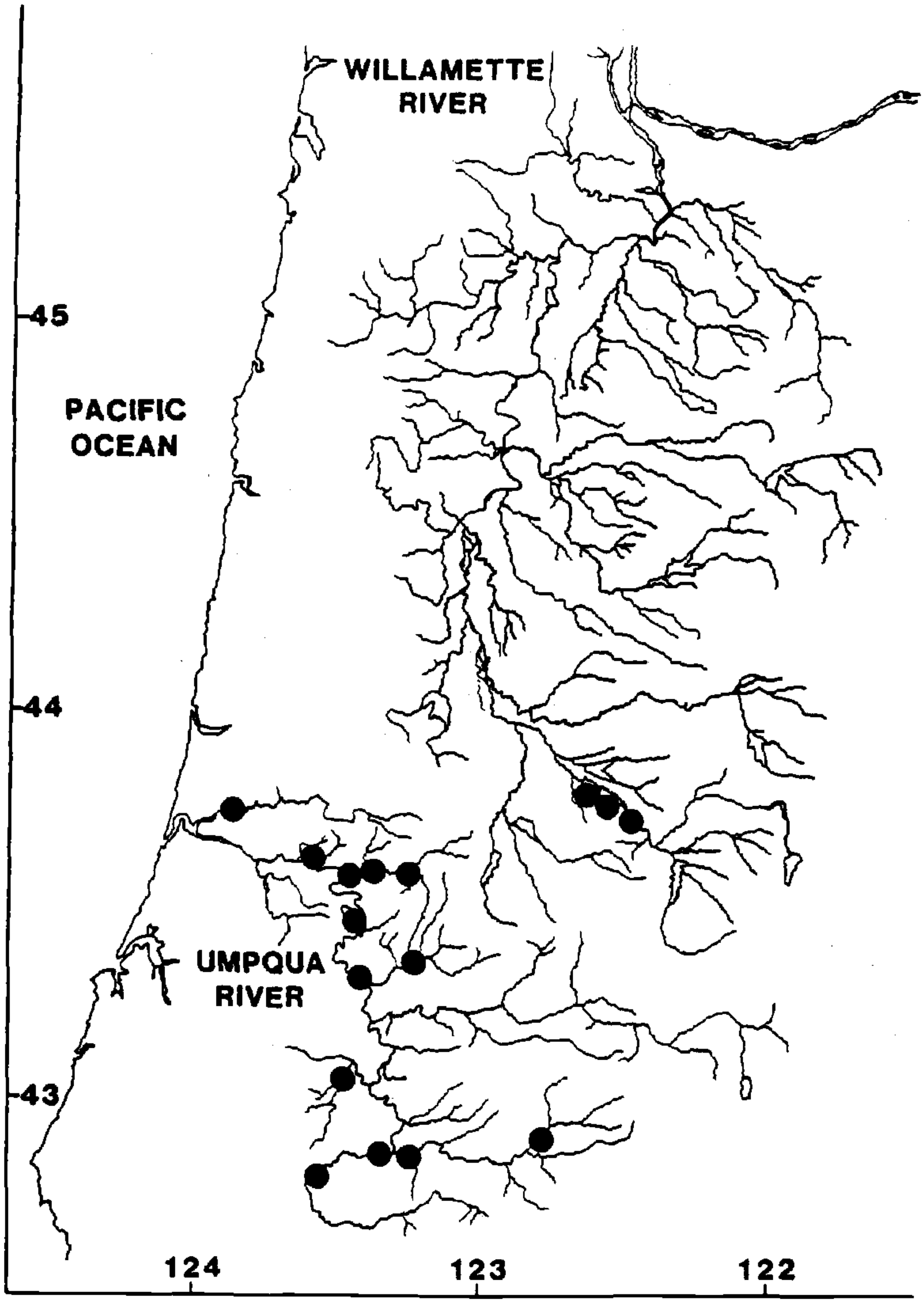

WILLAMETTE
RIVER
PACIFIC
OCEAN
UMPQUA
RIVER
45
44
43
124
123
122

Figure 8.

Figure 9. Channelization of the Willamette River at four intervals from 1854 to 1967. Reach of Willamette River examined was from the McKenzie River to Harrisburg. (Li *et al.*, 1987).

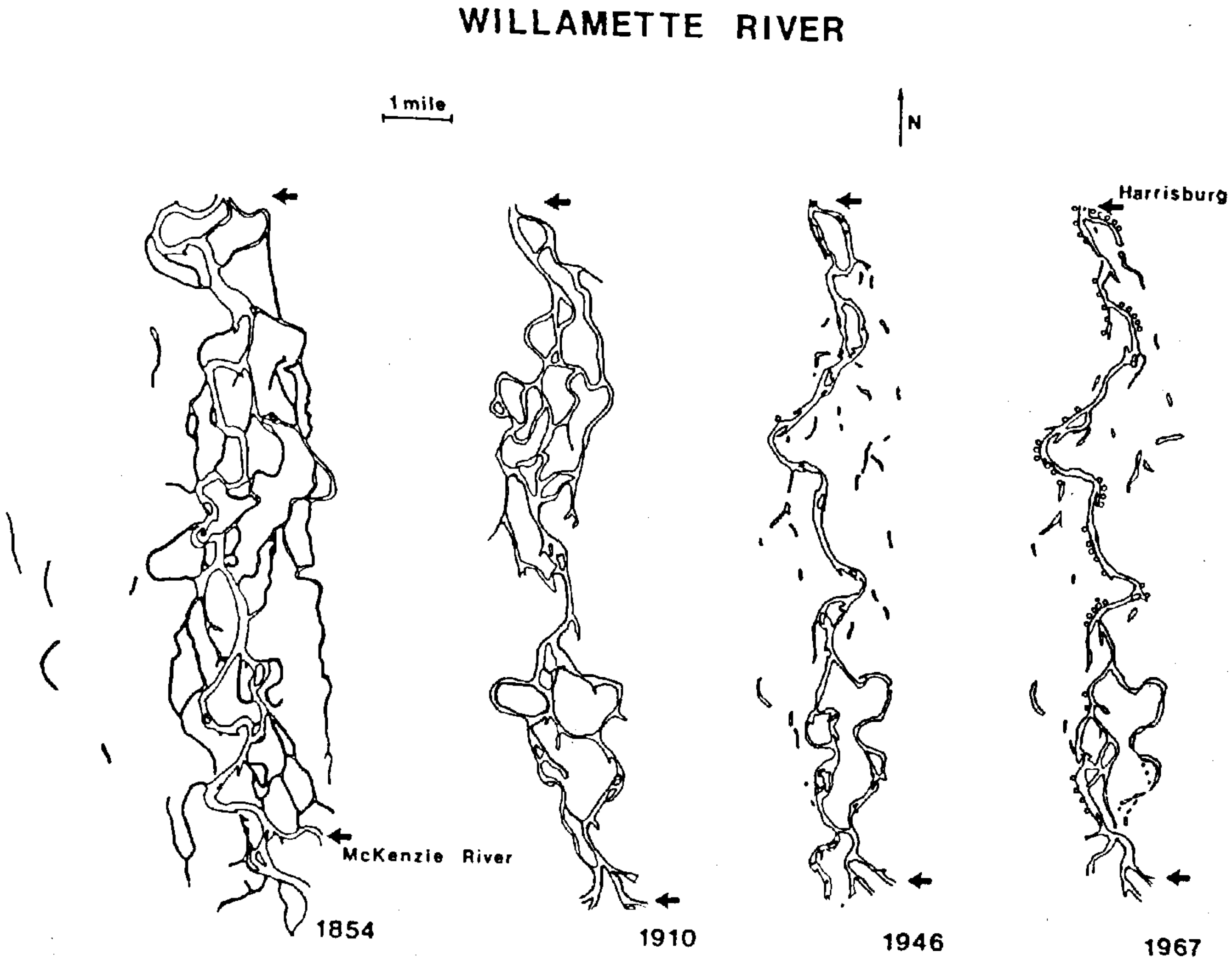

WILLAMETTE RIVER
1 mile
N
Harrisburg
McKenzie River
1854
1910
1946
1967

Figure 9.

Description and Illustration of Willamette Oregon Chub Larvae (*Oregonichthys crameri*)

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ABSTRACT

Larval stages of Willamette Oregon chub are described and illustrated. The following combination of characters distinguish Willamette Oregon chub larvae from other cyprinid larvae found in the Willamette drainage: 33-37 myomeres, preanal length of 52-61%, and absence of snout pigment.

INTRODUCTION

The Oregon chub inhabits the Willamette and Umpqua river drainages of western Oregon (Bond, 1966, 1974; Long, 1980; this study chapter 1). Long (1980) stated that Willamette and Umpqua Oregon chub may be different subspecies. The Willamette Oregon chub is now restricted to approximately 15 miles of the Middle Fork of the Willamette River (See this study chapter 1). Little is known about the biology of this rare species (Long, 1980; this study chapter 1), and there is no information in the literature regarding Oregon chub larvae.

Larval stages of cyprinid larvae present in the Willamette drainage are well documented for *Carassius auratus* (Jones *et al*., 1978), *Cyprinus carpio* (Jones *et al*., 1978), *Tinca tinca* (Muus, 1967), *Mylocheilus caurinus* (Miura, 1962), *Ptychocheilus oregonensis* (Miura, 1962), *Rhinichthys cataractae* (Fish, 1932; Fuiman and Loos, 1977), *Rhinichthys osculus* (Winn and Miller, 1954), *Richardsonius balteatus* (Weisel and Newman, 1951; Miura, 1962). Larval descriptions and illustrations were not found for *Acrocheilus alutaceus*, *Oregonichthys crameri*, and *Rhinichthys falcatus*. A description and illustration of Willamette Oregon chub larvae is presented to aid identification.

METHODS

Willamette Oregon chub larvae were collected on June 6, 1986, May 20, 1987, and June 3 and 11, 1987 at Shady Dell Pond. The larvae were fixed in 5% buffered formalin and illustrated with the aid of a camera lucida.

Morphometric characters recorded were total length (TL), standard length, preanal length, head length, and eye diameter. Preanal length, head length, and eye diameter were divided by their respective TL and regressed with fish TL. Slopes significantly different from zero suggested allometry. Meristic characters recorded were dorsal, anal, and caudal fin ray counts, preanal myomeres, and total myomere counts. Descriptive characters recorded were pigment development, state of flexion, state of pelvic and pectoral fin development, state of swimbladder formation, presence of preanal finfold, shape of eye, and shape of intestine. Following Fuiman et al. (1983), measurements are expressed in mm, and total length is used rather than standard length.

RESULTS

Eighteen Willamette Oregon chub larvae ranging in size from 6.2 mm to 16.0 mm were used for the analysis (Table 8).

Pigment

From about 6.2 to 6.7 mm scattered melanophores cover the snout, and an outlined oval of melanophores over the brain tapers posteriorly, extending in two series on either side of the dorsal fin fold (Fig. 10.A). From 8.5 to 16.0 mm increasing numbers of dorsal melanophores cover the dorsum but follow the same pattern as described above.

Laterally (6.2 to 6.7 mm) there is a series of melanophores extending from the head region to the swimbladder, and then continuing along the notochord (Fig. 10.B). From 8.5 to 16.0 mm melanophore density increases over the swimbladder (Fig. 11.A, and 11.B). The distinct line of pigment over the notochord becomes obscured from an increase in melanophores extending downward along the myomeres. Melanophores overlaying the myomeres are most evident posteriorly, with melanophores anterior to the dorsal fin more evenly spaced and not overlaying the myomeres as they do posteriorly. A thin line of melanophores on the body can be seen along the margins of the dorsal surface, and the ventral surface behind the anus (Fig. 10.B). By 8.5 mm melanophores extend onto the dorsal surface of the intestine (Fig. 11.A, and 11.B). Melanophores form on both sides of the developing caudal rays (Fig. 10.B, 11.A, and 11.B).

From 6.2 to 6.7 mm the isthmus has a distinct wedge shaped outline of melanophores (Fig. 10.C). A ventral series of melanophores extends from the anus to the posterior end of the body. From about 8.5 to 11.6 mm a series of melanophores on the ventral surface of the body beneath the intestine are beginning to outline the gut posteriorly (Fuiman et al., 1983). By about 13.0 mm the ventral outline of the gut is complete.

Head

Head length increased from 1.2 mm (6.2 mm TL) to 3.3 mm (16.0 mm TL; Table 8). The relationship can be described by the equation: head length = 0.023 + 0.21 (TL mm) (overall F-test $p << 0.0001$; df=1, 16). The standard errors for the intercept and slope are 0.108 and 0.01 respectively. Change in head length is isometric with total length (overall F-test $p < 0.935$; df=1, 16). The mouth and nasals openings were noticeably more developed by 9.5 to 9.9 mm.

Eye diameter increased from 0.4 mm (6.2 mm TL) to 1.1 mm (16.0 mm TL; Table 8). The relationship between eye diameter and TL can be described by the equation:

eye diameter = 0.13 + 0.065 (TL mm) (overall F-test $p << 0.0001$; df=1, 16). The standard errors for the intercept and slope are 0.05 and 0.005 respectively. Negative allometric growth may be suggested for eye diameter (overall F-test $p < 0.050$; df=1, 16).

From 6.2 mm TL to 6.7 mm TL the eye was flattened (Fig. 10.B; see Fuiman et al., 1983). From 8.5 mm TL to 9.0 mm TL the eye was in transition to the rounded state (Fig 11.A). Larvae longer than 9.5 mm had round eyes (Fig. 11.B).

Body

Preanal length increased from 3.5 mm (6.2 mm TL) to 8.7 mm (16.0 mm TL; Table 8). The increase in preanal length can be described by the equation:

preanal length = 0.24 + 0.54 (TL) (overall F-test $p<<0.0001$; df=1, 16). The standard errors for the intercept and the slope are 0.24 and 0.02 respectively.

Allometric growth for preanal length is not suggested (overall F-test $p<0.568$; df=1, 16).

Preanal myomeres ranged from 19-21. Total myomeres ranged from 33-35. The preanal finfold was present in all larvae up to 13.4 mm TL (Fig. 10.B and 11.A) and resorbed by 16.0 mm TL (Fig. 11.B).

Larvae shorter than 6.7 mm had a one chambered swimbladder that was located anteriorly. By 8.5 mm larvae had two chambered swimbladders.

Larvae shorter than 10.1 mm had straight intestines. From 10.7 mm to 11.6 mm the intestine started to bend. From 13.0 mm to 13.4 mm the intestine was quite bent (s-shaped) and fish greater than 16.0 mm had intestines that were almost completely bent or were completely bent.

Fins

Larvae smaller than or equal to 6.7 mm had no structural elements in the dorsal fin (Fig 10.B; Table 8). From 8.5 to 9.0 mm the larvae had 3-6 anlagen that began forming in the middle of the fin (Fig 11.A). Between 9.5 mm and 16.0 mm the larvae had from 8 to 11 rays (Fig. 11.B). The majority of the larvae (67%) in this size range had 10 rays.

Larvae smaller than or equal to 8.5 mm had no structural elements in the anal fin (Table 8). Four to five anlagen were present between 8.7 and 9.0 mm (Fig. 11.A). Between 9.5 mm and 11.6 mm a minimum of 3 rays and 4 anlagen was present whereas a maximum of 10 rays was present. Throughout this size range the counts did not increase steadily with increasing TL. Larvae longer than 11.6 mm had essentially the adult complement (9 or 10 rays).

Larvae smaller than or equal to 9.8 mm had no upper caudal procurrents (Table 8). Between 10.1 mm and 11.6 mm larvae had 1 upper procurrent (one 11.6 mm larva had 4 upper procurrents). Between 11.6 mm and 16.0 mm larvae had from 3-6 upper procurrents.

Larvae smaller than or equal to 6.2 mm had no upper primary rays or anlagen in the caudal fin (Table 8). A 6.7 mm larva had 5 upper primary rays and 4 anlagen. All larvae longer than 8.5 mm had 10 upper primary rays.

Larvae smaller than or equal to 6.2 mm had no lower primary rays or anlagen in the caudal fin (Table 8). A 6.7 mm larva had 5 lower primary rays and 3 anlagen, and an 8.5 mm larva had 8 lower primary rays and 1 anlage. Larvae greater than or equal to 8.7 mm had 9 primary rays.

Larvae smaller than or equal to 9.0 mm had no lower procurrents. Between 9.5 mm and 10.4 mm larvae had 1 or 2 lower procurrents. Between 11.6 mm and 16.0 mm larvae had 2-6 lower procurrents.

Caudal flexion began at 6.7 mm and was still observed in larvae 13.4 mm long. The smallest postflexion individual was 16.0 mm.

Pelvic buds started forming from 9.5 mm to 9.8 mm. Buds were present from 10.1 mm to 11.6 mm. From 11.6 mm to 13.4 mm, pelvic fins were forming with some rays present or forming. Fish longer than 16.0 mm appeared to have complete pelvic fins.

Pectoral buds started forming at 6.2 mm. Rudimentary pectoral buds were present until larvae reached 9.0 mm (Fig. 11.A). Well developed buds were observed between 9.5 mm and 11.6 mm. From 11.6 mm to 13.4 mm, pectoral fins were forming with some rays present or forming. Fish longer than 16.0 mm appeared to have complete pectoral fins (Fig. 11.B).

DISCUSSION

A method for distinguishing Willamette Oregon chub larvae from the other cyprinids in the Willamette drainage is described below.

Based on vertebral counts of greater or less than 33-37, *O. crameri* can be separated from the following species, *Acrocheilus alutaceus* (44-45), *Carassius auratus* (usually 28 or 29), *Mylocheilus caurinus* (44-46), *Ptychocheilus oregonensis* (44-46), *Tinca tinca* (38-39), *Rhinichthys falcatus* (38-40), and *Richardsonius balteatus* (38-43) (Scott and Crossman, 1973).

Species that had vertebral counts that overlapped the range of 33-37 (*Cyprinus carpio*, *Rhinichthys osculus*, and *Rhinichthys cataractae*) were separated by % preanal length, and lateral snout pigment. *Cyprinus carpio* has preanal lengths greater than 65% TL (Fuiman *et al*., 1983) whereas Willamette Oregon chub have mean preanal lengths equal to 52-61% TL. *Rhinichthys sp*. have lateral snout pigment

(Fuiman and Loos, 1977), which the Willamette Oregon chub does not have (Fig. 10.B, 11.A,B).

Since a small number of specimens were examined and the redside shiner is often associated with the Willamette Oregon chub (this study chapter 1), additional characters for distinguishing the two species are presented. The development of Willamette Oregon chub will be contrasted to development of the redside shiner as reported by Weisel and Newman, (1951). Pectoral fins are well developed in the redside shiner (rays are apparent only in pectoral fins) by 6.0 to 8.0 mm TL, whereas Willamette Oregon chub have well developed pectorals at about 11.6 mm TL. "The extreme tip of the caudal vertebrae is barely upturned and caudal fin rays are just evident" in the redside shiner at 8.0-8.5 mm TL. In contrast the Willamette Oregon chub begins flexion and has caudal fin rays evident at or before 6.7 mm. The swimbladder in the redside shiner does not become divided until 11.0-11.8 mm whereas the swimbladder is divided in the Willamette Oregon chub by 8.5 mm. Anal fin rays are variable but are greater than or equal to 10 by 12.8-13.4 mm (Table 8), whereas the anal fin ray count for the Willamette Oregon chub is always 10 or less for the rest of it's development. It is interesting to note, that the pectoral fins develop earlier in the redside shiner but the caudal fin develops earlier in the Willamette Oregon chub.

Fuiman et al., (1983) identified four major characters that could be used to segregate cyprinid larvae into groups (though unrelated) from eastern North America. The characters used were relative preanal length, eye shape, preanal myomere number, and midventral pigmentation (presence of midventral stripe, scattered breast melanophores, and outlined gut). Willamette Oregon chub larvae have a flattened eye early in development (Fig. 10.B) and have an outlined gut later in development. Fuiman et al. (1983) set up their larval groupings so that "a particular species may fit into several groups, but it is discussed only in the first one that describes it." Since the flattened eye group comes before the outlined gut group, the Willamette Oregon chub falls into the former. This group consists of 3 species of Hybopsis, 3 species of Notropis, 2 species of Pimephales, and 1 species of Phenacobius.

TABLE 8. Meristic and morphometric characters for 18 larvae of the Willamette Oregon chub. All lengths are in mm. Anlage in parenthesis, UP = upper procurrent, LP = lower procurrent, U = upper rays, L = lower rays.

Character	Specimen Number								
	1	2	3	4	5	6	7	8	9
Total length	6.2	6.2	6.7	8.5	8.7	9.0	9.5	9.9	9.8
Standard length	5.9	6.1	6.4	7.6	7.9	7.9	8.7	8.7	8.8
Head length	1.2	1.3	1.4	1.7	1.8	1.9	2.3	2.1	2.1
Eye diameter	0.4	0.5	0.6	0.7	0.7	0.7	0.8	0.7	0.8
Preanal length	3.5	3.6	3.6	4.7	4.9	4.9	5.6	5.6	5.6
% Preanal length	56	58	53	56	56	55	59	57	57
Dorsal rays	0	0	0	(3)	(7)	(6)	10	8	10
Anal rays	0	0	0	0	(5)	(4)	6(2)	3(4)	4(3)
Caudal UP	0	0	0	0	0	0	0	0	0
U	0	0	5(4)	10	10	10	10	10	10
L	0	0	5(3)	8(1)	9	9	9	9	9
LP	0	0	0	0	0	0	2	1	1

TABLE 8. Continued

Character	Specimen Number								
	10	11	12	13	14	15	16	17	18
Total length	10.1	10.7	10.7	10.4	11.6	11.6	13.0	13.4	16.0
Standard length	8.8	9.2	9.4	9.5	10.3	10.6	10.7	11.8	13.1
Head length	2.1	2.2	2.2	2.4	2.4	2.6	2.7	2.9	3.3
Eye diameter	0.8	0.8	0.8	0.9	0.8	1.0	1.0	1.0	1.1
Preanal length	5.6	6.1	6.0	6.3	6.5	6.9	6.8	7.4	8.7
% Preanal length	55	58	56	61	56	60	52	55	54
Dorsal rays	10	10	10	10	9	10	11	10	10
Anal rays	8	7(1)	6(2)	6(2)	7(1)	10	9	10	9
Caudal UP	1	1	1	1	1	4	3	4	6
U	10	10	10	10	10	10	10	10	10
L	9	9	9	9	9	9	9	9	9
LP	1	2	2	2	2	5	3	4	6

Figure 10. Dorsal (A), lateral (B), and ventral (C) views of Willamette Oregon chub larvae, (OS 11494), TL = 6.4 mm.

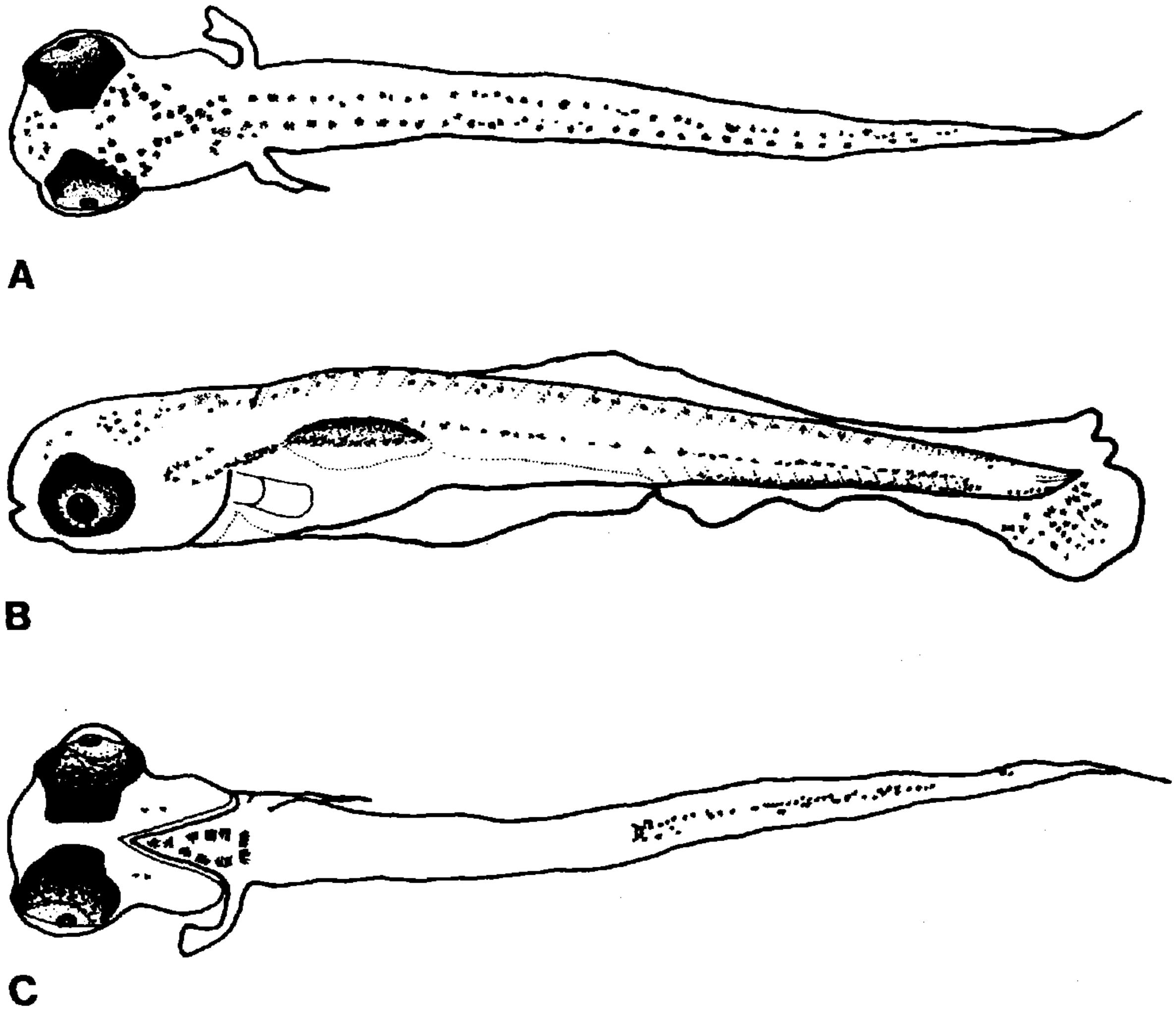

Figure 10.

Figure 11. Lateral views of larvae of Willamette Oregon chub, (OS 11494), (A) TL = 9.0 mm, (B) TL = 16.0 mm.

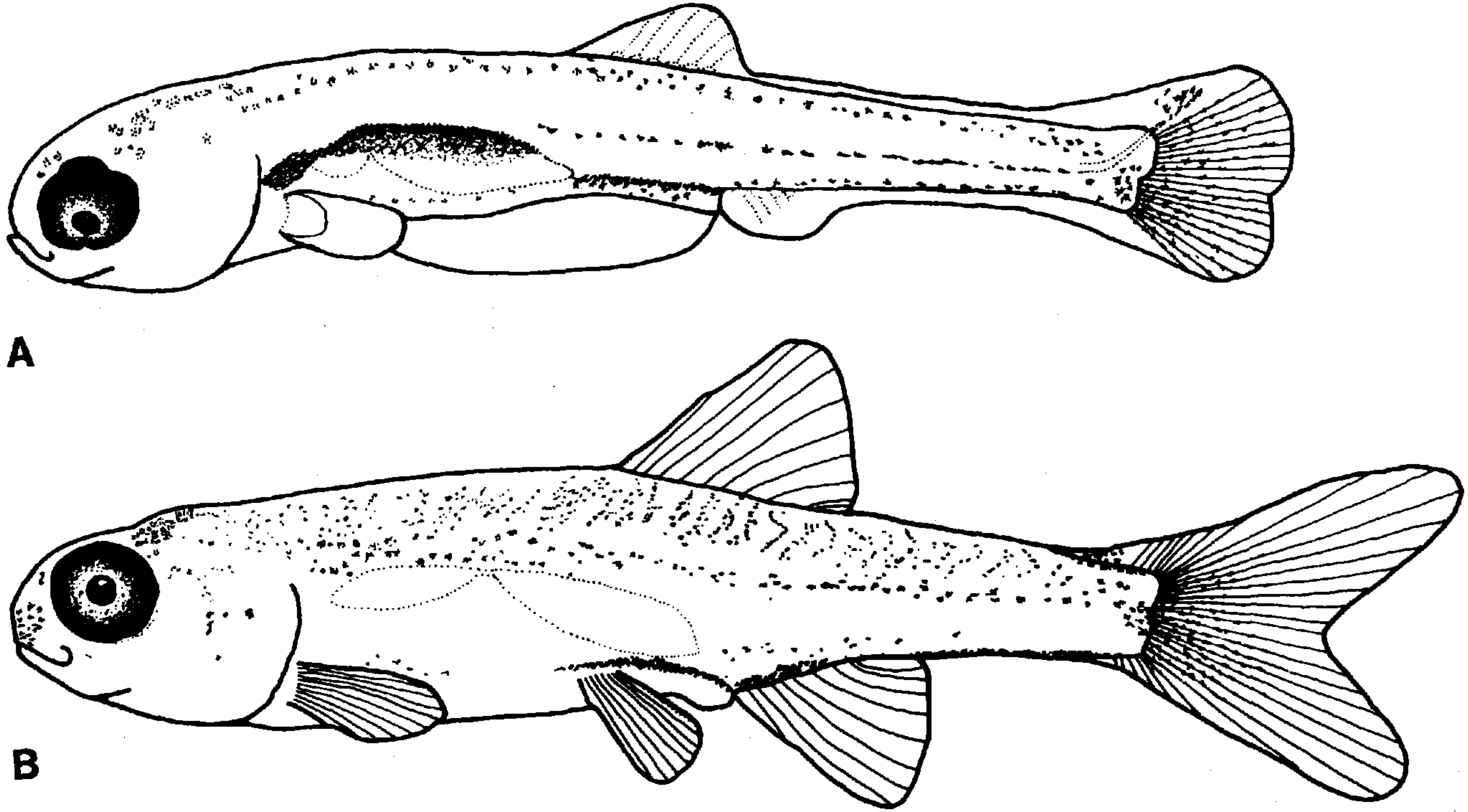

Figure 11.

GENERAL DISCUSSION

The Oregon chub should be allowed to exist if the value of preserving Oregon chub outweighs the value of driving it to extinction. Endangered species are usually undervalued, and by default, valued economically because there has been "an incomplete specification of the full range of values associated with biological diversity, and a lack of empirical, numerical, and commenssurable assessments of these values" (Kellert, 1986). Kellert (1986) lists seven discrete values that people in developed countries associate with wildlife: naturalistic/outdoor recreational value, ecological value, moral or existence value, scientific value, aesthetic value, utilitarian value, and cultural, symbolic, and historic value. Not all species have the same values associated with them.

For most people, Oregon chub have moral or existence, scientific, and perhaps ecological and utilitarian value. As snorkeling in the freshwaters of Oregon is not very popular, Oregon chub have little naturalistic/outdoor recreational value. Few would think Oregon chub have aesthetic value, and to my knowledge Oregon chub do not function as expressions of group identity (cultural, symbolic, and historic value). Oregon chub may be important ecologically but little is known about the Oregon chub, and the interaction of Oregon chub with the habitat and the rest of the biotic community that it is difficult to speculate. Oregon chub may have utilitarian value but ignorance of the biology of the fish precludes a definitive answer. From a moral or religious standpoint most people would agree that the Oregon chub has the right to exist or has some kind of spiritual importance.

Scientific value may be the most important reason for preserving the Oregon chub.

Although little is known about the Oregon chub (Long, 1980) what is known should encourage us to preserve this fish. Oregon chub are the sole member of the genus Oregonichthys, (Mayden, 1988). Extinction of the Oregon chub results in elimination of an entire genus. If the main aim of conservation is to maintain a high level of floral and faunal diversity, higher taxa should be given preservation priority over lower taxa. Oregon chub in the Willamette drainage may be different taxonomically and ecologically from those in the Umpqua drainage (Long, 1980).

Land use practices that threaten Oregon chub existence (Long and Bond, unpublished data; Li et al., 1987) have associated cultural values but also have direct economic values. Channelization of the Willamette River has benefitted those involved in agriculture and river transportation. Increasing the land available for farming can be accomplished by filling in backwaters, and by revetting the banks to prevent erosion.

Exotic species may have been a reason for the decline of the Oregon chub (Long and Bond, unpublished data), but may increase the angling opportunities of a region, creating increased revenue. Salmonids are economically the most important game fishes in the Willamette and Umpqua basins. Exotic species may compete or prey (Taylor et al., 1984) on salmonid species. Although the diversity of angling opportunities may increase with the introduction of exotic fishes the money made from angling may decrease from the loss of revenue from the salmonid fishery.

Values associated with activities that compete with Oregon chub existence are primarily economic and cultural whereas values associated with Oregon chub existence are primarily moral or existence, and scientific. Economic values, such as an increase in arable land, are easily quantified and can be realized in the short term. Moral or existence, and scientific values are more difficult if not impossible to quantify and may be realized in the long term. Two strategies exist: 1) a high risk option in which there is permanent loss of an unknown value (extinction of the Oregon chub) with immediate economic return or 2) a low risk option in which economic return is reduced (preservation of the Oregon chub) with long term moral or existence, and scientific return. Society will determine the fate of this rare Oregon fish based on the values it esteems highest during the present time period.

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APPENDICES

TABLE 9. Water chemistry at Shady Dell Pond and Buckhead Creek Slough.

	Shady Dell 7/30/86	Buckhead 7/30/86	Shady Dell 1/9/87	Buckhead 1/9/87
Alkalinity[a]			36	41
Chlorides	1.0	7.8	2.7	3.5
Copper	0.004	0.003	<0.002	<0.002
Hardness ($CaCO_3$)	36	40	33	26
Iron	0.09	0.26	0.38	0.50
Manganese	0.012	0.015	0.007	0.013
pH	9.25	7.60	6.41	7.03
Solids: (Residue)				
Filterable (Total Solids)	56	67	61	57
Nonfilterable (Sand)	7	6	1.2	<1.0
Specific Conductance	110	125	103	77
Sulfates	5.3	2.4	5.3	3.9
Total Dissolved Solids (Est)	56	63	52	39
Zinc	0.004	0.0085	0.005	0.003
Arsenic	<0.010	<0.010	<0.010	<0.010
Barium			<0.20	<0.20
Cadmium	0.003	<0.002	<0.002	<0.002
Chromium			<0.005	<0.005
Fluoride			0.10	0.10
Lead			<0.01	<0.01
Mercury			<0.0002	<0.0002
Nitrate	<0.01	<0.01	<0.01	0.05
Selenium			<0.002	<0.002
Silver			<0.002	<0.002
Sodium			3.8	2.8
Temperature (C)	27	19	3	3
Dissolved Oxygen	10	11	9	12

[a]Except for temperature and dissolved oxygen, above analysis performed by Water Analysis & Consulting, Inc. (All values are expressed as mg/l, except Specific Conductance which is expressed as umho/c).

TABLE 10. Aquatic vegetation seen at Shady Dell Pond and Buckhead Creek Slough.

	Shady Dell	Buckhead
Strict Aquatics		
Fontinalis antipyretica	x	x
Spirogyra	x	x
Callitriche	x	
Potamogeton filiformis	x	
Azolla filiculoides	x	x
Lemna minor	x	x
Elodea densa		x
Ludwigia palustris		x
Spirodela polyrhiza		x
Marginal Aquatics		
Alisma	x	x
Sparganium	x	
Eleocharis	x	
Typha latifolia	x	
Equisetum	x	
Mentha	x	
Juncus	x	x
Assorted grass species	x	x

TABLE 11. Aquatic insects collected at Shady Dell Pond and Buckhead Creek.

	Shady Dell	[a]Buckhead
Order Ephemeroptera		
Baetidae		
Callibaetis	x	
Siphlonuridae		
Siphlonurus	x	
Heptageniidae		
Cinygma		x
Ameletus		x
Order Plecoptera		
Perlodidae		x
Order Hemiptera		
Corixidae	x	
Gerridae	x	
Gyrinidae	x	
Nepidae	x	
Notonectidae	x	
Veliidae	x	
Order Megaloptera		
Sialidae	x	
Order Odonata		
Aeshnidae	x	
Coenagrionidae	x	
Lestidae	x	
Libellulidae	x	
Order Coleoptera		
Dytiscidae	x	
Haliplidae	x	
Order Trichoptera		
Limnephilidae	x	
Lepidostomatidae		x
Hydropsychidae		x
Rhyacophilidae		x
Order Diptera		
Ceratopogonidae	x	
Chironomidae	x	
Culicidae	x	
Dixidae	x	

[a]List from Buckhead Creek (0.5 km from entrance to the Middle Fork of the Willamette River) not likely to contain all taxa.